Brazil Study Tour Report

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In May 2026, CRDC in collaboration with ABRAPA (Brazil Cotton Growers Association) sponsored a technical exchange between Australia and Brazil for the purpose of sharing knowledge and information between each country with regard to tropical cotton production and the management of key pests and disease. 5 delegates from Australia travelled to Brazil between 9 and 24 May 2026. The delegates were:

Paul Grundy – QDPI and CottonInfo
Sharna Holman – QDPI and CottonInfo
Jamie Street – CGS
Penny Goldsmith – ORDCO

These delegates were also joined by Alex Roughley from CSD who was sponsored by his own organisation.

The group travelled to the Mato Grosso and Bahia regions where they were hosted by various organisations and growers. Key focus points for the visits were to better understand:

- Boll weevil and pest management
- Management of foliar diseases
- Soil management
- Growth and canopy management
- Use of cultivars
- Other aspects of the farming system relevant to Australian cotton production.

A range of valuable learnings and observations were attained during the visit with perspectives shared by local researchers, extension staff, growers and their advisors. Many observations are highly relevant for cotton production in Australia's tropical regions and for crop protection and biosecurity preparedness. These are captured in the following report.

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Study Tour Region and Farming System

The Mato Grosso and Bahia regions visited are located within the Brazilian Cerrado, a vast tropical savanna that covers 24% of Brazil's land area. This biome is the second-largest in South America after the Amazon and includes much of the states of Mato Grosso, Bahia, Goiás, Mato Grosso do Sul, Minas Gerais, and the Federal District where cotton production is undertaken to varying degrees.

Originally, the Cerrado was characterised by a mosaic of grasslands, shrublands and open woodlands growing on deep, highly weathered, acidic soils that were naturally low in phosphorus, calcium and other essential nutrients, with high levels of exchangeable aluminium. These conditions made the region unsuitable for intensive cropping until major advances in soil science during the 1970s and 1980s.

The transformation of the Cerrado since the late 1990s into one of the world's most productive agricultural regions is commonly referred to in Brazil as the miracle of Cerrado and was enabled by:

- Application of lime to overcome soil acidity and aluminium toxicity.
- Large applications of phosphorus fertilisers to build soil fertility.
- Development of crop varieties adapted to tropical day lengths and climates.
- Expansion of mechanised farming and irrigation where required.
- Strong investment in agricultural research.

This region produces most of Brazil’s grain and fibre. Cotton production is concentrated in the western Bahia and Mato Grosso regions, where deep soils, relatively flat landscapes, and a well-defined wet season provide excellent conditions for high-yield irrigated and dryland production.

The farming system of which cotton is a part consists of 40 million hectares of soybeans, 18M ha of maize and 1.5-2M ha of cotton. Other crops such as millet and sorghum are grown to a lesser extent generally to manage ground cover and/or disease issues. These crops are grown with rainfall only, apart from about 10-15% of the cotton in the Bahia region that is finished with overhead irrigation as insurance against an earlier than expected finish to the wet season and to allow production in areas with less reliable rainfall.

Climate

The climates for the Mato Grosso region (largest cotton area) and Bahia region share similarities but also differ in their implications for the respective farming systems that have evolved. Mato Grosso has a milder climate, both in terms of lower daytime dry season temperatures and higher rainfall that is spread over more months of the year with meaningful rain from September to May (Fig 1). This has allowed double cropping with soybeans followed by cotton or maize.

In comparison, the Bahia region has less overall rainfall and a more restricted wet season duration of October to April (Fig 2). Cropping is largely focused on a single crop per year and in some cases a cover crop grown in the latter part of the wet season post crop where this fits for the purpose of increasing ground cover.

Compared to current rainfed cotton production regions of Australia's Northern Territory (predominantly in the Douglas Daly; Fig 3) both regions in Brazil hold important advantages. Firstly, both regions of Brazil are elevated with Mato Gross region ranging from 700 m elevation (Campo Verde) to 450 m (Rondonópolis) and Bahia between 850 m (Luís Eduardo Magalhães, LEM) and 500 m (Barreiras). In comparison the Douglas Daly to Katherine region where cropping is undertaken ranges from 100 to –150 m, and Kununurra in the eastern Kimberley where irrigated cotton is undergoing expansion has 40-50 m elevation.

The major cotton regions of Mato Grosso occur at almost exactly the same latitude as Katherine and Kununurra (Table 1), while western Bahia is 2–3 degrees closer to the equator. However, with the Brazilian regions being typically 600–800 m higher, temperatures are substantially moderated. A rule of thumb is that temperature decreases by about 6.5°C per 1,000 m elevation gain. Thus, the 700–800 m elevation of Campo Verde and Luís Eduardo Magalhães production regions provide roughly 4–5°C of cooling relative to a lowland location at the same latitude, which explains why Campo Verde (15.5°S, 736 m) has mean annual temperatures around 23–24°C and Katherine (14.5°S, 108 m) has mean annual temperatures around 27–28°C. The elevation of the Mato Grosso and Bahia production plateaus create a much more favourable environment for cotton during flowering and boll filling.

Table 1. Comparison of Northern Australia and Brazil location, latitude, mean temperature and elevation where cotton production is taking place.

Location	Latitude	Elevation (m)	Mean Annual Temp (°C)	Rainfall (mm)
Katherine	14.5°S	108 m	27.5-28	950-1000
Kununurra	15.8°	45 m	27-28	790-820
Campo Verde	15.5°S	736 m	23-24	1700-1900
Luís Eduardo Magalhães	12.1°S	800 m	24-25	1400-1600

Rainfall across the two regions in Brazil also vary markedly from northern Australia. The spread of rainfall is more favourable in each Bazilian region with a 'dry' season spanning only 3-5 months compared to Australia's longer 5-6 months. The total amount of rainfall is much higher in Brazil and importantly more evenly spread throughout the Brazilian wet season. In comparison, Australia's current northern cotton regions have nearly half the rainfall and the bulk of this predominantly falls between the December-March period. The implications for the availability of soil moisture and cropping are evident in these comparisons.

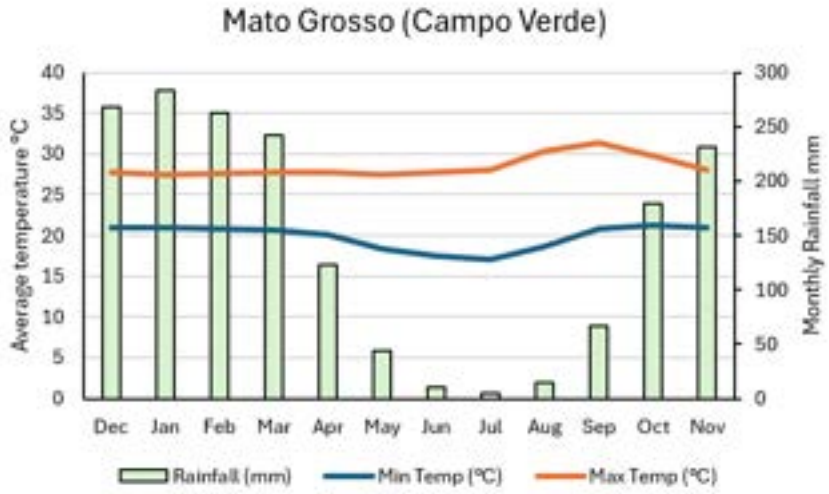


Fig 1. Monthly average minimum and maximum temperatures and rainfall for Mato Grosso cotton production region utilising data from Campo Verde (2001-2021).

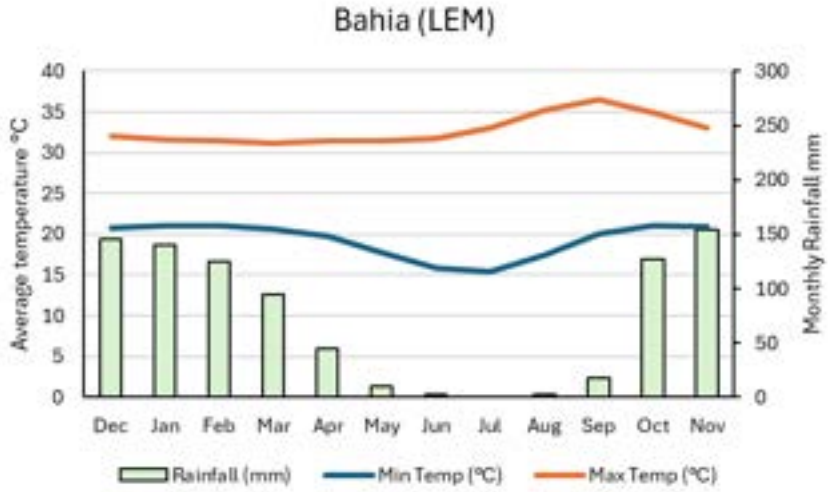


Fig 2. Monthly average minimum and maximum temperatures and rainfall for the Bahia cotton production region utilising data from LEM (2001-2021).

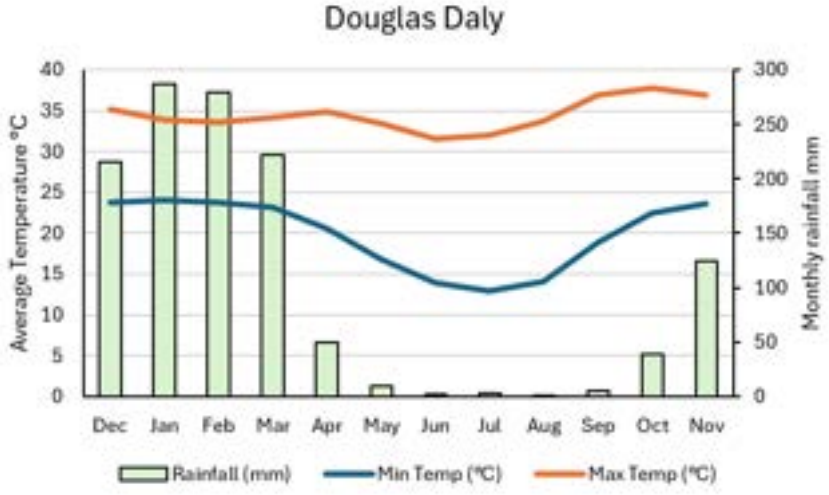


Fig 3. Monthly average minimum and maximum temperatures and rainfall for the Douglas Daly region utilising data from research farm (1960-2024).

Soils

A variety of soil types were observed in Brazil that ranged from quite sandy soils to loamy earths and are generally described as highly weathered Oxisols and Ultisols. Key soil characteristics that were apparent across all farms visited were:

- Soils were metres deep with no obvious B horizon within the zone that crop roots could be expected to reach or be constrained by.
- Plant water holding capacity was generally considered to be unimportant as it was not a typical production constraint due to the spread of rainfall and cropping calendar.
- Soils were largely homogenous at the paddock scale. Soil variation occurred across kilometres rather than hundreds of metres.
- Soils were generally mildly acidic with a managed pH of around 5.8-6.2. Some soils at the commencement of production were highly acidic.

Practices associated with soil management were:

- Large amounts (between 8-15 t/ha) of lime (dolomite) were applied to new country in the first years of production. Following this, routine liming is undertaken as part of the cropping program (generally 1t/ha of lime per annum). In some cases, growers applied 3 t/ha every 2nd or 3rd year, depending on the cropping program and whether the soil was periodically deep ripped.
- For soils with a higher clay content in the wetter Mato Grosso region, ripping was undertaken every 3-5 years to ameliorate machinery related compaction.
- In the Bahia region, the growers visited did not report utilising deep ripping. Instead biological soil amelioration was popular, with millet and brachairia grass used as a cover crop to access nutrients at depth and recycle these to the surface via above ground biomass production. Cover crop roots were reported to penetrate as far as 5 metres. These regions were also sandier and had a lower clay content and were potentially less prone to machinery compaction.
- Precedence is given to maintaining stubble cover of the soil throughout various crop production cycles.For example, brachairia grass is grown in the Bahia region underneath maize to assist with maintaining ground cover and weed suppression.
- Observations of the soil surface suggested that the soils were not as prone to hard surface setting as has been observed in the Northern Territory. This may be due to the inherent sand, clay and silt fractions of the soil but is also likely due to the use of gypsum and focus on maintaining soil cover via retained crop residues or purpose planted cover crops. Surface organic matter was considered important for improving moisture infiltration and retention as well as limiting surface erosion.



Photos showing residues from the previous crops (soybeans or millet) were still evident in these fields long after the conclusion of the wet season.

An interesting observation from the Bahia region were large borrow pits from which soil was removed to assist with increasing the platform base for the construction of the highway between Brasilia and LEM. These pits were sizeable (50-100 m across in each direction and 3-4 m deep) and occurred every 1-2 km beside the highway throughout the cropping area over a distance of more than 100 km. On every farm, the pits were cropped along with the rest of the field. What was interesting is that crop observed growing within these pits irrespective of it being cotton, maize, sorghum or millet had a good stand and similar appearance of vigour to that of the surrounding crop. Given that these crops were planted during the wet season it highlights two things. Firstly, the quality of the soil even after several metres of soil was removed is still sufficient to allow cropping. Secondly, the soils are clearly well drained as these large depressions would otherwise retain water and cause waterlogging. This does indicate some favourable soil characteristics that would come into play during wet season cropping.

Crop Nutrition

Crop nutrition would be best described as high input. The consensus from each of the farm visits is that most cotton crops receive the inputs listed in Table 2.

Table 2. Macro-nutrient application to cotton in Cerrado regions of Brazil.

Element	Form	Brazilian Applied Rate (kg/ha)	**Converted Elemental Rate (kg/ha)**
Phosphorous	P_2O_5	200	**80-90**
Potassium	KCl	140-190	**120-140**
Nitrogen	Mix of Ammonian sulphate and Urea	180-200	**180-220**

Phosphorous

The major cropping areas of Mato Grosso and Bahia are dominated by highly weathered Oxisols and Ultisols that have very low native phosphorus reserves combined with high iron and aluminium oxide contents. As a result, these soils can strongly fix phosphorus, making much of it unavailable to crops.

As a result, growers have a robust phosphorous program. During initial cropping seasons, large applications of phosphorus were made to saturate fixation sites and increase soil P reserves. This was followed by maintenance applications that allow for crop removal and continued phosphorous fixation. Most growers reported using 200 kg of phosphorous per hectare with applications being made prior to growing cotton and residual amounts then benefiting subsequent rotation crops. Applying the phosphorous prior to cotton as opposed to other crops in the rotation was deemed to be the most beneficial approach. The rate of 200 units of phosphorous seemed very high by Australian standards and was questioned at several farms. Pat Hulme who also visited Brazil subsequently to our visit was able to shed light on this with the learning that Brazil report phosphorous as oxides (P_2O_5) which are 44% less concentrated in terms of elemental phosphorous when converted. Dividing the P_2O_5 rates reported by 2.3 gives an approximate rate of elemental phosphorous which is how phosphorous use is expressed in Australia (Table 2). Even when converted to the elemental rate, the amount of phosphorous

applied in Brazil is very high compared to rates used in Australia, reflecting their chemical soil constraints.

Potassium

Potassium is generally applied as muriate of potash in Brazil. However, the rates reported by growers are generally expressed as K_2O equivalents which are 1.2 times less than the elemental value (how K usage is described in Australia). Factoring this in for reported usage rates by different farmers suggested a typical application rate range of 120-140 kg K/ha. Within the farming system K is applied prior to planting cotton. The reason for these high rates is linked to both the removal rate for cotton (25 kg/ha) combined with the temporary high rate of uptake during the crops growth. Subsequent soybean crops are also high removers of applied K. Researchers also reported that the application of high rates of K assist in reducing crop susceptibility to cotton foliar diseases.

Potassium may be applied pre-plant although two growers also reported applying potassium after emergence but prior to flowering.

Nitrogen

Applied nitrogen rates were similar to Australia in the sense that most growers are applying 180-220 kg of N with a yield objective of 9-11 bales/ha. The form of nitrogen used by growers varied. Ammonian sulphate was the more commonly applied form of nitrogen with several growers commenting that this form was less volatile and prone to loss during the wet season and the elemental sulphur was helpful in soils that are largely deficient. Two Bahia state growers reported using primarily urea but these growers also reported utilising gypsum periodically which would likely address sulphur requirements. Nitrogen rates reported in the Bahia region were marginally higher than in the Mato Grosso region. This might reflect the double cropping of soybeans with cotton in the Mato Grosso region with cotton immediately following soybeans. In the Bahia region soybeans are grown a full season prior, which may reduce nitrogen carryover. Yield potential was a bit higher in Bahia so higher rates of N might also reflect crop requirements.

Nitrogen is largely applied post-emergence. Growers in Mato Grosso reported making applications at 15, 30 and 45 days after emergence. Up-front applications are avoided due to the potential for losses. Fields are easily trafficable, allowing in-crop applications to be made.

Growers also reported using a range of foliar applied micro-elements, including boron. molybdenum and zinc.

Crop Rotations

The Brazilian farming system is centred around soybean production as the pillar crop. Soybeans are sown anytime as soon as rain allows from October onwards and harvested from January onwards. After soybeans, growers plant maize, cotton or other minor crops such as millet or sorghum. The approximate cropping areas grown in Brazil are 40M hectares of soybeans, 18M ha of maize, and in 2026, 2M ha of cotton. Cotton is a relatively minor crop in terms of annual farming area, but is high value.

In the state of Mato Grosso, sufficient rainfall occurs to allow double cropping each year. Soybeans are the pillar crop each season which is generally followed by either cotton, maize or a

number of other minor crops such as sunflower (Fig 4). In the drier Bahia region, the wet season only allows for 1 main crop and in the case of soybeans a cover cropping post-harvest may also be grown during the last phase of the wet season. Cotton and maize are then sown the following wet season. Covers might consist of millet or brachiaria grass. A key focus under all circumstances is to maintain soil cover by retaining crop residues at the surface.

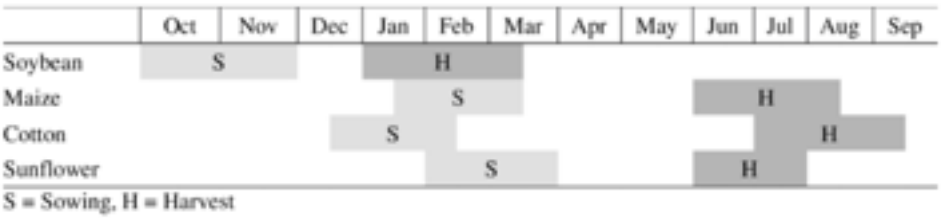


Fig 4. Agricultural calendar for the state of Mato Grosso (IMAmt).

Stubble retention to provide ground cover was considered important for several reasons. Firstly, it keeps the soil surface more friable, making the establishment of the following crop easier. Stubble retention also aids moisture management, improving water infiltration by slowing overland flow whilst also serving to reduce surface evaporation. Stubble conservation was also reported to improve soil organic matter, carbon and health. Stubble cover also plays a role in suppressing weed germination.

Tillage is used sparingly in Brazil. Some growers in Bahia reported not using tillage at all for some farms. Others reported strategic ripping every 3 years, utilising this as an opportunity to apply gypsum and lime. Mato Grosso growers visited used strategic deep ripping every 3-5 years prior to planting soybeans as a means of managing machinery-related compaction arising from wet conditions during soybean harvest in January coupled with soil types that have a higher clay fraction.

A key learning repeated by several growers during farm visits is that the system is centred around soybeans and maize. Cotton was added to the system once the cropping system was established 3-4 years after commencing cropping. Thereafter, cotton is grown every 2-3 years as a cash crop as opposed to being a pillar crop.

Weed, ratoon and volunteer management

Being minimal tillage, the Brazilian farming system is completely dependent on herbicide for weed control. Soybean, maize and cotton grown in this system all have various herbicide tolerant traits.

Post-harvest, cotton is mulched and then entirely controlled with the use of herbicides. Interestingly, the Brazilian cotton industry decided not to not utilise 2,4-D herbicide tolerance in varieties. Some growers have also avoided cultivars with glufosinate tolerance. This has enabled growers to use glufosinate and 2,4-D in subsequent soybean crops that have these traits to enact control of regrowth cotton and volunteers.

Initially cotton may be sprayed with 2,4-D immediately following mulching. It is then subject to further applications in tolerant soybeans. Without this option, the ability to control cotton without tillage would be compromised. Interestingly, fluroxypyr was not a preferred herbicide for ratoon

and volunteer management due to plant back issues in soybeans. Effective ratoon and volunteer management is critical for the management of boll weevil and various other pests and diseases.

Weed control in cotton begins with the use of various burn down options just prior to planting. Treflan and diuron is then applied as a residual herbicide before reliance after emergence on over the top applications of glyphosate and increasingly glufosinate which are the two herbicide traits available in Brazil cotton varieties. Some growers reported that weeds are becoming more problematic in the farming system, with species of concern including vines (*Ipomea* sp), chicken foot grass (*Eleusine indica*) and *Digitaria* grass species that have become resistant to glyphosate. Palmer amaranth (*Amaranthus palmeri*) was also detected in some regions in 2015. Although these occurrences were quarantined to stop the spread, pollen escaped and has hybridised with local amaranths making these problematic weeds. The small seed of this hybrid is easily spread in harvesting equipment as it is very difficult to remove the seeds from machinery.

Farm Scale

A key observation from the growers visited during the tour was the scale at which operations were conducted and the associated efficiencies derived. Growers were either very large 20,000-30,000 ha, and as such operated their own ginnery and direct imported crop inputs such as fertiliser and pesticides. Smaller growers (2000-4000 ha) were able to achieve similar scale advantages through the formation of grower cooperatives. These cooperatives consisted of 8-12 growers who then operated a ginning facility and could collectively bulk purchase inputs such as fertiliser and chemicals, enabling them to achieve cost efficiencies that helped offset the relatively high use of inputs. Setting up operations at scale either individually or via cooperatives enabled growers to overcome the lack of a service sector for inputs and commodity processing given the Cerrado was undeveloped 25 years ago.

Cotton Cultivars

Brazil growers have access to over 70 cotton varieties from a range of local and multi-national seed suppliers. Many of the varieties on offer had been developed locally via organisations such as IMAmt, Embrapa and TMP, with cultivars also available from larger multi-national suppliers such as BASF and Bayer/Deltapine. This differs significantly from Australia, which is typically dominated by 10-15 varieties at any one time from a single supplier.

Cultivar development in Brazil has been driven by a range of factors with the most frequently mentioned including:

- Ramularia resistance
- Root-knot and reniform nematode resistance
- Response to high fertility
- Harvest timing
- Long-season yield potential
- Fibre quality – usual characteristics along with a focus on reducing seed coat fragments during ginning.

Cultivars come with a range of GM traits and interestingly, earlier versions of Bt traits have not been withdrawn from the market with growers able to grow 1,2 and 3 gene products, compared to Australia where only varieties with triple stack Bt traits are available.

Table 3. Current Cotton GM traits available for use in Brazil

Trade Name	Company	Insect Resistance	Herbicide Tolerance
Bollgard	Monsanto/Bayer	Cry1Ac	None
Bollgard	Monsanto/Bayer	Cry1Ac	None
Bollgard II	Monsanto/Bayer	Cry1Ac + Cry2Ab2	None
Bollgard II RF	Monsanto/Bayer	Cry1Ac + Cry2Ab2	Glyphosate
Bollgard 3	Monsanto/Bayer	Cry1Ac + Cry2Ab2 + Vip3A	None
Bollgard 3 XtendFlex	Bayer	Cry1Ac + Cry2Ab2 + Vip3A	Glyphosate + Glufosinate + Dicamba
Roundup Ready Flex	Monsanto/Bayer	None	Glyphosate
Liberty Link	Bayer	None	Glufosinate
GlyTol	Bayer	None	Glyphosate
TwinLink	Bayer	Cry1Ab + Cry2Ae	Glufosinate
TwinLink Plus (GLTP)	Bayer	Cry1Ab + Cry2Ae + Vip3A	Glyphosate + Glufosinate
WideStrike	Corteva	Cry1Ac + Cry1F	Marker-based glufosinate tolerance
WideStrike 3	Corteva	Cry1Ac + Cry1F + Vip3A	Typically stacked with herbicide traits

In discussions with cotton breeders at IMAmt it was clear that priority was being given to selecting for cultivars with better resistance to diseases such as ramularia and nematodes with also a clear focus on improving fibre quality characteristics. Breeders and pathologists indicated that to date there had been no progress with identifying host plant resistance to target spot (*Corynespora cassiicola*) disease.

As an overarching theme it was clear from various discussions that the Brazilian industry has a clear focus on improving fibre quality and becoming a producer of premium quality fibre on the world stage.

Canopy Management

The topic of canopy management and how decisions were made for mepiquat chloride (MC) usage was asked during all farm visits. It was clear from the interactions with various people that there was no common strategy for MC usage decision making. Different agronomists indicated that they examined typical growth indicators such as the most recently expanded upper internode lengths and crop colour. Most growers indicated that managing growth in such a way as to not compromise compensation for wet season shedding was a key objective. One observation that was common to nearly all farms was that MC was used in low dosages frequently. Given the high level of spraying undertaken for pests and disease (at least every second week), MC was often applied in conjunction with one of these applications that would be occurring .

Visual inspection of many crops across different farms found that all crops were relatively tall with a large proportion of bolls in the upper canopy with many lower canopy bolls having been shed or tight locked due to earlier wet conditions.

Several agronomists commented that the crop is 'the height it needs to be to achieve yield' which speaks to the objective of compensatory yield set. These agronomists also indicated that a shorter crop would be preferred but that ultimately crop height depended on wet season conditions and fruit set in the lower canopy.



All of the crops observed in the Bahia region (top and bottom right) were tall with a predominance of fruit in the upper canopy. Crops in Mato Grosso (bottom left) were much shorter with growers indicating that it had been a relatively drier and sunny season that favoured better early season boll retention, and that in many seasons crops are tall to enable compensatory boll set.

Crop Protection

Learning about crop protection challenges was a major objective for the study tour. Brazil has a range of key pests and diseases that challenge their production system. While some are already present in Australia, several are considered priority exotic pests from a biosecurity perspective.

Nematodes

Several plant-parasitic nematode species are important pests of Brazilian cotton, including root knot, *Meloidogyne incognita* and reniform, *Rotylenchulus reniformis* together with *Pratylenchus brachyurus* and *Meloidogyne enterolobii*. While resistant cotton cultivars are available for *M. incognita*, only a few commercial cultivars have resistance to *R. reniformis*, making it one of the most significant nematode threats. Growers highlighted that nematodes are particularly difficult to manage because infestations often remain undetected until crop symptoms become evident and yield losses occur. With continuous cropping, nematode numbers can build up to high levels and cause complete crop loss across large swathes of field area.

Management tactics for nematodes are limited within the farming system. Crop rotation is not a viable option as the pillar crop soybean, and cotton are both host species which makes negates the ability to have a host free period in the farming system.

Growers were asked about the use of cover crops such as sunn hemp, *Crotalaria juncea*. Responses indicated that sunn hemp could provide valuable reductions in nematode numbers however, including it in the rotation entailed giving up the opportunity to grow a commercial crop (due to the rain grown system) and for this reason it was not widely utilised by growers. In the Bahia region the use of millet and Brachiaria grass was considered to help with nematode suppression.

The primary focus for most growers was to utilise where possible resistant cultivars to reduce nematode impacts.







Reniform nematodes have devastating impacts on cotton yield within the rain grown farming systems. The compromised root system results in premature moisture stress and cut-out. The photo top left shows up close plant wilting followed by the patchy distribution of reniform nematodes across a field area (top right and bottom left). The grower (bottom right) estimated that the crop will make less than 2 bales/ha.

Foliar Diseases

Brazil has a range of diseases that impact cotton production. Unlike Australia where the most damaging diseases are soil borne wilt diseases, the most common and damaging diseases in Brazil affect the foliage. The two primary diseases are target spot and ramularia . Lesser diseases include ramulose and leaf curl disease.

Target spot

Target spot (*Corynespora cassiicola*) has emerged to become one of the leading causes of cotton disease in Brazil since the mid 2010s. This disease has always been present in Brazil but for reasons that are not well understood, it has only become a prevalent problem in cotton requiring active management in the last decade, surpassing ramularia in importance. When left untreated, target spot causes extensive crop defoliation commencing in the lower canopy and spreading to the upper canopy.

To date, there has been no success in identifying cultivars with resistance to target spot in Brazil. Researchers did indicate that some varieties might exhibit better tolerance to disease but this is not considered resistance as such. Control relies on fungicide intervention with reports of spraying up to 8 times per season to achieve control. The amount of spraying varies between seasons and regions. Many of the fungicides used for target spot control are also efficacious for ramularia.

Target spot is also a disease of soybeans which is the primary pillar crop of the Cerrado region. Given that soybeans precede cotton, this may explain the increased prevalence of this disease and was considered by some researchers to be a driver for the increase. The fungus also survives well on infected residues. Brazil's minimum tillage system where the residues of the previous crop are retained on the surface may also explain the increased prevalence of this disease.

The disease survives well on crop residues and alternative hosts. Conidia are produced after rainfall and infection commences in the lower canopy close to the soil surface. As the infection progresses, it moves upwards through the canopy and causes premature defoliation. Yield loss

depends on disease severity and canopy loss. Yield impacts of up to 22% loss were reported by researchers at IMAmt.



Images of target spot severely impacting cotton crops in Mato Grosso.

Ramularia

Ramularia (*Ramulariopsis* sp.) is a significant disease of Brazilian cotton crops. In the last decade management has improved through the integration of tolerant cultivars, fungicides and improved cultural control of out of season cotton. Recent molecular work has shown that the majority of Brazilian isolates sampled and examined are actually *Ramulariopsis pseudoglycines*, with only a limited proportion being 'true' ramularia (i.e. *Ramulariopsis gossypii*). Despite this, growers refer to both these pathogens and the disease caused as ramularia.

Ramularia is a foliar disease and occurs in crops from the late vegetative stages through to crop maturity. Researchers described ramularia as a disease that has changed over time. Initially the disease was only a curiosity for growers, turning up late in the season and considered to be helpful for defoliation. Disease prevalence then began to change, with outbreaks occurring earlier in the season and requiring control. The reasons for this are not well understood but potential theories include change within the pathogen potentially coupled with an intensification of the cotton production system as acreage expanded.

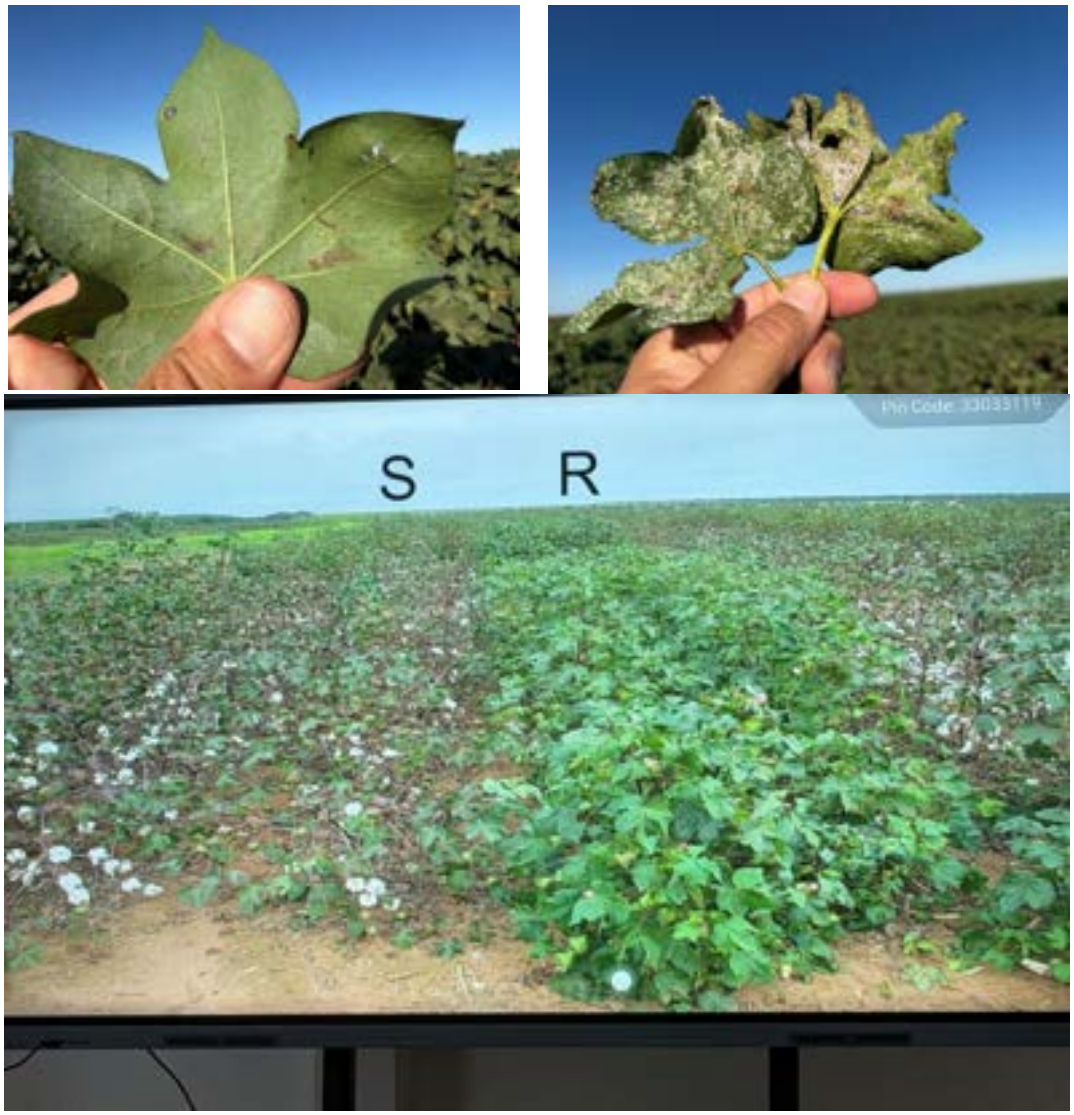
The disease is spread via conidia that move with wind and rain splash. Once upon the leaf conidia germinate with hyphae that grow across the surface to locate stomata through which infection occurs. Hyphae then grow within the leaf intracellularly in the mesophyll cells and sporulation subsequently occurs back through the stomata on both the upper and lower leaf surfaces. Disease symptoms are distinctive, beginning with small angular lesions bounded by leaf veins that correspond with pale green to yellow lesions on the upper leaf surface. As the disease progresses, white, powdery sporulation occurs primarily on the underside of leaves. The lesions at this point coalesce and cause premature leaf senescence. Early infections often begin low in the canopy where humidity is highest before progressing upwards.

Management is achieved with the use of fungicides (5-8 applications per season) that are generally commenced before disease is obvious rather than waiting for symptoms. Host plant

resistance is available across a range of cultivars which has markedly reduced the need for fungicides although targeted fungicides can be applied in conjunction with host plant resistance. The level of resistance achieved via host plant resistance can also break down over time and therefore selecting for resistance remains a focus within cotton breeding programs.

Growers also undertake cultural practices for control. This includes crop residue management and not growing cotton back to back, destruction of volunteers outside of the cotton cropping period and maintaining canopy aeration where possible though the use of mepiquat chloride.

Fungicide resistance is an emerging problem. Growers rotate FRAC groups and avoid repeated applications of the same mode of action. The use of single site fungicides is also avoided.



Photos from top left clockwise; a ramularia resistant cultivar. Note that white smudge like marks which are hyphae that have germinated under high disease pressure but subsequently have not infested the leaf through the stomata; top right; ramularia susceptible variety and bottom; Ramularia susceptible (left) and resistant (right) cultivars within plot trials showing the marked difference in symptoms.

Cotton blue disease

Cotton leaf roll dwarf virus causes the disease known in Brazil as cotton blue disease. It is transmitted by cotton aphid (*Aphis gossypii*). The impact of this disease is severe, particularly if cotton crops are infected early – similar to cotton bunchy top disease in Australia.

This disease is now managed with the use of resistant cultivars.



A photo of cotton blue disease affecting a susceptible cultivar compared with a resistant line.

Ramulose

A less frequent disease in Brazil that can cause devastating loss when it occurs is ramulose (*Colletotrichum gossypii* var. *cephalosporioide*s). This disease is unique to Brazil, Venezuela and Colombia. It is a disease that concerns growers because of its ability to permanently alter plant architecture early in the season, stunting regular growth and subsequent yield. It is related to anthracnose but causes distinctive cotton symptoms with star-shaped lesions in the leaves and a 'tipped out' growth habit. The name ramulose is a Portuguese term to describe the excessive branching that crops develop after infection. The fungus infects apical meristem tissue, causing terminal buds to die and the plant to lack apical dominance with the plant developing a broom like appearance.

The disease can originate from infected seed and crop residues. Spores are also spread by wind and rain splash. Seed transmission can result in the disease moving between farms and production regions

Currently the disease is managed through resistant cultivars or the use of fungicides requiring 1-2 well timed applications during the early crop stages leading into flowering. Certification of planting seed health is also an important aspect for management at a regional level.

Being seed borne, this disease is of relevance to Australia from a biosecurity perspective.





Power point presentation at IMAmt showing the impact of fungicides on ramulose disease, which reduced yields by approximately 40%.

Fungicide Use on Cotton

Fungicide use is extensive in Brazil for cotton production and is a routine component of crop management. This is due to the aforementioned impacts of several foliar diseases that if left un-treated can cause premature leaf senescence and yield loss. The majority of fungicide application occurs from very early flowering through until boll filling. On average various people reported and average of 7-8 applications with some reporting as high as 12 per season. Researchers reported issue with resistance to some products for some diseases. The typical range of fungicides used is given in Table 5.

Table 4. Fungicides used in Brazil for the control of foliar diseases.

Common name	FRAC Group	Mode of action
Difenoconazole	3	DMI (triazole) sterol biosynthesis inhibitor
Tebuconazole	3	DMI (triazole)
Prothioconazole	3	DMI (triazolinthione)
Pydiflumetofen (trade name: Adepidyn®)	7	SDHI
Fluxapyroxad	7	SDHI
Bixafen	7	SDHI
Inpyrfluxam	7	SDHI
Fluindapyr	7	SDHI
Methyl tetraprole	11	QoI (strobilurin-like)
Florylpicoxamid	13	Pyrrolidinone – tubulin assembly inhibitor
Fentin hydroxide (Triphenyltin hydroxide)	30	Multi-site organotin fungicide
Mancozeb	M03	Multi-site dithiocarbamate
Chlorothalonil	M05	Multi-site chloronitrile



A typical program of fungicides being used for foliar disease management in Brazil.

Insect Management

Discussions with researchers from the Mato Grosso Cotton Institute (IMAmt), Dr Guilherme Rolim and Dr Jacob Netto, highlighted several key insect pests affecting cotton production during the 2024–25 season. The most significant pests identified were boll weevil, lepidopteran pests including *Helicoverpa* spp. and *Spodoptera frugiperda*, silverleaf whitefly, and mites. Researchers estimated that insecticide costs are approximately USD $380/ha for boll weevil control and USD $120/ha for the management of other insect pests, equating to a total of around USD $500/ha, excluding the cost of GM cotton seed. However, these estimates are likely to be conservative, as the number of insecticide applications reported by researchers at IMAmt was generally lower than that reported by growers during the study tour.

Boll Weevil

The boll weevil, one of Australia's high priority exotic pest threats, is the most economically damaging insect pest of cotton in Brazil. If left uncontrolled, infestations can result in yield losses of up to 98%, with the insect showing a preference for squares and young thumbnail-sized bolls. Since its arrival in Brazil in 1983, boll weevil has remained one of the greatest threats to cotton production. During the Pest Management Workshop, one agronomist commented that the pest has become so difficult and costly to manage that some growers have abandoned cotton production altogether.

Research has shifted towards a more holistic understanding of boll weevil biology, ecology and population dynamics, recognising that successful management requires an integrated approach rather than relying solely on in-crop insecticide applications. A strong emphasis is now placed on reducing population recruitment between cotton seasons through cultural control, particularly by managing volunteer and ratoon cotton plants in soybean crops. These plants provide an important off-season refuge for boll weevil populations, allowing them to persist and reproduce between cotton crops. Effective volunteer cotton control relies on planting cotton and soybean varieties with different herbicide tolerance traits, enabling selective destruction of volunteer plants. The purposeful avoidance of including 2,4-D tolerance in cotton has enabled the use of this herbicide to remove volunteers and ratoons in tolerant GM soybeans. Volunteer cotton present from August to January can support up to seven boll weevil generations, substantially increasing pest pressure in the following cotton season. Boll weevils can survive for 3–4 days without food, although survival extends to 9–10 days when feeding on lipid-rich food sources. Researchers also indicated that approximately 15% of the population can survive by feeding on pollen and within cotton bracts. On one farm visited, growers continued boll weevil management throughout the cotton-free period by applying insecticides every seven days between seasons.

Insecticide management during the cotton season targets adult boll weevils, as immature life stages remain protected within cotton fruiting structures. With 5–6 generations occurring during a single cotton season, timely monitoring is essential to ensure insecticide applications are made before eggs are laid. Malathion remains the primary insecticide used for boll weevil control in Brazil. Monitoring programs are extensive, with the Instituto Mato-Grossense do Algodão (IMAmt) coordinating surveillance across the Mato Grosso region, alongside similar programs in other cotton-growing regions. Approximately 30,000 pheromone traps are maintained across Mato Grosso with support from growers to monitor adult boll weevil movement. Traps are typically

positioned around field boundaries and adjacent soybean crops to detect immigrating adults. On one farm in Bahia, approximately 1,400 pheromone traps were deployed; with lure replacement every two weeks, this occurs at considerable cost.

Detection of adult boll weevils in pheromone traps generally triggers border insecticide applications. If field assessments indicate more than 2% boll weevil damage, insecticide applications are extended across the entire field. Researchers at IMAmt estimated that approximately 5–6 insecticide applications are required each season for boll weevil management; however, growers consistently reported applying between 18 and 22 sprays per season, highlighting the significant management costs.



Photos (clockwise from top left): Boll weevil larvae found within cotton flowers in an entomology trial at the IMAmt research farm; pheromone trap on a commercial farm in the Bahia region; lavae being reared as part of a laboratory culture.

Lepidopteran pest complex

The principal lepidopteran pests of cotton in Brazil are fall armyworm (*Spodoptera frugiperda*), *Helicoverpa armigera* and *Helicoverpa zea*. Among these, fall armyworm is considered the most important pest, causing significant damage across maize, cotton and soybean production systems. In contrast, *Helicoverpa* species are generally more susceptible to insecticides and are considered less challenging to control than fall armyworm.

Fall armyworm

Resistance to Bt proteins has been reported in Brazilian fall armyworm populations, reducing the effectiveness of some Bt crop technologies and increasing reliance on insecticide applications. Researchers indicated that approximately 12% survival is now being observed on three-protein cotton varieties containing Vip3A (Bollgard® 3), unlike in Australia, where fall armyworm are still susceptible to Vip3A.

Maize is the primary host for fall armyworm and serves as the major source of population recruitment. Large populations develop within maize crops before dispersing into neighbouring cotton fields following maize dry down and harvest. The substantially larger area planted to maize compared with cotton supports continual population growth and migration. In Mato Grosso, for example, approximately 7.5 million hectares of maize are grown compared with 1.4 million hectares of cotton.

The maize/cotton production system provides a near-continuous supply of suitable host plants, enabling fall armyworm populations to persist and exert sustained pressure on cotton throughout the growing season. Within cotton, larvae feed on all plant structures, including bolls, increasing the potential for economic damage. To reduce movement of fall armyworm from maize into cotton, growers are increasingly using the Australian invention - Magnet® - as an attract-and-kill strategy. This approach aims to suppress adult populations and reduce migration into neighbouring cotton crops as part of an integrated pest management program.

In contrast, fall armyworm has not been considered a major pest of Australian cotton. Based on our observation, this is likely due to the continued susceptibility of Australian fall armyworm populations to the Vip3A protein expressed in Bollgard® 3 cotton, together with the absence of the extensive maize production systems that support large-scale population recruitment. Consequently, Australian cotton is not exposed to the same resource bottleneck following the harvest of maize that occurs in Brazil. However, the Brazilian production system demonstrates how reduction in Bt susceptibility, combined with landscape-scale host availability, can alter the pest status of fall armyworm in cotton.

Mites

Mites have become an increasingly important pest in Brazilian cotton production over recent seasons and are commonly observed in cotton, maize and soybean crops. Growers reported that management has intensified from an average of three to eight pesticide applications per season. Resistance to commonly used miticides is also emerging, with abamectin reportedly no longer effective for mite control and etoxazole also showing reduced efficacy.

Silverleaf whitefly

Silverleaf whitefly (*Bemisia tabaci*) populations are supported by Brazil's year-round cropping systems, which provide a continuous availability of host plants and enable populations to persist between crops. This ongoing population makes management in cotton challenging. Growers reported that silverleaf whitefly populations were generally higher during dry conditions, with adults also migrating from soybean into neighbouring cotton crops. In addition to direct feeding

damage, commercial penalties are incurred where honeydew contamination reduces lint quality, highlighting the importance of effective whitefly management.

Biological programs

There has been significant investment in, and adoption of, microbial biological control agents within the Brazilian cotton industry since approximately 2017. Today, biologicals represent a USD $6.5 billion market in Brazil, reflecting strong industry and government support for their development and use. To facilitate this growth, Brazil has established a dedicated regulatory framework for biological products, with separate legislation and registration pathways from those used for conventional chemical pesticides. This streamlined regulatory process has supported the development, commercialisation and adoption of biological control products.

Many of the research institutes and large farming operations visited either had dedicated biological control research programs or were producing their own biological products for on-farm use. For example, the Mato Grosso Cotton Institute (IMAmt) operates an extensive bioprospecting program aimed at identifying bacterial and fungal species with potential for use as biological control agents in either plant-incorporated applied protectants. To date, the program has collected and characterised 16,214 strains of fungi and bacteria. Research efforts focus on screening these strains to determine their efficacy against key pests and diseases, as well as assessing their potential for commercial development. For example, a fungal isolate (*Beauveria* sp.) achieved 100% mortality of boll weevil under laboratory conditions but showed little to no efficacy under field conditions.

The objective of these investments is to identify promising biological control candidates and generate the supporting research required for product development. Once strains demonstrate commercial potential, they may be transferred to commercial partners associated with the organisation, such as Comdeagro, for further development, registration, and eventual market release.

Notably, biological control agents are generally not viewed as replacements for conventional crop protection products, but rather as complementary tools within integrated pest management (IPM) programs. Across the regions visited, biological products were commonly applied in combination with conventional insecticides to improve overall pest control, extend residual activity, and help manage increasing levels of insecticide resistance. This integrated approach aims to maximise efficacy while reducing reliance on individual chemical modes of action.

In contrast, the Australian biological control market remains relatively small, with product use more common in broadacre grain production than cotton. This difference is likely to reflect the continued effectiveness of conventional insecticides (and Bt cotton) against many key pests, reducing the need for additional biological control inputs. As a result, Australian producers generally use either a conventional insecticide or a biological product, rather than applying both in combination as commonly observed in Brazil. Under current Australian insect populations with susceptibility to commonly used insecticides, the additional cost of combining biological and conventional products may not provide sufficient economic benefit to justify adoption and use in this manner. Brazil also treats biologicals differently to chemical insecticides with different

registration criteria. This regulatory change (3 years ago) has led to the expansion of biologicals as a mainstay approach used by growers as part of pest management programs.



Photos (top): Various commercialised biologicals produced in Brazil for insect control; (bottom) photo from Fazenda São Francisco on farm biologicals factory producing *Cordyceps javanica* for whitefly control.

Takeaway learnings for Australia

This section highlights the farming system and crop protection lessons from Brazil most relevant to Australia, particularly northern Australia. It is not intended to prescribe a Brazilian model.

Farming system

Unlike northern Australia, Brazil's farming systems were established around soybean and maize before cotton was introduced. Cotton remains a cash crop, generally grown in a field at most every second year, within rotations that prioritise soil cover through retained residues and strategic cover crops.

The most suitable rotation for northern Australia, where cotton is likely to remain the pillar crop, is unclear. Soybean is unlikely to fit without suitable GM traits and an established market. Maize has persisted intermittently, depending on price and market access, while sorghum, millet and mungbean may also have a role. Their suitability will depend on climate, markets and agronomic performance.

Vertebrate pests present an additional challenge. The scale of Brazilian cropping buffers losses from birds and feral animals in a way that may not be possible in northern Australia.

Soils

Low soil pH is a major constraint in Brazil and is actively corrected with lime when new land is developed. All growers visited relied on grid soil testing to manage pH and fertility over time.

The farms also benefited from relatively uniform soils within large management units, compared with the variability found within some Northern Australia cropping fields. Brazil's systematic approach provides a useful starting point for managing similar low-pH soils in northern Australia.

Climate

Despite frequent comparisons, the Cerrado climate differs markedly from Australia's northern production regions. Brazil generally has a longer, more reliable wet season, higher wet-season radiation and cooler temperatures, particularly at night due to elevation. These conditions favour photosynthesis, boll retention and boll filling.

This climatic reliability has supported long-term investment in correcting soil constraints. Rainfed production in northern Australia faces a shorter effective rainfall period, less favourable temperatures and greater cloudiness, resulting in more variable yield potential. Investment in soil amelioration and other inputs must therefore be matched to realistic production potential and risk.

Nutrition

Brazilian cotton relies on substantial nitrogen, phosphorus and potassium inputs applied after soil acidity has been corrected. Emphasis is placed on building phosphorus and potassium reserves to overcome low initial levels and nutrient tie-up, with micronutrients applied where required.

Nitrogen inputs were broadly similar to Australia at approximately 20 kg N/ha per bale produced. Most nitrogen was applied in-crop, staged between emergence and early flowering to reduce environmental losses.

This approach provides a useful template for northern Australia, although inputs must reflect local soils, climate, yield potential and economics.

Canopy Management

Brazilian crop managers use canopy management primarily to support yield compensation following weather-related fruit loss, rather than simply to restrict plant height. Frequent, low-rate applications of mepiquat chloride are used as required during vegetative growth and flowering. Crop height is a secondary consideration and varies between seasons according to conditions.

This objective should also guide canopy management in Australian tropical cotton.

Weeds

Weeds appeared manageable within Brazil's zero-tillage systems, supported by GM herbicide-tolerance traits in soybean, cotton and maize. Consideration was being given to limiting the traits used in cotton to retain options for controlling volunteers and ratoons in following soybean crops. Nevertheless, herbicide resistance is emerging.

Weed management may be more difficult in tropical Australia because comparable traits are unavailable in potential rotation crops. Many of Brazil's problematic weed genera are already present in northern Australia.

Disease

Foliar diseases are a major constraint in Brazil because wet-season production favours their development. Risk is compounded by rotations containing susceptible hosts and the retention of crop residues.

Serious disease problems took years to emerge, increasing as cropping expanded and intensified. Fungicide use is now routine, adding cost and increasing resistance risk.

Australia should anticipate similar pressures as northern cropping develops, particularly as ramularia and target spot are already present. Fungicide resistance stewardship should be considered from the outset of product registration and use.

Nematodes

Nematodes are a persistent constraint in Brazil, favoured by intensive rotations dominated by host crops and lighter-textured soils. Management relies on crop rotation and resistant cultivars where available.

Nematode risk must be considered as northern Australian farming systems develop, particularly as resistance is not currently a major priority in Australian cotton cultivar development.

Boll weevil

Boll weevil is Brazil's most significant constraint to cotton production. Its management relies heavily on the organophosphate insecticide maldison, effectively preventing IPM and negating much of the benefit of Bt cotton.

Its ranking as a major Australian biosecurity threat is warranted. If detected, every reasonable effort should be made to eradicate it provided post-incursion circumstances allow.

Bt technology stewardship

Bt traits have been deployed across several Brazilian crops by multiple technology providers without the coordinated stewardship applied to Australian cotton. The absence of formal planting requirements and structured refuges, combined with double cropping, has imposed sustained selection pressure. Resistance has consequently eroded much of the technology's value.

Australia's stewardship of Bt cotton has been highly successful, although our situation is simpler because Bt traits are limited to one crop and supplied by one company. Strong stewardship must remain central to any future deployment of Bt crops.

Fall armyworm

Brazilian cotton is typically sprayed two to three times each season for fall armyworm. This largely results from a host bottleneck as extensive maize crops mature while cotton remains available.

Australia will not reproduce the scale of Brazilian cropping. However, as northern production expands, the movement of pests and diseases between host crops throughout the year must be considered in crop sequencing, resistance management and area-wide management.

Study Tour Itinerary and Key Contacts

Table 5. Summary of locations, organisations and key contacts visited during the Brazil study tour from 9 to 23 May 2026.

Region	Visited	Contacts
Brasilia	Workshop de Manejo Integrado de Pragas e Doencas (MIPD) do Algodao ABRAPA head office 	Fábio Antônio Carneiro Sustainability Manager, ABRAPA fabio.carneiro@abrapa.com.br Barbara Bonfim Costa Sustainability Consultant, ABRAPA sustentabilidade.abrapa@abrapa.com.br Alvaro Moreira Better Cotton alvaro.moreira@bettercotton.org
Mato Groso	IMAMT 	Dr Jacob Crosariol Netto Entomologist, IMAmt jacobnetto@imamt.org.br Dr. Guilherme Gomes Rolim Entomologist (boll weevil), IMAmt guilhermerolim@imamt.org.br Dr. Tamiris Rolim P&D Biologicals tamirisrego@imamt.org.br Dr. Rafael Galbieri Plant pathologist, IMAmt rafaelgalbieri@imamt.org.br Dr. Edson Andrade Junior Weed researcher, IMAmt edsonjunior@imamt.org.br Dr. Jean Louis Belot Plant breeder, IMAmt

		jeanbelot@imamt.org.br
	2 commercial farms within the Mato Grosso region	
Bahia	ABAPA fibre quality laboratory 	Gustavo Prado Executive Director executivo@abapa.com.br
	Bahia Foundation (Fundação Bahia) 	Dr. Fabiano Jose Perina Plant pathologist, EMBRAPA Algodao fabiano.perina@embrapa.br Various Researchers for breeding, farming systems and soil health.
	3 commercial farms with the Bahia region	

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We would like to thank all of the people listed above (and others too numerous to mention) for taking the time to show us there facilities and share knowledge and information. We also thank the various growers who welcomed us onto their farms and shared so much information, openly about their success and challenges.

The hospitality that we received from every organisation and farm that we visited was exceptional and the openness with which information was exchanged.

We would also like to thank and acknowledge the Cotton Research and Development Corporation for supporting the travel of the participants along with our host organisations Cotton Seed Distributors, Cotton Grower Services, Ord Co and Qld Dept of Primary Industries.



At the top of the world – a lookout on the edge of the elevated Mato Grosso plateau before descending on the highway back to Cuiabá.



Capybara's were a regular sight next to water courses.



Just one example of our Brazilian hosts generous hospitality - afternoon tea at Fazenda São Francisco.



Enjoying Brazil's national drink on Saturday afternoon – Caipirinha!