Cotton Production in Northern Australia 2025

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Cotton production in Northern Australia

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Since the introduction of Bollgard® 3 cultivars, cotton production in Northern Australia has expanded significantly. However, the growing conditions in Northern Australia are very different to traditional production areas, impacting the plant, its pests and the management of inputs. This guide seeks to inform decision makers to better understand these interactions and best take advantage of the opportunities for cotton production in northern Australia.

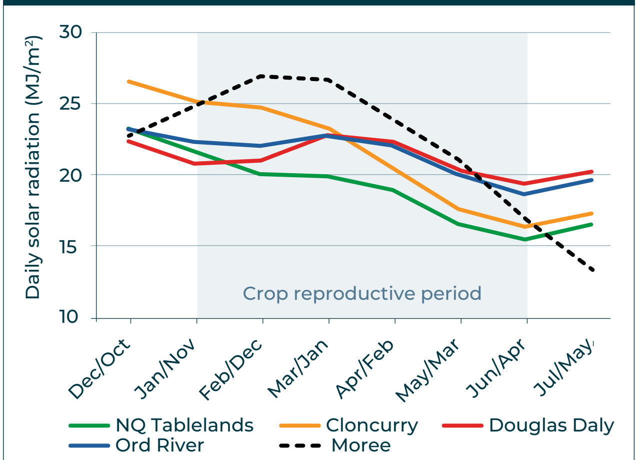
Climate

Differences in solar radiation (due to latitude) and monsoonal cloud, rainfall and temperatures alter the pattern of growth and development, creating both challenges and opportunities for cotton production. A dynamic approach to agronomic management is necessary to mitigate the risk of high seasonal variability.

Solar radiation

Solar radiation (sunshine) is lower and more variable in the tropics compared to temperate regions where cotton is traditionally grown. A shorter day length during the summer months reduces sunlight hours compared to southern temperate areas (Figure 1). While there are more sunlight hours during the tropical winter, this is tempered by cool night constraints, particularly for inland areas. Increased cloudiness during the summer wet season limits solar radiation, impacting photosynthesis and the way in which the cotton plant allocates energy between leaves, stem and bolls.

FIGURE 1 Average daily solar radiation for Moree (dashed line) and for Ord River, Douglas Daly, Cloncurry and NQ Tablelands (coloured lines), assuming October sowing for Moree and December to early January sowing for Northern Australia.



The shaded area indicates the approximate boll-growing period for all areas, which corresponds with markedly lower solar radiation in Northern Australia. Sowing delays until February or March in some northern regions can extend the reproductive period until early July.

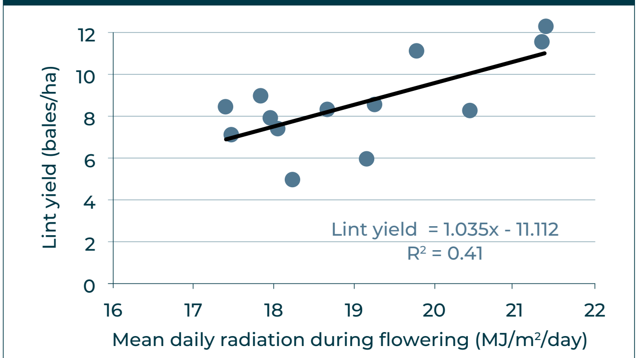
Impacts of reduced radiation

Cloudiness during flowering and boll filling is problematic. The developing seed within cotton bolls contain plant oils that are energy intensive to produce and therefore crops are at their most sensitive to cloud from flowering onwards. The natural response of cotton to disrupted photosynthesis during flowering is to reduce internal energy demand by shedding fruit. Additionally, cloudiness is often accompanied by hot night temperatures (≥24°C) and rainfall that can exacerbate shedding and subsequent canopy growth responses.

How much cloud is too much?

Every cloudy day has an impact as potential energy is lost from the system. For example, three cloudy days during a week have the same impact whether they occur consecutively or not. A reduction in sunlight during flowering decreases lint yield by approximately one bale per hectare for every 1 MJ/m² decrease in average radiation (Figure 2), although the relationship can vary with management. Crops with improved sunlight penetration into the lower canopy during flowering are less prone to fruit shedding. Where irrigation and season length allow, earlier shed bolls can be compensated by intentionally prolonging the flowering period to make up for lost sunshine.

FIGURE 2 The relationship between mean daily radiation during the flowering period and machine-picked lint yield. Each 1 MJ/m² reduction in average daily radiation equates to approximately 1 bale/ha yield reduction.



In addition to fruit shedding, a common response to cloudy wet periods is increased stem and leaf growth, that if left unmanaged can exacerbate self-shading of the lower leaves, increasing fruit shedding and creating a negative feedback loop leading to rank growth. Ideally, manage crops to enable light penetration into the lower canopy leading up to cut-out.

Light interception can be improved by utilising lower sowing rates to establish 5-7 plants per metre row particularly when sowing early in December and January. Similarly for early sown crops, wider row spacing is another tactic to improve light interception within the lower canopy which can reduce shedding although there are trade-offs to consider (see row spacing section).

The growth regulator mepiquat chloride (MC) can be used from early squaring onwards as excessive growth can begin quite early during wet conditions. However, caution is also required as MC application can exacerbate crop responses to stressors such as low soil moisture or nitrogen. Overuse can also limit a crop's ability to later compensate fruit loss. See the 'Canopy management' section later in this chapter for MC usage guidelines.

Compensatory boll setting in the upper and outer canopy can offset lower canopy boll loss provided sufficient resources (moisture, heat units, radiation, and nutrition) are available to enable continued growth. Cloudiness after cut-out is difficult to compensate for, as existing bolls utilise the majority of assimilate being produced, leaving little energy to initiate replacement fruiting sites. Growing a crop on (as practiced in Central Queensland) by encouraging a second cycle of flowering may be a valid compensation strategy, although success would depend on season length, irrigation availability and being able to sustainably manage leaf disease and insect risks (which can be substantial in the tropics). It should also be noted that the Bollgard® 3 Resistance Management Plan has been modified with additional compliance requirements (e.g. larger refuges) for Central Queensland growers who elect to grow on. This is not currently in place for Northern Australia which also has specific crop destruction date requirements which limits the period in which a crop might be grown.

For irrigated crops, select a sowing time that coincides the commencement of flowering (45-55 days later) with the likelihood of decreasing cloudiness as the monsoon ends to enable boll maturation under sunny conditions before cooler night temperatures limit growth (see Fig 6). For rainfed crops, balance soil type and water availability against potential cloudiness constraints. Sandy or loamy soil types may sustain active growth for 3-6 weeks after rainfall stops, while roots in clay soils may be confined to the upper layers due to wet season waterlogging, or sodicity at depth can limit water extraction by roots. Rainfed crops sown earlier in the wet season will likely receive more rainfall, but this benefit often will be negated by cloud-induced fruit shedding that delays the setting and filling of bolls that contribute to final yield.

Variable cloudiness between November and April in Northern Australia is a primary determinant for yield potential. Just as drought limits production in the south, wetter than average seasons with high levels of cloudiness will lower lint yield potential irrespective of inputs. Factor this risk into seasonal agronomic planning to avoid overspending on agronomic inputs during seasons with lower yield potential. The key challenge is that wetter than average seasons are often not apparent at the outset of the monsoon season.

Ambient temperatures

Both high and low temperatures can be constraints for tropical cotton production.

Hot days

Extreme daytime temperatures during the lead-in to the wet season pose significant challenges for crop establishment. Exposed soils with a high fraction of silica can exceed 60°C at the surface, creating challenges for seedling establishment. Vegetative cover can mitigate this – see the 'Cover crop' section.

As the wet season proceeds, extreme temperatures become less frequent due to increased cloud and rainfall, however, drier than average wet seasons can be extraordinarily hot. During flowering, hot days (maximums ≥35°C) that are typically coupled with high humidity stymie crop transpiration and can impact flower formation and pollination resulting in boll shedding or deformed 'parrot-beaked' bolls. These deformed bolls are potentially more detrimental than shedding as the plant expends resources growing a small low-quality boll.

Hot nights

High night temperatures of ≥24°C are also a substantial constraint for cotton production. Hot nights increase plant respiration and energy consumption, reducing net energy for growth. The impact can be similar to a cloudy day. Hot nights often coincide with cloudy days, exacerbating fruit shedding.

Low temperatures

Cold nights during the mid-dry season are a growth-limiting constraint. For more northern, warmer growing areas such as Kununurra and Douglas Daly, growth may continue but at a reduced rate. In locations further south or inland, overnight temperatures are sufficiently cold to cause flower abnormalities, boll shedding and reduced boll size. Cool temperatures also exacerbate foliar disease, further compromising the plant's ability to support growth. Ramularia and a complex of leaf spot diseases caused by *Alternaria* sp., *Stemphylium* sp., and *Cercospora* sp. are more prevalent when overnight temperatures fall below 17°C, particularly when dew fall becomes a regular occurrence.

Rainfall

Until boll opening, rainfall itself does relatively little harm to the plant. Sowing time should aim to minimise the risk of rainfall from the first open boll onwards. For most northern regions this excludes November sowing, which would coincide boll opening with the wettest month of February. Rainfall coupled with high humidity in the tropics can cause devastating levels of tight lock and boll rot if this coincides with boll opening.

The majority of negative impacts from rainfall arise through disrupted agronomic management. Reduced field trafficability has obvious implications for timely sowing, fertiliser or spray applications. Tropical downpours straight after sowing on some soil types can seal in seed, preventing emergence. Wet conditions can also cause significant loss of soil nitrogen and prevent root development at depth, making crops more susceptible to moisture stress later on. Regular rainfall coupled with warm conditions can result in rapid canopy growth that may need to be moderated with strategic MC applications.

High levels of boll rot or tight lock can occur when wet weather overlaps with boll opening. Paul Grundy

The impact of rainfall on nutrient loss and subsequent trafficability are reduced with appropriate overland field drainage. This sodden field which received over 300 mm of rain in the previous 48 hours has drained well. Paul Grundy

Key considerations for agronomic management

Twenty years of research and test farming in various locations in Northern Australia have shown there are a number of rules of thumb for successful tropical cotton production.

Sowing and seed placement

In general, sow cotton seeds shallower than you might think using fewer seeds. Appropriate depth will vary with soil type and conditions, but planting deeper than 3 cm risks poor establishment as rainfall deluges can surface seal un-emerged seed. Avoid moisture seeking at depth unless 4-5 dry days are confidently forecast.

When planting during the first half of the wet season, aim to establish 6 plants per metre of row. Canopy management is much easier for crops with 5-7 well spaced plants per metre row whilst conditions remain wet and overcast. This reduces inter-plant competition within the row and the tendency for crops to grow 'up instead of out'. Seedling disease is uncommon in Northern Australia and other issues that impact emergence are unlikely to be mitigated by using higher seeding rates. Avoid sowing above 7.5 seeds per metre. High plant densities increase inter-plant competition and the potential for rank growth during wet season conditions.

For crops sown towards the end of the wet season (late February onwards), 7-10 plants per metre can be established as these crops will be exposed improving weather conditions as the wet season recedes. Growth will be comparatively slower and more compact as flowering coincides with improved radiation and milder temperatures.

Cover cropping to improve establishment

Cover crop residues can reduce soil surface temperature and improve cotton establishment. Growing a short-term cover crop as a precursor to cotton, particularly in rainfed systems, can provide secondary benefits. Soil nitrogen uptake by grass species or fixation by legumes can provide a temporary immobile nitrogen reserve that is later released as residues break down during the wet season. Cover crops can also protect the soil from surface erosion.

Cover crops require active management – too little cover and soil protection is limited whilst too much growth can create difficulties for crop sowing and emergence. Check cover crops for the presence of caterpillars (e.g. *Spodoptera* spp.) and grasshoppers and use an appropriate knockdown insecticide at sowing as these pests can be displaced onto emerging cotton seedlings as herbicides take effect.

Cotton established following a grass cover crop in the NT.
Steve Yeates

Wet season root development

Cotton crops sown during the wet season typically develop shallow root systems in response to long periods of soil saturation that limit oxygen availability at depth. Roots will initially be confined to the top 10-20 cm aerobic soil layer and deeper root penetration will resume as the wet season recedes and the soil drains and aerates.

For irrigated crops, root penetration can be encouraged through gradual increase of irrigation intervals and depths applied, taking care to avoid excessive crop stress from greater moisture deficits. For rainfed crops, the ability of roots to penetrate more deeply will depend on how quickly rainfall recedes, with internal competition for assimilate between roots and boll filling being an important factor. In the case of a 'hard finish', crops will rapidly cut-out, curtailing both the opportunity for boll setting and overall yield potential.

From a management perspective, there is little that can be done to encourage greater rooting depth during the wet season as this is largely governed by soil type and the pattern of rainfall. Deep ripping during the dry season is unlikely to produce lasting change for subsequent soil water conditions during the wet season.

Interestingly, Brazil grows over 1 million hectares of tropical cotton on well drained loam soil. These crops routinely have shallow root system development during the rainy season. The question of shallow rooting depth was raised with various people during a recent visit to Brazil, and nobody considered it to be unusual. Following the wet season, if circumstances allow, roots can continue to grow and penetrate more deeply in the soil as conditions dry out. For both irrigated and rainfed crops, roots have been found to reach 1.2 m in clay soils and over 2 m on loamy soil types without subsoil constraints.

Typical root system development in Northern Australia. Reduced oxygenation at increasing depth cause roots to expand sideways in the upper surface layer. Paul Grundy

A typical root system of a Brazilian rainfed cotton crop growing on a well drained, minimum tillage red loam field. Shallow root system development during the wet season would appear to be typical.

Nutrition management

The wet/dry seasonal cycle contributes to the low fertility of many soils in Northern Australia by increasing mobile nutrient loss (nitrogen & sulphur) and challenging the retention of soil carbon.

Potassium (K) and **phosphorous** (P) levels are often low. A prudent approach that has been used successfully for a range of cropping is to apply rates that are above replacement over consecutive seasons with the aim of slowly building up the 'bank' of these elements in the soil.

In particular, low potassium (as opposed to outright deficiency) may render crops more susceptible to foliar diseases caused by *Alternaria* sp., *Stemphylium* sp., and *Cercospora* sp., particularly during flowering and boll filling. Potassium application rates above replacement may reduce these foliar disease outbreaks and should be considered as part of an integrated disease management strategy for locations such as north Queensland where boll filling coincides with cooler night temperatures (<17°C) and dewy conditions.

Given that P and K are relatively immobile in the soil, application can occur pre-planting with little risk of environmental loss. Aim to incorporate into the soil during application either through the use of a tyned application rig or some other form of tillage when surface spreading is used. P and K left on the soil surface will remain largely unavailable for plant uptake, however because cotton root systems are often restricted to the surface layers during the wet season, incorporation does not have to be overly deep.

Removal rates for K & P vary with crop yield. A 4 bale crop will remove approximately 12 and 11 kg/ha of K and P whilst a 10 bale crop will be 36 & 23 kg/ha respectively. P removal rates have reduced with newer smaller seeded varieties. Refer to the Nutrition chapter in the ACPM for removal rates for all nutrients across the yield spectrum.

Nitrogen (N) is challenging to manage during the wet season due to product handling difficulties and the significant potential for post-application loss. While post wet season nitrogen mineralisation can be substantial in some areas, generally less of the crop's N requirements are achieved from the organic nitrogen pool (arising from decaying plant and microbial residues) than in southern growing areas. This is because organic sources cycle more rapidly and wet conditions increase losses of resulting nitrates. Tropical cotton production is therefore more dependent on applied nitrogen fertiliser. An exception is Cununurra clay soils, where post-wet season mineralisation of high biomass crop residues (e.g. maize) during subsequent irrigated cropping can be substantial, providing >75 kg/ha of nitrogen, and in fields with regular fertiliser use and cropping history >200 kg/ha of nitrogen mineralisation has been recorded. Similarly, where cotton followed dry season (November-harvested) maize in the Burdekin, significant mineralisation occurred during March and April coinciding with the boll filling period of the subsequent cotton crop. In these instances, fields were irrigated and used to grow a succession of high biomass crops in rotation.

Nitrogen in its plant-available nitrate form (irrespective of whether the origin is from mineralised plant residues or fertiliser) is highly soluble and not well retained by soil. It is also easily lost to anerobic microbes under saturated conditions. On well drained sandy soils, rain can leach nitrates deeper into the profile. With average rainfall often exceeding 800 mm during the wet season there is tremendous potential for leaching, deep drainage and denitrification loss in northern regions.

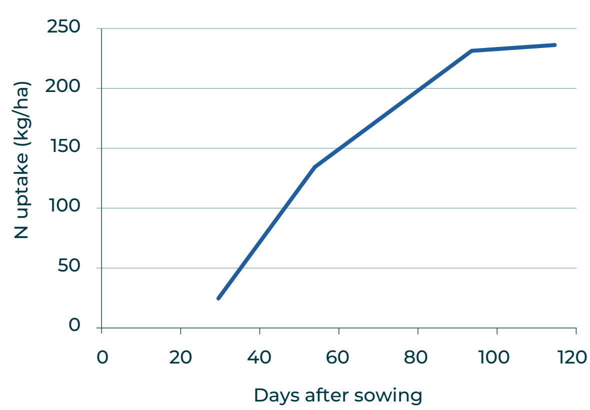
An effective approach for limiting the loss of applied fertiliser is to coincide the product's nitrate release with cotton crop development to enable rapid plant uptake. Cotton is sufficiently developed at 25-30 days after sowing to absorb 3-4 kg ha of nitrogen per day through until mid-late flowering (Figure 3). High nitrates in the soil prior to this stage are prone to loss, which makes large pre-planting applications of nitrogen particularly risky.

Ideally crop managers should aim to ensure nitrate from applied fertiliser is primarily available between squaring and early flowering. Broadly this can be achieved in two ways:

N strategy 1: Enhanced efficiency products

Nitrogen in the ammonium form is more stable than nitrate, and due to its positive chemical charge is better retained in the soil and less susceptible to gaseous loss. Most applied fertilisers are either in ammonium form or pass through the ammonium stage before being nitrified to nitrate, so the use of enhanced efficiency fertiliser (EEF) technologies that slow the conversion process can greatly reduce wet season losses from **pre-plant** fertiliser application. These products temporarily hold nitrogen in the ammonium phase, giving the crop time to grow. As the EEF technology gradually fades, the subsequent release of nitrate can be quickly absorbed by the roots of the developing crop, lowering the risk of environmental loss. EEF technology is available in various forms. Considerations for the use of each type are covered in the nutrition chapter of the ACPG.

FIGURE 3 Cotton crop nitrogen uptake over time in North Queensland. Minimal fertiliser is taken up in the first 30 days after sowing. The crop then extracts 3-4 kg per day, peaking at 90-100 days after sowing.
(Yeates 2016 CRDC Final Report CSP1302).



Research conducted in the Burdekin comparing cotton crop uptake efficiency of urea treated with different EEF technologies applied prior to sowing found that untreated urea had an uptake efficiency of 26% (range 24-30% over 3 years) and EEF products ranged from 35-57%. EEF products continue to evolve, but the underlying principle of how they work and might be deployed to limit losses from pre-plant nitrogen application remains the same.

N strategy 2: Targeted timing

Nitrogen losses can also be reduced with timely in-season fertiliser application coinciding with when a crop is sufficiently developed to enable rapid uptake. From approximately 30 days after sowing, crop uptake ability increases to 3-4 kg of nitrogen per hectare per day before declining at around 90 days. For best results, apply nitrogen between 25-65 days after sowing. For example, a 30 day old crop can absorb the nitrogen content from 45-60 kg of urea/ha within a week.

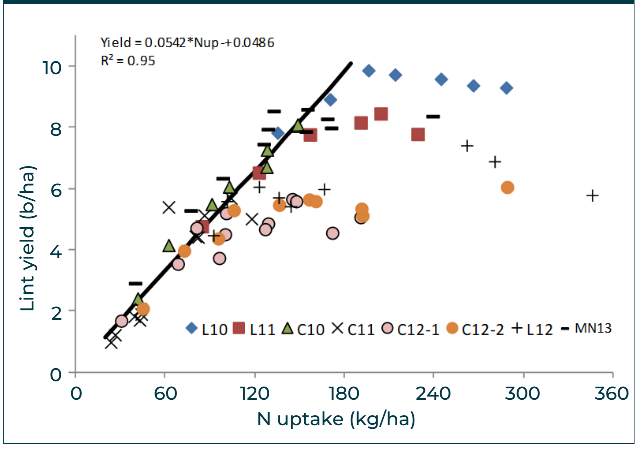
Recent research in WA has demonstrated that drilling urea prior to flowering (approx. 35 days post plant) has been highly effective for maximising N uptake and lint yield on the clay soils of the Ord River Irrigation Area. Placed just deep enough to ensure full coverage with soil, a nitrogen uptake efficiency of 45-55% was achieved with this method compared with efficiencies of only 20-35% for pre plant urea application (prior to the wet season). This increase in uptake efficacy equated to 1.5-4.0 lint bales per hectare. In these experiments a tactical approach even surpassed several of the 'all up front' EEF treatments.

A key constraint to in-crop application is being able to traffic fields as weather and soil type constraints are likely to be challenging in some seasons.

Aerial fertiliser spreading can solve trafficability issues, but nitrogen fertiliser spread onto the soil surface is highly dependent on rainfall or irrigation for incorporation. Too little infiltration and fertiliser can volatilise or remain unactivated. Too much and fertiliser can be washed off or fail to infiltrate in sodden field conditions.

Aerial application can result in fertiliser granules being caught by the crop foliage where they cause uncharacteristic lesions.
Paul Grundy

FIGURE 4 Nitrogen uptake across 8 different experiments spanning 4 seasons and two soil types in NQ where nitrogen availability was unlimiting. The line indicates the relationship between maximum yield and nitrogen uptake equating to approximately 1 lint bale per 18 kg of N uptake. Note however that many crops continued to take up N without an improvement of yield. This is because other factors (in these cases poor radiation due to cloud) became limiting. (Yeates 2016 CRDC Final Report CSP1302).



Where fields are trafficable, another option could be the application of stabilised liquid nitrogen sources (Easy N®) directly to the soil surface via droppers fitted to a spray rig. This method is still reliant on rainfall or irrigation to aid incorporation but can reduce volatilisation risk.

How much to apply?

Application rate decisions should reflect a realistic target yield potential while accounting for potential nitrogen losses. Research conducted in North Queensland showed that in-season nitrogen uptake averaged approximately 18 kg/ha per bale of lint yield produced. While this ratio might vary for other environments, and potentially reduce when climatic conditions are more favourable (e.g. less cloud), it is useful as a guide. When combined with an estimate of background soil nitrogen contribution and anticipated loss, it can be used to calculate an appropriate fertiliser rate to achieve a target yield. Table 1 demonstrates how urea requirements can be determined for a rainfed crop with a target yield of 4.5 bales/ha with various application strategies.

When calculating fertiliser requirement, avoid overestimating yield potential for a given location, sowing time and likely seasonal forecast. Nitrogen that is excess to yield requirements will be readily taken up by the crop. However, additional uptake will not convert to yield if other factors such as soil moisture or solar radiation are limiting. Figure 4 depicts nitrogen uptake across numerous experiments and clearly demonstrates that the additional uptake of nitrogen produced no extra yield because cloudiness became the most limiting factor.

TABLE 1 Example of potential fertiliser application required to grow a rainfed crop with a target yield of 4.5 bales/ha.

	Nutrition strategy		
	Pre-plant with standard fertiliser	Pre-plant with enhanced efficiency fertiliser	Tactical in-crop placement (of standard fertiliser)
N required from fertiliser application (kg N/ha)	49	49	49
Uptake efficiency of applied nitrogen	26%	45%	50%
Units of N needed (kg/ha)	188	108	98
Amount of urea (@46% N) required (kg/ha)	408	234	213

*Plant uptake is assumed to be 90 kg N/ha of which 35 kg N/ha is supplied by current soil N. Note that background soil N contribution will vary considerably depending on soil type, field history etc., but is likely to be low in northern regions compared to southern soils. Use of nil strips over time can provide a picture of likely background fertility.

Fruit shedding

One aspect of cotton production that is unique to Northern Australia is the high likelihood that crops will abort squares and bolls from the lower and middle canopy during flowering. This fruit shedding is a natural response to stress-induced disruptions of photosynthesis and respiration that affect the plant's internal energy balance. Key stressors are reduced sunlight due to cloudiness, high daytime temperatures (≥35°C) with humidity and hot nights (≥24°C). There are no specific agronomic tools that can prevent fruit shedding. However, the impact of shedding can be reduced with the following strategies:

1. **Avoidance:** Reducing crop exposure to environmental stresses during flowering and boll filling stages. This is primarily achieved through sowing dates that aim to reduce crop exposure to weather related risks during flowering and boll filling.
2. **Canopy management:** Shedding in the lower canopy can be exacerbated when the canopy becomes overly leafy leading into early flowering and the upper canopy prematurely shades lower leaves. Managing canopy expansion to reduce canopy self-shading during squaring and early flowering can reduce fruit shedding, particularly during moderate periods of climatic stress. The tools for managing canopy growth are varied. Establishing 5-7 plants per metre of row will reduce inter-plant competition for light and the tendency for inter-node expansion. When conditions are dry irrigation timing can be used to moderate growth, particularly prior to flowering. Applying the growth regulator mepiquat chloride will reduce cell expansion, reducing the length of stems and leaf and reduce self-shading. Wider row spacing will also enhance light interception by the lower canopy and reduce shedding. There are factors to consider when deciding on potential row spacing options, see row spacing section.
3. **Compensation:** Fruit loss during early to mid-flowering can be compensated when weather conditions subsequently improve through increased boll retention in the upper and outer canopy. Canopy expansion during later flowering to increase yield recovery can often be further encouraged through agronomic practice (e.g. irrigation). Compensation will more readily occur following early flowering shedding compared to mid or late flowering fruit loss, as an existing boll load during stress periods will both exacerbate the shedding response and subsequently limit recovery. Crops that experience shedding near cutout are particularly challenging to compensate. This is often compounded by shorter days and cooler temperatures, which limit the plant's ability to generate enough energy to fill existing bolls and initiate additional fruiting sites.

When attempting to encourage compensatory growth, consider the constraints of the growing environment and whether remaining season length is sufficient to convert new squares into mature bolls. Compensation is generally easier in irrigated crops, where growth is primarily limited by the length of the growing season (radiation and temperature). Rainfed crops will be unable to compensate if soil moisture becomes limiting.

Extended rainfall coinciding with boll opening can cause seed to germinate. Paul Grundy

Fruit shedding from the lower to middle canopy is a typical response to cloudy or hot weather, particularly after flowering commences. Paul Grundy

Climate and production timing for Bollgard 3 crops

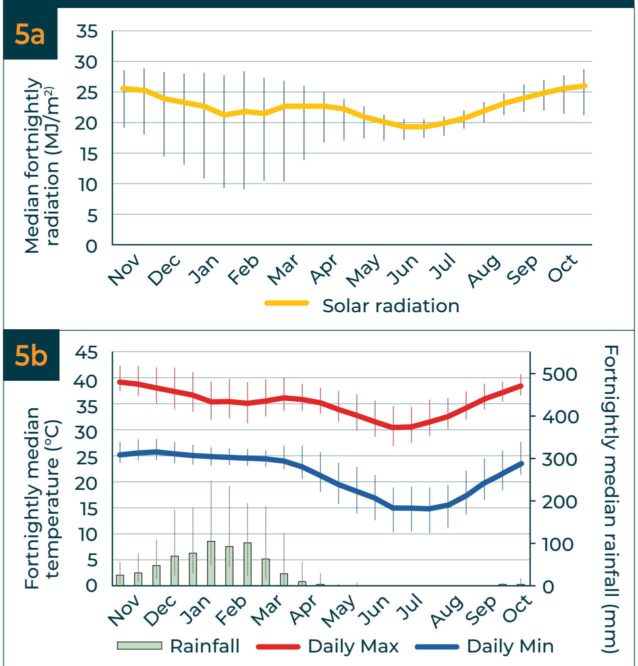
Bollgard 3 crops are able to be sown within an eight or 12-week window, from December to May. The exact start of this planting period in each region is determined by Bayer in consultation with local growers. Time of sowing within the allocated window will directly impact how the crop interacts with local weather patterns, which vary widely across Northern Australia.

A more important question than “When is the best time to sow?” is “When is the best time for crops to be flowering and maturing bolls?” In Northern Australia, flowering typically begins 45-55 days after sowing and lasts 3-6 weeks, depending on field conditions. Shedding (requiring additional compensatory fruiting sites) is likely to extend the flowering period. Boll maturation is complete about 50 days after the last effective flowers for most regions. Therefore, sowing time can be strategically chosen to align boll production (roughly 50-130 days after sowing) with the time of year that temperatures, solar radiation, and soil moisture are most likely to be optimal for crop photosynthesis (see Fig 6).

While no two wet seasons are the same, historical patterns of radiation, temperature, and rainfall offer valuable guidance for agronomic decision-making. Fortnightly median values for these climatic factors provide greater insight than monthly mean data. Importantly, looking at the best and worst 10% of years for each factor helps to assess the scope of potential risks.

Utilising Kununurra as an example, fortnightly median values (Figure 5a) for solar radiation suggests that sowing in early March to coincide flowering with mid-April would largely avoid cloudiness risks that peak between December to mid-March. However, it’s essential to consider all climatic factors together, as the subsequent boll maturation during cool nights in June (Figure 5b), could negatively impact boll filling and yield potential. In comparison, sowing in mid-February could balance these two risks with flowering commencing in late March and maturation complete by June, but in many seasons, rainfall will prevent sowing during mid-February, particularly on clay soils. Early January sowing reduces rainfall-related risks for sowing field trafficability, but flowering would commence mid-February, when crops are most likely to be exposed to cloudiness and hot nights that exacerbate fruit shedding, creating challenges for canopy and boll setting management.

FIGURE 5 Fortnightly median values for (5a) solar radiation (MJ/m²) and (5b) maximum, minimum temperature and rainfall for Kununurra from 1970-2024. The ends of the bars denote the top and bottom 10% of years as a departure from the median.



This example underscores a core challenge for wet season cotton production where there is no risk-free planting window option.

Instead, the potential risks vary depending on when a crop is sown, the soil type and how the season unfolds. This demands a nuanced approach to both sowing and subsequent crop management to address likely risks. Again to think about how this might apply, let’s consider Kununurra as an example. This region is fully irrigated and largely consists of clay soils that are challenging to traffic in the wet season. The optimal time to plant from a boll setting and filling perspective is mid to late February but this is the most difficult time to sow due to rainfall. To ensure that sufficient cotton is sown each season to underpin gin viability will likely require the wider 12 week planting window option that spans early January till late March. Agronomic management will need to vary markedly according to the likely climatic conditions that crops would be exposed to with January, February or March sowing.

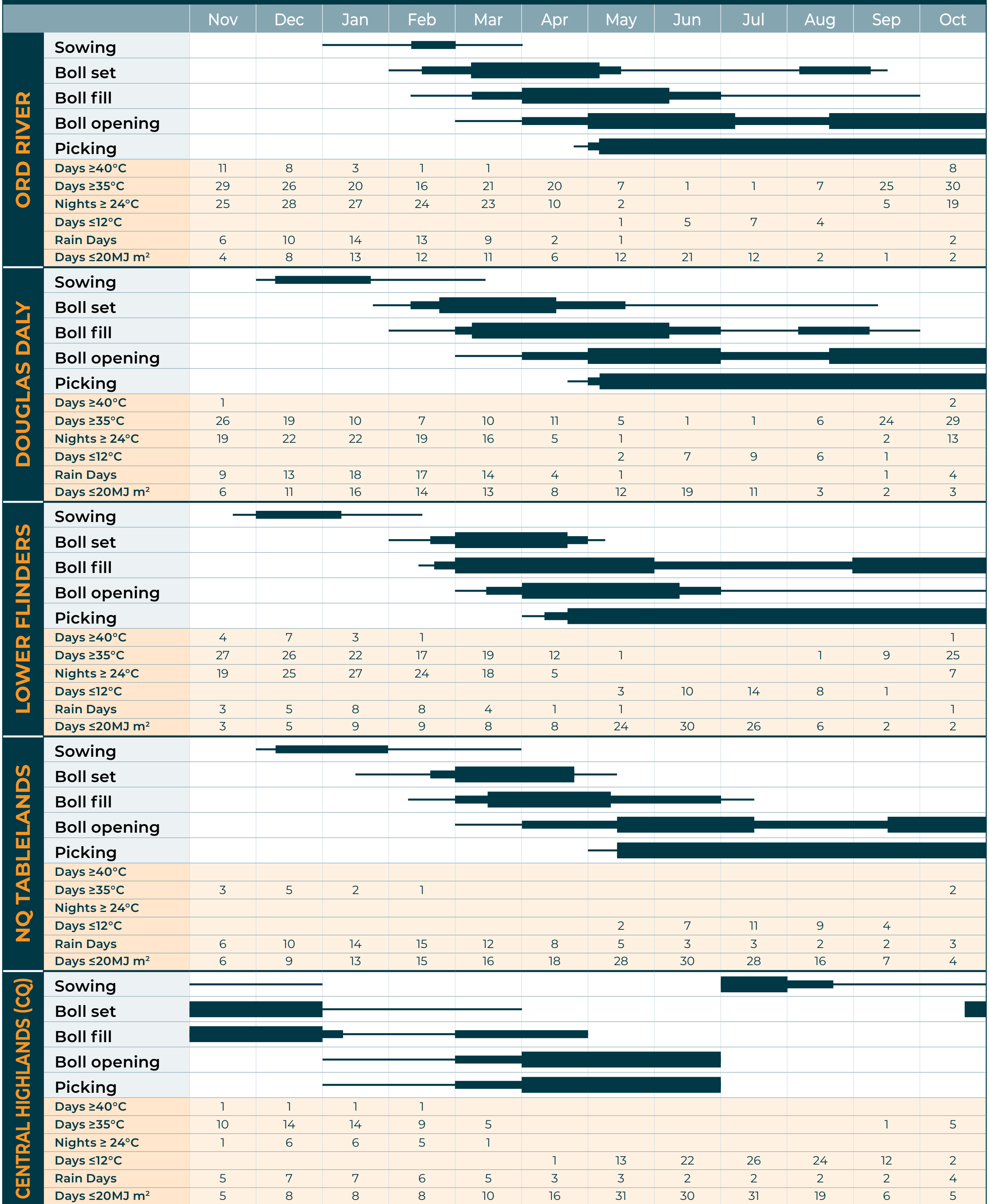
An early sown January crop could produce 20 nodes of growth without the retention of a single boll if February and early March are cloudy and hot. In this situation, compensating for extensive boll losses on a large plant would present unique challenges. Therefore, the focus for early January sown cotton crops in the Ord may be to curtail growth as much as possible leading into early flowering and then take advantage of the remaining season length and the ability to irrigate to grow a compensatory top crop. To achieve this would likely entail the use of restrictive practices such as minimal nitrogen application before flowering, a much more stringent MC use regime and lower planting rates or perhaps wider row spacing to improve crop light interception during cloudy periods. More radical approaches such as crop slashing to reset and delay the onset of flowering, as was tested in the Burdekin (see Norpak insidecotton.com/norpak-burdekin-and-nq-coastal-dry-tropics), may also be worthy of consideration. Ultimately, the crop would need to reach the end of the wet season with a manageable canopy that could support 5-15 nodes of additional growth from mid-March to early May upon which a compensatory boll load could be set.

At the opposite end of the window, crops sown mid-late March at the end of the wet season are likely to experience sunny, milder conditions throughout flowering but face the risk in some seasons of cooler than average conditions in June that hamper the filling of late set bolls. In this instance, agronomic management should focus on tactics that ensure rapid establishment and secure yield potential as quickly as possible with crop nutrition provided largely up front (lower risk of loss), increased plant density and regular row spacing, and a focus on developing a large canopy early that can set a high number of bolls within 4-5 weeks of first flower. This management approach is the opposite of that for January-sown crops.

As a general principle across all regions, earlier sowing increases crop exposure to cloudy, wet, and/or hot conditions during flowering that will exacerbate shedding, whilst delayed sowing could shorten the available growing season due to the onset of cooler mid-year temperatures and shorter days. These challenges require agronomic management to be tailored to deal with the impact of such conditions. For rainfed crops, there is an additional compromise between boll shedding caused by wet season conditions and subsequent soil moisture constraints when sunny conditions prevail, which can limit compensation and thus yield potential.

Figure 6 provides a depiction of climatic risk for different crop stages throughout the year. For further details on climatic risks during various crop development stages, including specific data for your region, consult the CottonInfo fact sheet (www.cottoninfo.com.au/publications/climate-analysis-cotton-production-across-northern-australia) or undertake a climatic analysis for your specific location based on SILO records using the fortnightly median calculator web-based tool rotsc-satfs.shinyapps.io/Climate_EDA.

FIGURE 6 Navigating climatic risk factors for cotton crop stages for locations in Northern Australia.



ORD RIVER

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days ≥40°C	11	8	3	1	1							8
Days ≥35°C	29	26	20	16	21	20	7	1	1	7	25	30
Nights ≥ 24°C	25	28	27	24	23	10	2				5	19
Days ≤12°C							1	5	7	4		
Rain Days	6	10	14	13	9	2	1					2
Days ≤20MJ m²	4	8	13	12	11	6	12	21	12	2	1	2

DOUGLAS DALY

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days ≥40°C	1											2
Days ≥35°C	26	19	10	7	10	11	5	1	1	6	24	29
Nights ≥ 24°C	19	22	22	19	16	5	1				2	13
Days ≤12°C							2	7	9	6	1	
Rain Days	9	13	18	17	14	4	1				1	4
Days ≤20MJ m²	6	11	16	14	13	8	12	19	11	3	2	3

LOWER FLINDERS

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days ≥40°C	4	7	3	1								1
Days ≥35°C	27	26	22	17	19	12	1			1	9	25
Nights ≥ 24°C	19	25	27	24	18	5						7
Days ≤12°C							3	10	14	8	1	
Rain Days	3	5	8	8	4	1	1					1
Days ≤20MJ m²	3	5	9	9	8	8	24	30	26	6	2	2

NQ TABLELANDS

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days ≥40°C												
Days ≥35°C	3	5	2	1								2
Nights ≥ 24°C												
Days ≤12°C							2	7	11	9	4	
Rain Days	6	10	14	15	12	8	5	3	3	2	2	3
Days ≤20MJ m²	6	9	13	15	16	18	28	30	28	16	7	4

CENTRAL HIGHLANDS (CQ)

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days ≥40°C	1	1	1	1								
Days ≥35°C	10	14	14	9	5						1	5
Nights ≥ 24°C	1	6	6	5	1							
Days ≤12°C						1	13	22	26	24	12	2
Rain Days	5	7	7	6	5	3	3	2	2	2	2	4
Days ≤20MJ m²	5	8	8	8	10	16	31	30	31	19	6	5

Bars denote how climate relates to various cotton production stages. The thicker bars represent zones of lower risk and more optimal conditions, while the thinner bars represent less optimal and/or higher risk conditions (temperature, rainfall or radiation constraints). The values provided for each location represent the mean number of days per month for each climatic parameter.

Canopy management

Managing canopy growth during the wet season is challenging due to high temperatures, fluctuating solar radiation and abundant soil moisture, that can promote rapid stem and leaf expansion. Disproportionate growth can result in inefficient sunlight interception in the lower canopy. Excessive fruit shedding can further accelerate canopy growth, creating a cycle where new growth shades existing leaves, exacerbating shedding and leading to unproductive, rank crops.

Mepiquat chloride (MC) can help regulate these responses, but a balanced approach is essential. While MC moderates excessive growth, compensating for fruit shedding requires continued canopy growth to sustain yield potential.

Getting off to a good start

Canopy management begins with seed placement. Establishing 5-6 well spaced plants per metre row reduces interplant competition and expansionary canopy responses. Avoiding higher plant populations is the first step in reducing the potential for excessive growth.

Once the crop is established, starts its vegetative expansion and begins to square (around 6-7 nodes), and is experiencing conditions that are conducive for rapid growth, consider applying MC at a low rate (e.g. 30-50 mL/ha of a 380 g/L product) to begin moderating canopy expansion. Higher rates may be appropriate for crops planted early wet season, particularly where irrigation is available, to allow subsequent compensation during the early dry season. Dry conditions after establishment may restrict growth naturally.

Balancing growth on the way to flowering

Assess the crop's total height and nodes each week and refer to tropical canopy management guidelines. Canopy growth generally gains significant momentum from 8 nodes and the period between early squaring and 15-16 nodes is ideal for managing crop growth with MC if required, with low risk to future compensation potential. Limiting crop growth during the pre-flowering period reduces the risk of premature row closure and self-shading that can exacerbate shedding and reduce boll size in the lower canopy.

Management between flowering and cut-out

A more cautious approach is required once flowering begins. Nitrogen application just prior to flowering and/or boll shedding can result in very vigorous canopy expansion during the first weeks of flowering. If fruit shedding has occurred, canopy management during this period needs to moderate growth without unduly impacting compensation. Excessive MC application can constrain node production of both the main stem terminal and side branches, reducing outer and upper canopy boll set. Measuring the rate of change for nodes above white flower (NAWF) can indicate underlying crop vigour. A rapidly declining NAWF may indicate a deficiency or stress of some sort, requiring caution with MC usage. It may be prudent to utilise repeat applications of MC at low rates if there is uncertainty about growing conditions during the immediate future. Keep in mind that once MC is applied it cannot be removed and it will remain active within the plant for 7-10 days. Refer to the tropical canopy management tool www.cottoninfo.com.au/tropical-cotton-production

Other canopy considerations

Tropical cotton crops are naturally taller than southern crops, primarily due to rapid growth between establishment and flowering, effectively placing most crops on 'stilts'. Fruit shedding can add to this dilemma because bolls lost during early flowering require additional nodes at the top of the canopy to create compensatory fruiting sites, adding to crop height and leading to reduced efficiencies for spraying and picking coupled with a risk of lodging. However, it is usually preferable to have a higher yielding tall crop than a short crop for which compensation and yield potential have become limited.

Excessive nitrogen (particularly during the wet season) can exacerbate canopy expansion and shedding responses. However, if nitrogen is deficient or conditions rapidly turn dry, the impact of a MC application can become exaggerated and cause premature cut-out. When making canopy management decisions it is important to balance what the crop is doing at that point in time against the likely environmental conditions and potential constraints it may experience in the immediate future. As MC affects new growth, consideration needs to be given to the conditions under which future growth will occur.

This Kununurra crop was exposed to prolonged cloudy weather during early flowering, causing almost complete loss of lower canopy fruit. Using the TCMT to sustain growth with regular low MC doses enabled the crop to compensate quickly once weather improved, yielding 12.2 b/ha despite the poor start. The crop reached 28 nodes, with 80% of pickable bolls on the top 12 nodes. The first 6 fruiting branches, excluding vegetative ones, bore no fruit. Additionally, upper canopy branches had abundant second position fruit. Excessive MC use from mid-flowering can reduce the setting of second position fruit in the upper canopy, affecting yield potential when compensation is required. Paul Grundy

Row spacing

Row spacing may play a useful role in managing climatic risk. Skip-row cotton configurations are used in temperate regions to maximise crop performance in dry environments and take advantage of stored moisture in clay soils that can typically hold 200-350 mm of plant available water. A skip row in these instances increases the size of the 'bucket' under the plant allowing it to grow for longer on stored moisture and increasing the value of any rain that might fall on the crop.

Skip row spacings have undergone some research testing in Northern Australia (primarily in rainfed systems). A focus of this work was to see whether the additional inter-row space would enable a longer period of continued growth during the early dry season that could improve yield and or lint quality. Results suggested limited crop response with different row spacings yielding similarly but with improved maturity earliness for narrower spacings because root systems usually fail to adequately explore the wider inter-row space during the wet season. When the onset of the dry season occurred rapidly these crops failed to make use of all of the moisture that might be available in the inter-row area. Hence the majority of rainfed crop have been sown on 1 metre spacings.

A key issue for these rainfed crops, particularly when planted in December to maximise the availability of rainfall, is that fruit shedding can be severe when persistent cloudy and wet conditions occur. The ability to compensate is often truncated as sunnier drier weather arrives, with crops cutting out prematurely due to shallow root systems on light soils. This has particularly been the case in the 2024/25 season where cloudy weather in late March and early April caused extensive fruit shedding across many crops.

A potential tactic based on anecdotal observations from on-farm strip trials is that wider row spacing may improve fruit retention during the wet season and reduce reliance on compensation to achieve yield potential. The exact approach would vary across systems and soil types and potential benefits would depend on the type of wet season encountered. In general, wider spaced cotton will maintain better light interception throughout the canopy that can partially offset the impact of cloudy weather. This will also encourage more compact inter-node lengths which can reduce the need for active canopy management. Increased airflow may also reduce the incidence of boll rots.

The optimal row spacing is currently unknown. Single skip spacing has been effective but will have a yield penalty in some seasons. An alternative option to exploit a middle path may be wider single spacing (1.5 m row spacing) that splits the difference between solid plant and skip row might improve fruit retention and better utilise the inter-row space for soil moisture extraction. It may also produce a canopy that is easier to manage with regard to height. However, at this stage the use of row spacing for the purpose of improving retention and reducing boll rots remains un-tested.

Climatic analysis tool. rotsc-satfs.shinyapps.io/Climate_EDA

Irrigation

The water holding capacity of soils growing cotton in the Douglas Daly Region of the NT is low, and therefore precision centre pivot irrigation management is ideally suited for optimising production. In contrast, the high water-holding capacity of Cununurra clays in the Ord Irrigation Area are ideal for supporting low-input furrow irrigation management, however some local growers report significant issues with irrigation water penetration to depth across this district. Therefore, improving the understanding of infiltrated water depths with furrow irrigation measurement of water advance rates and inflows is important for efficiency (see the irrigation chapters in the *Australian Cotton Production Manual*).

In both regions, water stress from extremes in water availability with the wet and dry season spanning cotton's critical crop growth periods will undoubtedly challenge crop yield potential in some seasons. With early season growth coinciding with wet season rainfall, and likely water-logging, objective assessment of soil water content is required immediately as conditions begin to dry. This will help ensure timely initiation of first irrigation during the critical flowering and fruit setting period as rains stop, to prevent crops drying down too much as this may cause premature cut-out. Sensor-based measurement in this instance is critical – install sensors and monitoring systems as soon as possible after planting. Good irrigation management with precise monitoring of soil water content using the full range of measurement tools available to growers can be used to improve yield outcomes in these challenging cotton growing environments.

In the Douglas Daly region, timely fertigation of nitrogen by centre pivots can be used as part of a nitrogen management strategy that can reduce losses compared with making large pre-plant or in-crop applications on light soil types with lower nutrient holding capability.

Crop destruction

For irrigated systems, crop destruction techniques will largely reflect the mechanical operations utilised in the south. However, for tropical rainfed systems sown on flat ground, crop removal via root cutting or tillage can be particularly challenging due to very dry hard-set soil. Under these circumstances, crop destruction requires an integrated approach of different measures. Where mechanical removal is unviable, mulching and treating the stump with herbicides to prevent regrowth is a potential alternative, but will generally require multiple applications to achieve complete control.

Management plans for the following crop will also need to consider the control of cotton volunteers. This can be particularly problematic for irrigated systems double cropped with legumes as herbicide options are limited. Avoid growing non-Bt cotton refuges on ground previously used to produce Bollgard 3 cotton. Refuges must also be free of volunteer or ratoon Bt cotton. Refer to the 'Management of volunteer and ratoon cotton' section within the Weeds chapter in the *Cotton Pest Management Guide*.

Economics

The cost of inputs such as fertiliser is generally higher in Northern Australia due to increased transportation costs. When budgeting, it is important to be realistic about yield potential, which will vary significantly between seasons, due to climate variability. Information on gross margins can be found at www.cottoninfo.com.au/publications/australian-cotton-industry-gross-margin-budgets

Pest management considerations for Northern Australia

Information in the *Cotton Pest Management Guide* is highly relevant and applicable for cotton production in Northern Australia. This section will focus on several pests and pest management scenarios that are unique to Australia's tropics.

Exotic pests and disease

Cotton production in Northern Australia is located within a known pathway for insects and diseases that can move naturally from Timor-Leste to the mainland. There are several biosecurity threats present in SE Asia that may arrive unassisted in Northern Australia. Key amongst these are Indian cotton jassid (*Amrasca biguttula*) and new viruses transmitted by silverleaf whitefly (Begomovirus cotton leaf curl disease complex) and aphids (various stunting diseases). If encountering unusual crop symptoms during crop checking alert your local regional extension officers or call the Exotic Plant Pest Hotline on 1800 084 881.

Bt Resistance Management Plan (RMP)

Northern Australia has a Resistance Management Plan for Bollgard® 3 crops that is different to southern regions with regard to planting windows, refuge requirements, trap crops and crop destruction dates.

For the latest details check online at www.crop.bayer.com.au/products/biotechnology-traits/bollgard-3-with-roundup-ready-flex-cotton

Cluster caterpillar

Research into cluster caterpillar (*Spodoptera litura*), an abundant pest throughout Northern Australia has examined why this pest (unlike *Helicoverpa* spp.) is sometimes found surviving in Bollgard® 3 crops. While *S. litura* larvae are naturally more tolerant of plant-expressed Bt proteins than *Helicoverpa* species and fall army worm (*Spodoptera frugiperda*), all plant parts (leaves, flowers, squares and bolls) of Bollgard® 3 (which includes the Vip3A protein) provide very high control efficacy. Bollgard® 3 control does not decline with crop age, but crop shading (for 1-2 weeks) can reduce efficacy. Cloudy weather during the wet season may therefore explain some of the periodic survival observed. Efficacy rapidly resumed when experimental shading was removed indicating that cloud impacts are temporary. Additionally, larvae that access non-Bt food sources are better able to survive exposure to Bt cotton, so the presence of weeds may confer a survival advantage. The very high densities of this pest during the season (confirmed by moth trapping in the Ord) may also partly explain why larvae are intermittently observed.

Research has found that flower feeding by cluster caterpillar (*Spodoptera litura*) is unlikely to cause crop damage. Paul Grundy

Although larvae are frequently observed in flowers, fruiting structures (squares, flowers and bolls) are a less suitable food source compared to leaves. In fact, larvae fed on a diet of flowers were mostly unable to complete development, and flower feeding by cluster caterpillars generally does not cause boll shedding (damage to petals and stamens is mostly cosmetic).

Collections of cluster caterpillar eggs and larvae from cotton fields in the Ord Irrigation Area found little in the way of parasitoid activity.

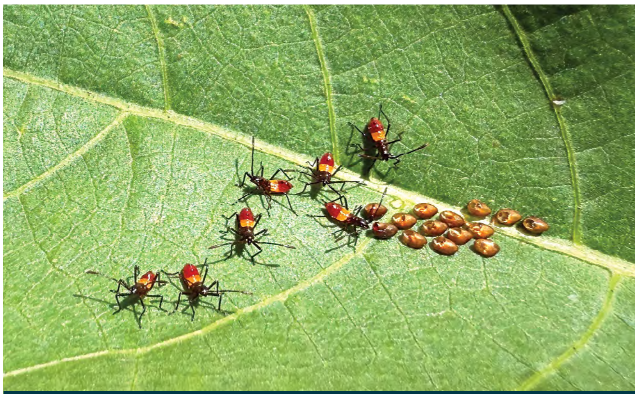
Ongoing research on this pest aims to develop a sustainable management strategy.

Sucking bugs

Sucking bugs are abundant in Northern Australia, requiring control in most seasons. Key species include green vegetable bugs (*Nezara viridula*), red-banded shield bugs (*Piezodorus oceanicus*), and cotton stainers (*Dysdercus* spp.). In the Northern Territory a damaging stainer-like cotton coreid bug, (*Aulacosternum nigrorubrum*) occurs in the Douglas Daly. Relatives of this species are pests of tree crops such as citrus and macadamias. This species reproduces in cotton with both the nymphs and adults causing damage to squares and bolls. In parts of North Queensland, cotton harlequin bugs (*Tectocoris diophthalmus*) are also abundant, although the pest status of this species is less clear (and the subject of current research).

These pests are difficult to manage from an Integrated Pest Management (IPM) perspective because (i) they directly damage developing bolls at a crop stage where compensation is unlikely, (ii) both adults and nymphs are difficult to sample and (iii) when control is required there are no genuine 'soft' selective insecticide options for their control. The latest thresholds and management guidance for these species can be found in the *Cotton Pest Management Guide*. These species typically become abundant at the end of the wet season when surrounding vegetation dries down, displacing adult bugs onto cotton crops. Generally, after a period of 1-2 months the immigration of these bugs into cotton declines as the resident population in the bush is depleted, although this can be drawn out if periodic rainfall in April results in a slow onset to the dry season.

The adult stage of the cotton coreid bug *Aulacosternum nigrorubrum*. The adult and nymph stages can damage squares and bolls. Simon Ong



Newly hatched nymphs of *Aulacosternum nigrorubrum*, the cotton coreid bug. Paul Grundy

A square that has been damaged by cotton coreid bug feeding and subsequently aborted. Paul Grundy

Aphids

Cotton aphids (*Aphis gossypii*) are common across Northern Australia. Aphid feeding can cause crop stunting, transfer of cotton bunchy top disease and contamination of open lint with excreted honeydew. Generally, this pest is very well controlled by a broad range of abundant natural enemies. However, all populations of cotton aphids tested have been found to carry extreme levels of Group 1A (organophosphate and carbamate) resistance. Therefore, the selective aphicide pirimicarb is ineffective in Northern Australia. The use of organophosphates such as dimethoate for mirid and stink bug control should also be avoided. There have been multiple instances where dimethoate use has resulted in severe aphid outbreaks 2-3 weeks post application. Aphids still remain susceptible to other registered insecticides. Check the latest *Cotton Pest Management Guide* for details.

Leaf beetles

Red shouldered leaf beetles, (*Monolepta australis*) are an occasional pest of cotton in the tropics during the wet season. Adult beetles are yellow with red patches on their wing covers, and can emerge from pasture areas and migrate into cotton crops in large numbers, often overnight. The beetles aggregate and chew on the crop causing foliar damage (that can appear like gramoxone herbicide damage from a distance) typically in patches or along field edges. Despite appearances, crop damage is usually confined to very small areas relative to the overall crop with control rarely required. Beetles will often move on after a day or two or disperse, at which point ongoing damage ceases.

Solenopsis mealybug

The solenopsis mealybug, (*Phenacoccus solenopsis*), is an exotic pest originally encountered in cotton crops during the mid 2000s. It is widespread and has been observed in cotton crops across all northern locations. Since initial outbreaks of this pest, it has become well controlled through deployment of on-farm hygiene to prevent establishment and growth of weeds and ratoon/volunteer cotton that would enable mealybug to carry over between seasons. The abundance of many natural enemies that feed on mealybugs (various lacewings, ladybirds and a parasitoid) has also increased and they often locate and destroy mealybug colonies before a hot spot can develop and cause crop damage. Many natural enemies are also key predators of aphids and therefore conservation (of ladybirds and lacewings in particular) through careful insecticide usage is a key component of IPM for the tropics.

Early infestations of mealybugs can cause reduced plant vigour, stunting and even death. If uncontrolled by natural enemies, mealybugs can spread causing large patches of dead or dying plants. Late season outbreaks can also pose a risk for lint quality as mealybugs secrete honeydew. If an early outbreak is encountered during crop scouting, it is useful to mark the spot so that it can be observed on subsequent checks. This will provide useful information on natural enemy presence and biocontrol efficacy and allow better management decisions for both mealybugs and other pests to be made.

A boll that has been damaged by cotton coreid bug feeding. Paul Grundy

A late instar cotton coreid bug. Paul Grundy

Disease management

Ramularia/Grey mildew (caused by *Ramulariopsis pseudoglycines*).

The exact behaviour and impact of this disease on Australian cotton is yet to be studied in detail. However, the impact is likely to be varied across the different cropping regions in Northern Australia due to climate differences. Ramularia infection in NT rainfed crops and in surface-irrigated crops in WA appears to be a sporadic event that occurs after crop cut-out and closer to defoliation. These scenarios leave limited opportunity for disease buildup and are unlikely to affect yield. However, pivot-irrigated crops in the NT may create more conducive conditions for an earlier and more persistent infection. Active monitoring is advised to determine a course of action.

Well developed ramularia symptoms on both the underside and top of cotton leaves. This disease is typically observed initially on the underside from which is progresses resulting in leaf shedding. Paul Grundy

Target spot (caused by *Corynespora cassiicola*).

Although the fungal pathogen responsible for this foliar disease has been observed in samples collected from both rainfed and irrigated crops across Northern Australia, disease outbreaks to date have only been reported in pivot-irrigated crops in Queensland (in the Tablelands region and surrounds). Key aspects that favour disease development are prolonged periods of leaf wetness, moderate temperatures (~25-30°C), and high relative humidity. If these conditions are met, crop managers are encouraged to scout for disease symptoms from flowering onwards to determine a course of action. Preliminary trials have shown that fungicides can be very effective for managing target spot, however, disease impact on yield and optimal management are subjects of ongoing research.

Lesions caused by target spot. Note the characteristic rings within the necrotic tissues. Leaves will defoliate as the infection progress. Paul Grundy

Leaf blights (caused by *Alternaria sp.*, *Cercospora sp.*, and *Stemphylium sp.*).

In Northern Australia, these leaf blights tend to appear late in the cropping cycle. The exact behaviour of these fungal pathogens is currently being investigated in more detail, but field observations indicate that cooler temperatures might favour their occurrence. Disease development has been mostly slow and rather mild, with no cases of defoliation reported in modern commercial varieties. Overseas literature indicates that the incidence of these leaf blights might be linked to low potassium levels in the soil at times of high demand by the plant (i.e. boll-filling). Potassium fertiliser is currently being investigated as a potential strategy to mitigate these leaf blights.

CRDC
CRCNA DEVELOPING NORTHERN AUSTRALIA

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NORTHERN GROWTH

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