FINAL REPORT 2018

Choose an item.

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: CSP1602

Project Title: **Northern Australia Cotton Development & Coordination Leader**

Project Commencement Date: 1/10/15

Project Completion Date: 30/9/18

CRDC Research Program: 1 Farmers

Part 2 – Contact Details

Administrator: Jo Cain
Organisation: **CSIRO**
Postal Address: Locked Bag 59 Narrabri NSW
Ph: 02-67991500 **Fax:** 02-67931186 **E-mail:** jo.cain@csiro.au

Principal Researcher: **Dr Stephen Yeates**
Organisation: **CSIRO**
Postal Address:
PMB PO Aitkenvale,
Townsville Qld 4814

Ph: 07-47538588 **Fax:** 07-47538600 **E-mail:** Stephen.yeates@csiro.au

Signature of Research Provider Representative: ______________________

Date Submitted: 10 December 2018

Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

At the commencement of this project in October 2015 drivers for geographic expansion of cotton where: success in southern NSW, CRDC/CSD study that is scoping new production regions; the Federal Governments plans to expand agriculture in tropical Australia and a changed political landscape within tropical Australia. The publication of the Flinders Gilbert Agricultural Resource Assessment (FGARA) study in 2013 made positive recommendations for land and water development with cotton as a key candidate crop. A year later land clearing and test farming prior to commercial production commenced in the Gilbert catchment with a development proposal for 15,000 ha of cotton lodged with the Qld Government in the Flinders catchment in January 2016 (Three Rivers Project on Glenore Station). The lifting of moratoria on GM crops in WA and a cotton growing ban in NT created opportunities for cotton investment in these jurisdictions.

In developing and new cotton regions cotton RD&E expertise is required to assist farmers and investors with fundamental questions such as: *Can I grow it here economically and sustainably? How do I grow cotton here? How much climatic variability is there and what are the impacts? I want to test farm a paddock of cotton, what information do you have and is relevant?* In addition governments request technical information on the potential and impacts of cotton production in a new region under investigating for irrigation development. While some of this information is available in the form of the publications much of it requires additional RDE and specialist technical skills and experience in new regions. Further, there was a pressing need to enhance the cotton model OZCOT to explore long term climatic risk scenarios for many new regions (dryland and irrigated).

The preceding CRDC project CSP1302 demonstrated the benefits of providing specialist technical support (Stephen Yeates), to CRDC projects throughout Australia's cotton growing areas, e.g. to Paul Grundy's CQ project and by establishing a partnership with Strathmore Station to support the pre-investment evaluation of cotton on newly cleared land. The aim of this project was to continue delivering specialist crop physiology, agronomy and systems expertise to existing, expanding and future cotton regions.

Objectives

2. List the project objectives and the extent to which these have been achieved, with reference to the Milestones and Performance indicators.

2.1. Continue established and develop new R&D partnerships for new region cotton development.

2.1.1. Continue the partnership with Strathmore Station

Achieved with enhanced capacity following the successful CRC project in November 2017 which included Strathmore's partner company 'Gulf Farming' (see 2.1.1). Partnership activities were also expanded to include providing support to dryland cotton evaluation not included in CRC project (see section 2.2.).

2.1.2. Develop new R&D partnerships

Achieved via success with the CRC for Developing Northern Australia proposal "Developing sustainable cropping systems for cotton, grains and fodder being successful" in October 2017; a key milestone for this CRDC project. The commercial entities ORDCO, NACRA, KAI the (Ord expansion developers) and

Strathmore Station / Gulf Faming leading the project that aims to use applied R&D to developing irrigated cotton / grains / forage faming systems at the Ord and Gilbert Rivers.

The participants received $3.0M in funding over 3 years to successfully undertake the cotton and double / rotational crop assessment, agronomic research, farming systems development, extension and communication described in this application. The participants, in total, are committing $8.76M to the $11.76M project, of which $1.5M will be direct cash contributions from producers at the Ord and Gilbert Rivers and businesses in the supply chain. This contribution is a sizeable investment by a small group of producers and those organisations which support them. There is a short, direct, tangible link between the cash investment from the farmers, and the R&D which will occur on their behalf.

The CRC project established irrigated cotton experiments with partners at the Ord River in early February 2018. It was accepted that there would be some unavoidable overlaps with this CRDC project in its final year.

Collaboration with NAWRA (Northern Australia Water Resource Assessment) was also established and continued until the project was completed in July 2018. This resource and economic feasibility assessment and included irrigated & dryland cotton and other irrigated crops in the Mitchell (S Cape York) and Fitzroy catchments (W Kimberley). This project provided tropical cotton expertise including climatic suitability, crop management and OZCOT simulation model application.

A joint project proposal to the CRC-DNA with Flying Fox Station & NT Department of Primary Industry and Resources (NTDPIF) “A new farming system design for north Australia irrigated agriculture” was submitted in May 2017 but unsuccessful. A revised proposal was submitted in September 2018.

2.2. To provide agronomic and technical support for commercial and government activities / enquires regarding cotton production in northern Australia.

Support was provided to Gulf Farming at Strathmore Station in the Gilbert Catchment in NW Qld to investigate dryland cotton. In April and June 2016 a trial dryland cotton field was monitored for soil water extraction and yield (report Appendix A). In September 2016 OZCOT-APSIM simulations of cotton yield were run combining sowing date x soil properties x nitrogen management scenarios with historic climatic data (report in Appendix B). In 2019 4,000 ha of dryland cotton is planned and will be monitored and supported by this CRDC project’s successor.

In April 2016 information was requested from the TIMS committee for the tropical Bollgard 3 RMP prior to registration. This analysis identified all regions with a realistic potential to grow cotton within 10 years, the likely growing season and pest issues for each region and produced a map so distance between regions could be measured. Information was presented to the TIMS committee on 20/4/16 (Appendix C). Tropical registration was gained.

In May 2016 Stephen Yeates was invited to brief Ord expansion proponents Kimberley Agricultural Investments (KAI) on the prospects for growing cotton as sugar was shelved as the base crop for the expansion of the Ord river irrigation area due to hold ups with land title on the NT stage. The impending registration of Bollgard 3 technology and the opportunity for KAI to develop wet season cotton suitable well-drained levee soils at Charlton Hill on the west bank of the Ord in WA coincided with this meeting. In October 2016 a tropical cotton workshop was conducted with Geoff Strickland (entomologist WADPIRD) for local growers via the Ord River District Coop (ORDCO) and KAI. A climatic sweet spot analysis was presented and a partnership established to investigate cotton in 2017. Securing funding from for the CRC-P project “Developing sustainable cropping systems for cotton, grains and fodder” expanded R&D activities in 2018 (see section 2.1). Results from research and test farming of 350 ha were very promising with yields > 11 b/ha and above basis fibre quality when planted in the February sweet spot. Land development has commenced at Carlton Hill and planning for gin construction in late 2020 initiated by the developers.

Instigated bioassay studies over two seasons to confirm the efficacy of BG3 (Vip3A protein) on the major wet season cotton pest *Spodoptera litura*. A review of published efficacy data of the VIP3A protein on Spodoptera species by WADPRID entomologist Geoff Strickland could not find evidence the tropical Australian species *Spodoptera litura* had been tested for efficacy.

Provided technical support and NORpak to Ken and Brendan Fry 'Forest Home Station' 60 km west of Georgetown in the Gilbert catchment who planted 130 ha dryland and irrigated cotton in mid-January and early-February 2018 on deep alluvial soil. A slightly above average wet season produced excellent dryland cotton on these soils. Soil was sampled to establish the depth of roots exploration and the plant available water essential for assessing the long term prospects on these soils (see report in Appendix D).

Produced a climatic analysis, provided NORpak and past Gilbert River reports and had several meetings with Maryborough Sugar who were investigating the prospects for cotton on developed land 20 km west of Mareeba (see appendix E). Four hundred ha of cotton is planned for the 2019 season.

Tipperary Station in the Douglas-Daly region NT enquired about the prospects of dryland cotton in May 2018. They will investigate the issues identified that is available water of soils and sufficient land to support gin. Following an 'Acres of Opportunity' presentation by CSD and Bayer in November 2018. They appear likely to test farm cotton in 2019.

Following a request from AUSTRADE the Brazilian cotton farming company Grupo JCN was briefed on prospects for growing cotton in north Qld in May 2018 followed by a face to face presentation to the group in September 2018 on 'Cotton opportunities and challenges in tropical Australia'. Key issue was access to new land and water in the short to medium term.

In July 2018 Paul Grundy (QDAF) Stephen Yeates were invited to present a cotton technical update for wet season and dry season production at the Burdekin 25 attended. After a 7 year hiatus there is renewed interest in growing cotton at the Burdekin due to low sugar and high cotton prices. Experiment reports written since NORpak-Burdekin was published in 2012 were emailed to all meeting attendees. A climatic analysis for June and August planting dates was conducted and emailed (Appendix F).

Provided information to Chinese investors at Florina Station, Katherine NT for a proposed development a trial program for 2017. No contact since.

As of May 2017 Stanbroke proposal near Normanton in the lower Flinders River is on hold waiting for water allocation from the Qld Government.

Provided face to face briefings on cotton opportunities and challenges in separate meetings to senior management of WADPRD and NTTDPIF while attending the Northern Food Futures Conference in Darwin in July 2018.

In April 2017 the Queensland Department of Natural Resources and Mines requested and were given advice on the climatic suitability for growing cotton in the Charters Towers area, and whether or not cotton can be grown over either the wet or dry season or both, given the rainfall and temperatures this area experiences. They were advised from the climate data available the and the climate is marginally better than the Burdekin for cotton area, wet season planting is best and average yields are likely to be modest and variable due to wet season cloud and a cool dry season. Advice on erosion risk and appropriate soil surface management to mitigate was also requested with minimum tillage with high much cover from past crop stubbles or cover crops recommended.

Other meetings and presentations: Chinese company Walin regarding west Kimberley and Roper NT; John Logan (KIMCO) re west Kimberley; Mark Sullivan Flying Fox Station Roper River NT; Sara Associates (India) re lower Flinders Qld and Roper NT;

2.3 **Continuation of support to established CRDC projects.**

Practicality and a rapidly expanding work load in tropical Australia required refocusing this objective to support to DAQ1401 – Strengthening the Central Highlands Cotton Production System. Contributed via to climatic analysis, experimental design, data interpretation and analysis. Presented at annual field days and review meetings. The outputs, outcomes and impact of this project are described in the final report.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

This section will focus on the methodology used to meet objective 1.2 "Continue established RD&E partnership with Strathmore Station, Gilbert River and new R&D the new partnership at the Ord River (section 2). The other project objectives 1.1 'dialog and written proposals' and 2.2 'provision of technical information to relevant stakeholders' have self-explanatory methodology with many activities described in the individual reports and included as Appendices (see section 2.2). Methodologies for objective 3.1 DAQ1401 – Strengthening the Central Highlands Cotton Production System are detailed in that projects' FRP and reports.

3.1 Strathmore Station irrigated cotton evaluation 2017.

R&D started in 2015 was recommenced in 2017 following a pause in 2016 due no access to irrigation water for trial purposes. River flow water was made available in 2017 via a transfer of licence water from the neighbouring property 'Forest Home'. The broad objective was to collect key production data on loam soils of the region before a commercial irrigation licence is obtained and infrastructure development begins. QDAF via Lance Pendergast managed grain legume and sesame evaluations at the same site. In 2018 this work was moved to the newly funded CRC project due to the rapid expansion of cotton R&D at the Ord River and the need to support dryland cotton activities (not included in the CRC project) in the Gilbert Catchment.

Aims

1. Growth, yield, quality and inputs sown late January – early February.
2. Validation and tailoring of cotton production packages developed at Burdekin.
3. Validate and calibrate modelling tools for climatic risk assessment in tropical Australia
4. Measure field efficacy of BG3 varieties to *Spodoptura litura* which is known to be present in the region.

Methods:

A 1.5 ha site was established on a river loam soil, 7 km NW of Strathmore Station homestead. Three Bollgard 3, two Bollgard II and one non-Bt variety were sown in three replicates to access cotton feasibility for the commercial partners Strathmore operations and Gulf Farming. Management according to NORpak-Burdekin was followed. Cotton was sown on 3/2/17 into 1m spaced hills and furrow irrigated from 10 cm diameter lay-flat hose using 2.5 cm take offs with taps. Plots were length of field (150 m) x 4 rows.

Data was collected on crop node & reproductive development, leaf area, biomass accumulation, pest and weed presence, yield, boll size, lint % and fibre quality.

3.2 Ord River cotton evaluations 2017 & 2018

Introduction

The release and registration of varieties with three genes coding Bt proteins (Bollgard 3) in 2016 created an opportunity to expand the planting window in much of tropical Australia by reducing the risk of *Helicoverpa armigera* developing resistance to these proteins. At the Ord River the addition of the VIP3A gene provided an unintended benefit, the potential to control the major wet season pest *Spodoptera litura* which was instrumental in the failure of cotton in the 1970's.

A wider planting window required a review of the climate to identify if a 'sweet spot' existed within what was now a wide window. Planting mid wet season in late January to February placed boll filling during April to mid-June when solar radiation and temperature were very favourable with picking in the driest months of June & July.

A review of published efficacy data of the VIP3A protein on Spodoptera species by WADPRID entomologist Geoff Strickland could not find evidence the tropical Australian species *Spodoptera litura* had been tested for efficacy.

The only management guide for cotton grown during the tropical wet season was developed in the Burdekin (Grundy et al. 2012). It clearly demonstrated locally developed management practices were essential to reliable cotton production in this climate. Hence validation and when necessary adaption of the Burdekin practices was seen as the first step in the evolution of a management system that could sustain cotton production in the unique abiotic and biotic environment that is the Ord River

Objectives:

- To provide a factual basis to invest or not invest in large scale mid wet season sown (Late January – February) cotton production on coarse textured soils in the Ord River Irrigation area via field trial data and modelling the impact of climatic variability on yield, water balance, irrigation management and fibre quality.

- Create a skills and knowledge base that could support future cotton irrigated production.

- Validate and adapt NORpak and modelling tools to the higher temperatures at the Ord River (particularly, crop development, gin turnout and fibre quality)

- Confirm the efficacy of BG3 (Vip3A protein) on the major wet season pest *Spodoptera litura*. (summary of efficacy studies presented separately)

It was necessary to locate the evaluation on a well-drained soil representative of the future cotton industry production site at Carlton Hill. The Packsaddle plane area at the southern area of the existing Ord irrigation area contained small areas of these soils on horticultural farms. It was not cost effective to transport seed cotton from a small area of cotton to a gin in Queensland. Hence the area sown to cotton had to balance to cost of compensating the land owner for income lost while being large enough to validate management practices implemented with commercial scale machinery.

Methods:
2017

Location: Well drained red earth on CERES farm at Packsaddle plane 15 km south of Kununurra. Four ha was planted.
Sown: 3 February 2017
Fertiliser: 12 Dec 2016; 46 N & 50 P kg/ha as DAP, 23 /2/17; 183 N, 41K, 22S, 50P
Insecticides: 30/4 Steward 400 ml + salt – mirids, 8/5 & 22/5 Shield 250 ml + salt – shield bugs
Pix: 400 ml/ha 12/3, 28/3, 5/4
Glyphosate: 18/2 & 12/3 1.5 kg/ha,
Irrigations: 5/4, 16/4, 23/4, 4/5, 15/5, 25/5, 2/6, 11/6 – many very quick due to poor subbing and shared tail drain.
Varieties: Three Bollgard 3 (VIP 3A protein) compared with 2 Bollgard II and 1 non Bt variety (not sprayed) for model parameterization and efficacy on *Spodoptera litura*. There were 4 replications of the Bt varieties while the non Bt variety was located as a single block (1.5 ha) at the tail end of the field.
Picking: 18/7 using a two row cotton picker. As seed cotton could not be transported for ginning, lint yield, fibre quality and lint% was calculated from sub samples sent to ACRI Narrabri for ginning and HVI testing by CSIRO. Lint % was corrected to commercially ginned lint% by deducting 7%; the relationship developed at the Burdekin.

Plate 1: The experiment was machine picked with 2 row picker and seed cotton destroyed after weighing.

Methods 2018

Four Bollgard 3 and 2 Bollgard II varieties were replicated 4 times. Plots of the Bollgard 3 varieties were 12 x 0.9 m spaced rows x length of the field (660m). Due small supplies of seed the Bollgard II varieties were planted in 2 x 40m long x 6 row strips inserted in their Bollgard 3 equivalent one and two thirds down the field. Comparative measurements were made were the Bollgard II & 3 varieties were adjacent. Yields were compared by hand picking 9m^2 in each strip. Machine picked yields were measured for the Bollgard 3 varieties by harvesting the length of field containing the 6 rows not planted with Bollgard II. Two hectares on the northern side of the field was planted to non bt cotton to provide a refuge for resistance management and a control for bioassay's measuring efficacy of Bollgard 3 varieties.

Plate 8: Well drained soil experiment (16 ha) at 'CERES Farm' 27 March 2018.

Management details:

- Sown: 25 January 2018
- Fertiliser: Late December DAP 250 kg/ha banded; 7/3 100 kg KSO4, 300kg urea banded in-crop.
- Insecticides: mirids 5/4 transform 0.3l, 21/4 Shield + salt 0.3l, 3/5 red banded SB Shield + salt 0.3l.
- Pix: 23/2 400ml, 24/4 600ml.
- Herbicide: 23/ Roundup 1.5 kg, 25/3 Roundup 1.5 kg + Verdict 0.16 l.
- Irrigations: 5 to 7 days 21/3 to 16/4 then 10 to 14 days until 9/6.
- Defoliation: 25/6, 3/7, 11/7 Mace 500 150ml, Promote plus 1l.
- Picking: Hand 9 to 11 July, Machine 15 July

Data was collected to validate NORpak-Burdekin wet season management practices (Grundy et al. 2012) and the APSIM-OZCOT model. Local agronomists were trained in cotton monitoring for growth and pest management.

Bollgard 3 efficacy on cluster caterpillar, *Spodoptera litura* Ord River 2017 & 2018

Spodoptera litura is prolific during the wet season at the Ord River. It mainly feeds on leaves. Bioassay studies using leaves from unsprayed non Bt Cotton, Bollgard II and Bollgard 3 cotton grown in these evaluations were conducted in 2017 by John Moulden and Geoff Strickland of WADPIRD in 2017 (report in Appendix G) and By Paul Grundy (QDAF) and Rebecca Clark (RaiTech) in 2018 funded by the CRC-P project.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

4.1. Strathmore Station irrigated cotton evaluation 2017

Climate

The crop received 296 mm of in-crop rainfall below the long term average of 338 mm for the growing period. Eighty nine millimetres in May was significant above the average of 8 mm and timely as it occurred during boll filling. Temperatures were slightly above average in March and April. Solar radiation reflected rainfall and was near average during boll filling from March to May (Fig. 1)

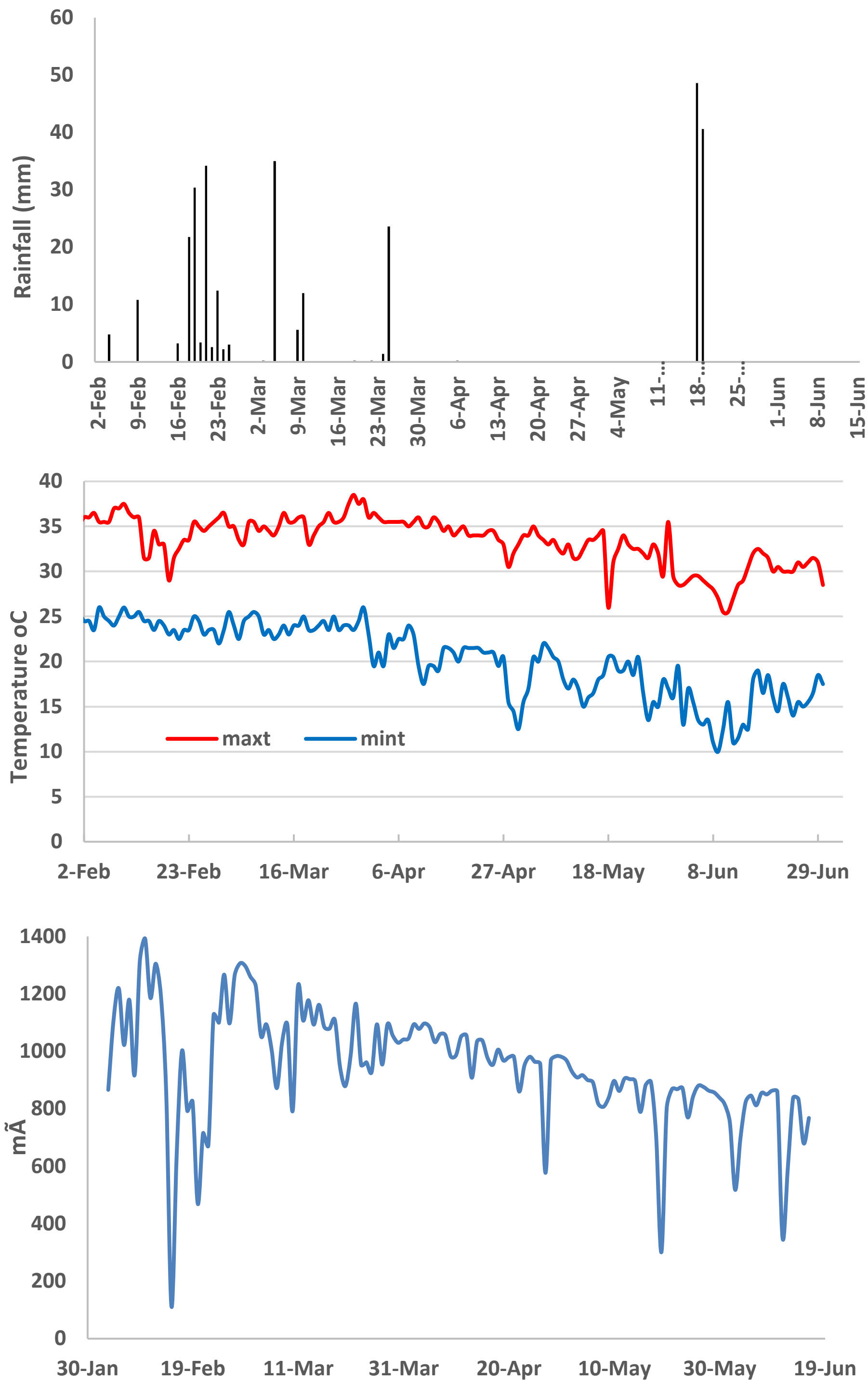

Fig 1: Daily rainfall, temperature and 4 day moving average solar radiation at the experimental site.

Crop.

Due to a licence requirement to take river flow water it was often difficulties to pump water during times of low flow from – Mid March to Mid-May this combined with variable plant available soil water at the site created huge within field variability for crop vigour and yield (see plates below).

Plate 1: Cotton at peak flowering on 4/4/17 showing better watered areas were confined to one side and tail end of field.

Plate2: Poor areas near head end of field showing variability of crop vigour and water deficit systems on 4/4/17.

Insect pest pressure was very low and *Spodoptura litura* were almost non-existent. Other than the collection of plant specific model parameters such as individual leaf area and leaf area per node the site was too variable for a complete model validation.

It was not possible to machine pick the experiment so better and poor areas from each plot were handpicked (10 m of a single row). Based on experience at the Burdekin handpicked yields were corrected to estimate machine picked yields by subtracting 7% from gin turnouts (clean sample) and 4% from seed cotton yield for picker loss. There were no significant differences in yields between varieties. Yields in better areas were as high as 10.6/ha while poor areas averaged only 2.6 b/ha (Table 1).

Table 1: Yields and turnouts from areas were soil water availability was better and poor.

Pick area	Turnout (%)	Average Lint Yield (b/ha)	Yield Range
Better	40.1	9.7	8.0 to 10.6
Poor	42.1	2.6	1.8 to 4.7

Plate 3: Cotton where soil water availability was better.

Plate 4: Cotton where soil water availability was very low. Yellow arrow shows lay-flat & irrigation take-off. Unfortunately the more frequent irrigation needed to grow a good crop in this soil was not possible in 2017.

Fibre quality was good where soil water was adequate (Table 2) consistent with experiments in previous seasons in the region.

Table 2: Average fibre length, strength and micronaire from areas were soil water availability was better and poor.

Variety	len (in)	Strength	Micronaire
Better	1.26	34.4	4.7
Poor	1.12	32.0	5.2

Plate 5: Paul McLennan CSIRO hand picking cotton.

Conclusions:

- The importance of farming areas with uniform soils of high soil water availability was highlight by this experiment and similar experience with commercial dryland cotton this season.
- Yields and fibre quality were above expectations from areas with better soils although lack of crop uniformity and inability to irrigate optimally limited the amount of quality data collected.
- For the better soil areas practices from NORpak-Burdekin were applicable.
- Funding for the development of a new site with more reliable water supply and uniform soil for future evaluations will be achieved via the new CRC project partnership.

3.2 **Ord River cotton evaluations**

2017

The red earth soils drain rapidly permitting trafficability during the wet season hence planting was possible in early February and in-crop N fertilisation three weeks later.

Climate

Rainfall during the wet season months December to March was about double the long term average (Fig. 1). Consequently solar radiation was below average. Temperatures February to June, the growing period, were near average.

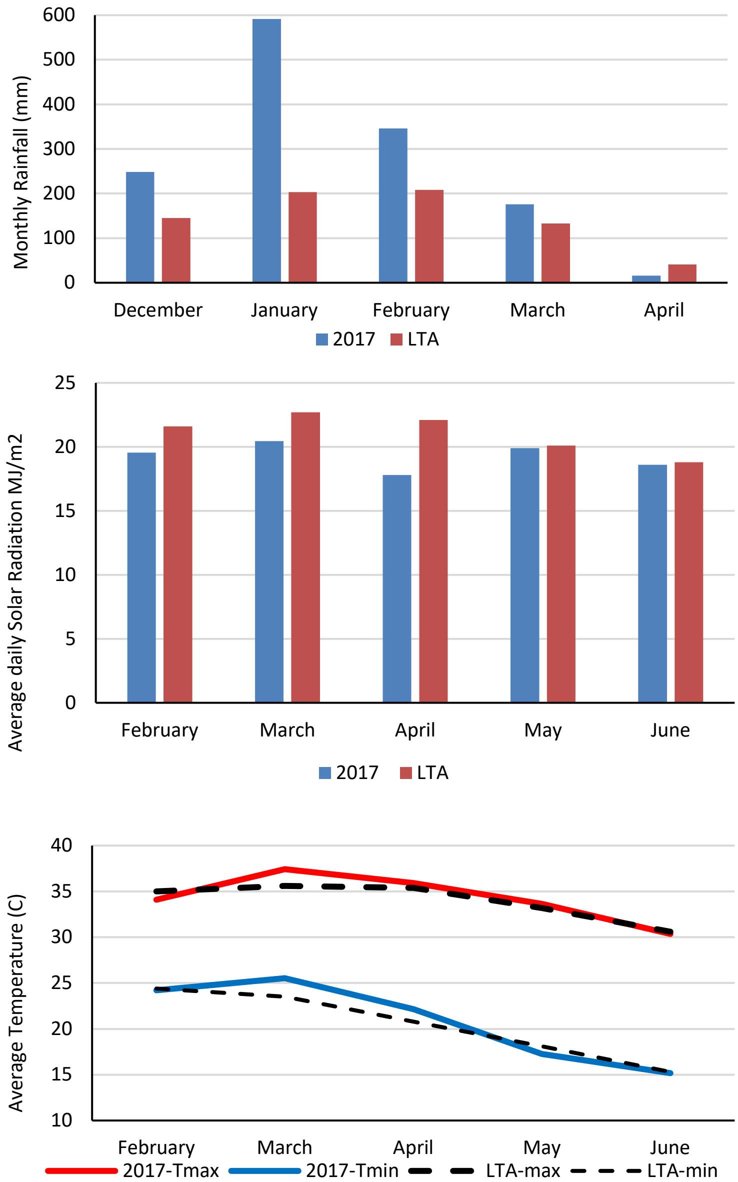

Fig. 1: Wet season rainfall, growing season solar radiation and temperatures at CERES farm Kununurra in 2016/17 compared with long term average (LTA).

Within season observations and measurements

The crop did not require irrigation until flowering in early April. *Spodoptera litura* was the only insect pest present and differences in Bt efficacy were visually obvious from late March with leaf damage non Bt > Bollgard II > Bollgard 3. A bioassay study was conducted by WADPIRD using leaves from this experiment (see below and Appendix F).

Plate 2: 21 February 2017 – 18 days after planting. Penny Goldsmith agronomist (ORDCO) downloading probes.

The Burdekin husbandry practices were broadly applicable but will require some tailoring. Due to much higher temperatures crop growth was significantly more vigorous at the Ord and crop went into moisture stress very rapidly after the end of the wet season. Plates 3 & 4 show the crop vigour 10 days prior to flowering and the physiological shedding of young squares.

Plate 3: 23 March 2017 only 48 days after sowing. The crop was rain grown up to this time. Pictured is Penny Goldsmith agronomist (ORDCO).

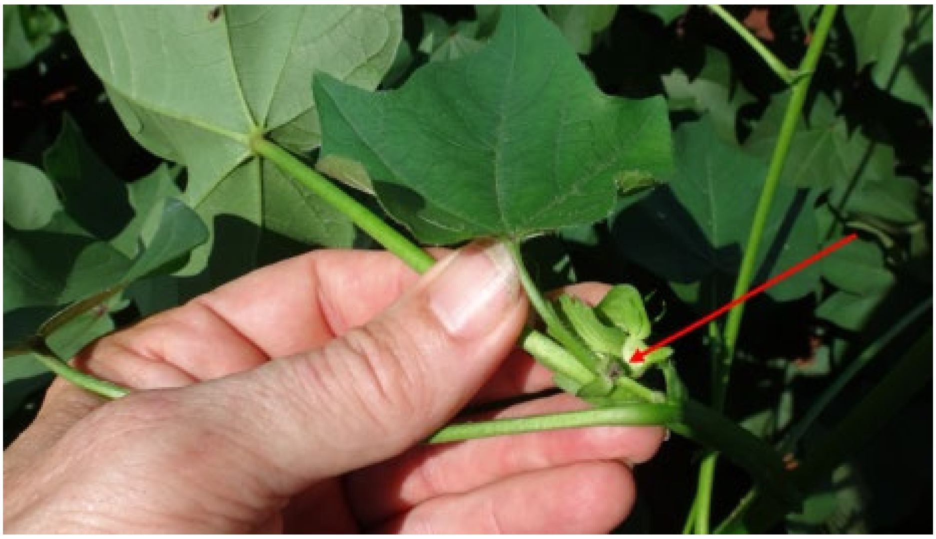

Plate 4: Physiological shedding of a young square on 23/3/17 due to prolonged cloud and high temperatures followed by sunshine causing excessive vegetative growth.

Table 1 shows key measures of crop morphology and fruit survival late in squaring. Of note is the high leaf area index for the age of the crop due to the warm & wet conditions during leaf expansion.

Table 1: Node of first fruiting branch, fruit retention and Leaf area index (LAI) at 14 nodes 48 DAS (23/3/17).

Variety	Node of 1st Fruiting Branch	Fruit Retention (%)	LAI
Sicot714B3F	7.5	86.5	2.89
Sicot748B3F	7.0	79.0	3.02
Sicot746B3F	7.9	80.2	2.99
$Lsd_{0.05}$	ns	ns	ns

Modification to growth regulator Mepiquat chloride (Pix) use combined with timely irrigation scheduling is likely to be required to manage early canopy development in these conditions. Fig 2 shows the crop grew excessively after 7 nodes and due to plentiful soil water could not be managed optimally with the Pix rates and timings used. However prompt growth regulator application was not always possible due to unavailability of the spray plane (due to this small area being one of the few crops in the valley requiring spraying at this time) or unsuitable weather. The expansion of internodes and the production of nodes was extremely fast from 7 March to 23 March; 46 cm and 6 nodes, reflecting high temperatures and luxurious growth conditions! In addition the crop was early in squaring and combined with shedding had minimal fruit demand for assimilate to slow vegetative growth.

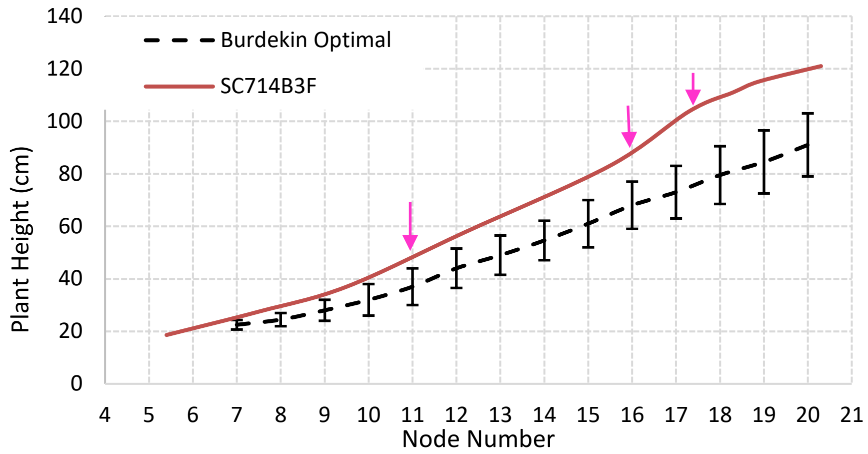

Fig. 2: Early crop vigour in 2017 compared with Burdekin optimal from NORpak-Burdekin (Grundy et al. 2012). Pink arrows show stage of treatment with Pix (Mepiquat Chloride) at 400 ml of product /ha (15.2 g ai/ha). A delay of 5 days with aerial application at 11 nodes exacerbated excessive growth in these hot humid conditions.

Plate 5: Left Local agronomists Penny Goldsmith (ORDCO) & Walter (KAI) doing fruit counts Right: Collecting OZCOT validation data in the ORDCO Board Room, front Walter, back Dave (ORDCO) (27/4/17, 83 DAS). Providing hands on training and experience for local agronomist in topical cotton management was a key goal of this work.

The red earth soil did not infiltrate irrigation water uniformly into the beds after the last wet season rains and combined with high temperatures moisture stress was exacerbated on 'soft' plants during the sensitive peak flowering stage (see Fig. 3 and plate 6). Hence by first flower in early April the crop was suffering water stress which suppressed fruiting site production near the top of the plants. Crop water extraction was below 90 cm by March 30 and 120 cm (the depth of the capacitance probes) by late April.

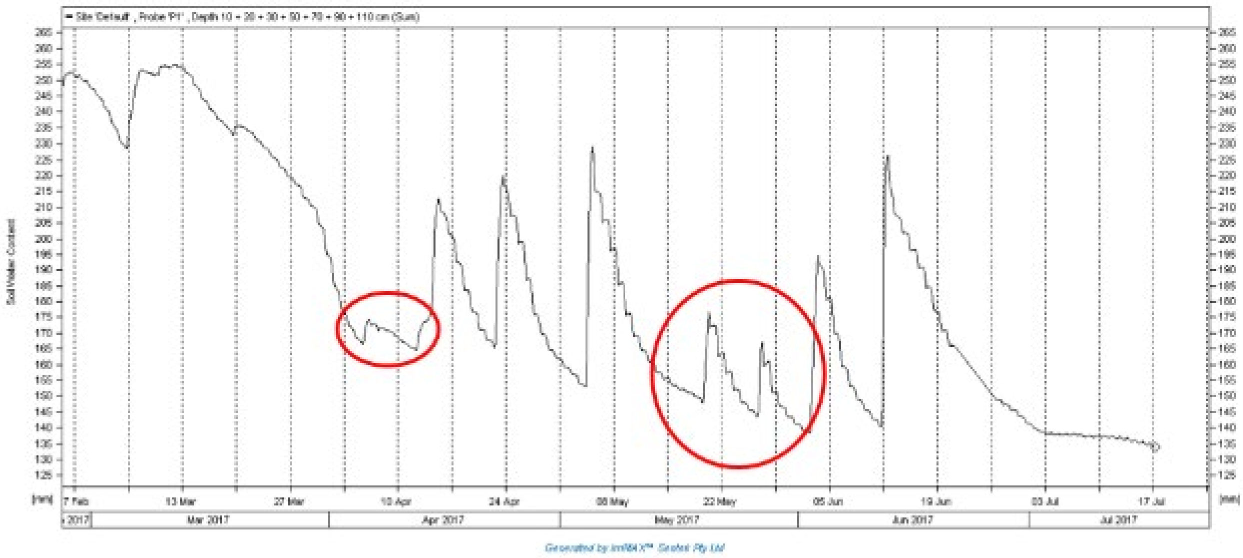

Fig. 3: Environ scan data (averaged to 120cm depth). First circle shows poor subbing of 1st irrigation water after wet season ended in late March; Second circle shows repeat later in boll filling.

Plate 6: Water subbing only to plant line 10 cm from shoulder of bed.

Despite these early set-backs the crop recovered reasonably well with better infiltration of subsequent irrigations particularly in the top half of the field, favourable temperatures and near average solar radiation from late-April.

Yield, turnout and fibre quality

Within field yields reflected effectiveness of post end-of-wet irrigations (see plate 7). Fortunately field variability aligned with the replication of the variety treatments.

Plate 7: Front left quarter highest yields (~ 11 b/ha), front right quarter lower yield and a little rank due to good subbing, lowest yields (7 to 9 b/ha) were at back sections of field were most effected by poor water infiltration post flowering.

Average lint yields and turnouts (4 replications) for the Bollgard 3 varieties are shown in Table 2. Water stress in early flowering favoured the longer flowering cycle variety Sicot7483F. Turnouts were consistent with wet season cotton at the Gilbert River being three points less than for the same variety grown in southern Australia.

Table 2: Lint % and yields.

Variety	Lint (%)	Lint Yield (b/ha)
Sicot71B3F	39.5	8.72
Sicot746B3F	41.6	9.05
Sicot7483F	40.3	9.92
$Lsd_{0.05}$	1.4	1.371

Fibre length, strength and micronaire were exceptional (Table 3). Although fibre properties were measured from research ginned samples, which are usually better than commercially ginned cotton they would still translate to well above market preference when commercially ginned (see 2018 evaluation).

Table 3: Fibre length, strength and micronaire

Variety	len (in)	Strength	Micronaire
SC71B3F	**1.27**	**33.6**	**4.5**
SC746B3F	**1.31**	**33.6**	**4.2**
SC748B3F	**1.33**	**34.2**	**4.2**
$Lsd_{0.05}$	0.018	ns	0.28

Conclusions Ord 2017

- Despite the challenges with variable infiltration of irrigation water and canopy management some excellent yields and fibre quality was produced.
- Planting in early February ensured flowering and boll filling coincided with very favourable climatic conditions from April to early June.
- Fibre quality was excellent but only 1 season
- Variability in yield linked to variable subbing of irrigation water and having to apply Pix to whole field not individual varieties (narrow plots) after wet finished.
- Modell parameterisation data was collected but will need more seasons of data for calibration (more details in 2018 evaluation).
- Local agronomists and farmers gained experience with management of wet season cotton.
- Greater efficacy of Bollgard 3 on *Spodoptura litura* was measured in 2017 a further season of testing is required (see & Appendix G)

Results Ord 2018

<u>Climate</u>

Seasonal rainfall, temperature and solar radiation are shown in Fig 4. Rainfall was below average after February. Solar radiation was near the long term average. Average maximum temperature for March and April was 1.5 and 3 °C above the long term average respectively.

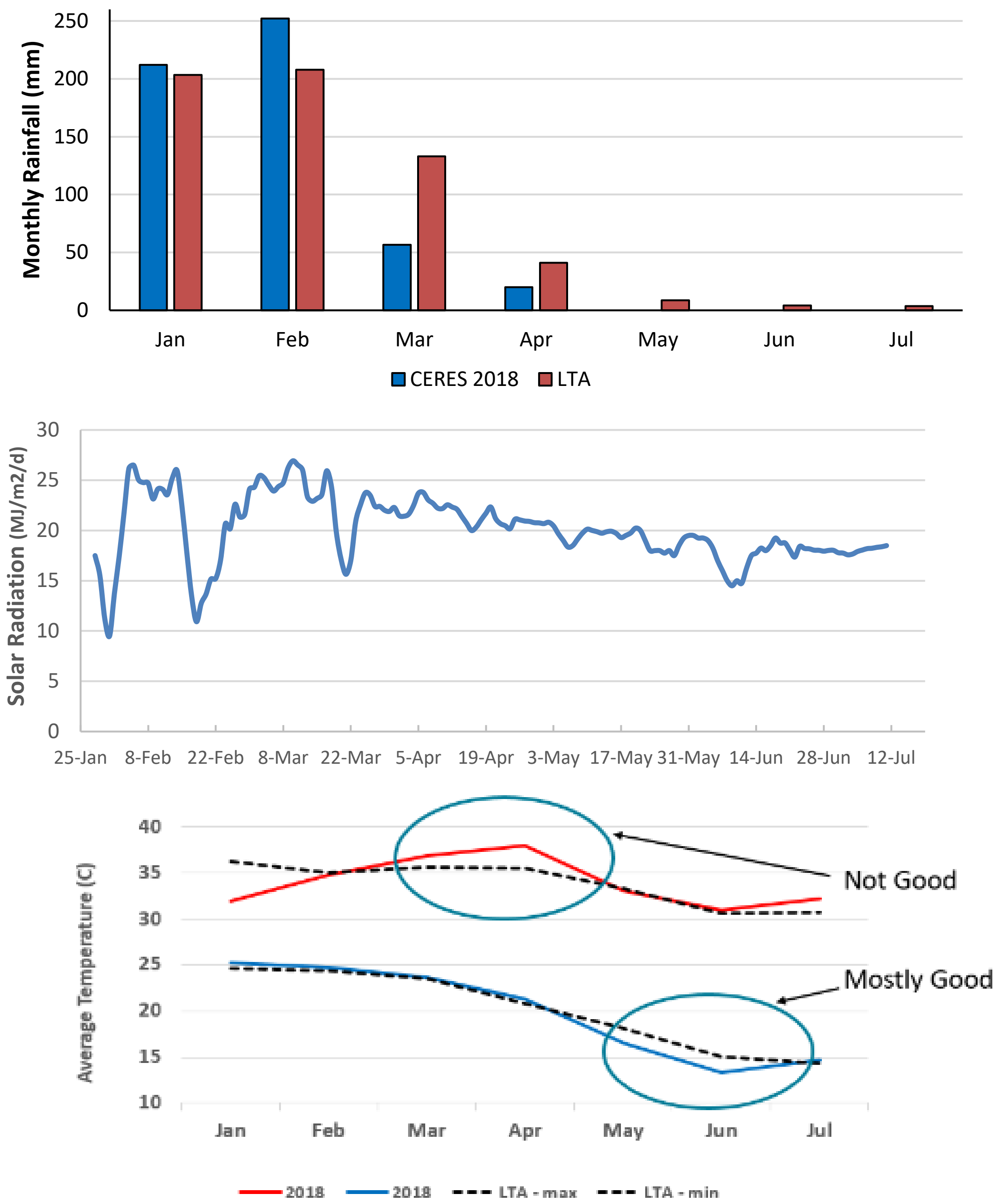

Fig 4: Monthly rainfall, temperatures compared with long term average (LTA) and seasonal solar radiation as a moving 4 day average for 2018 growing season.

Within Season Observations

Pre-flowering: Early growth was as expected in the wet season with leaf area and node development faster than for a spring sown crop in southern Australia.

Plate 9: 27 days after sowing (22 Feb 2018), pictured is Ord Agronomist Penny Goldsmith.

First Irrigation: Coincided with first flowering on 21 March 2018 with hotter, sunnier and drier weather prior to flowering than in 2017 the crop was shorter, with smaller leaf area, higher node of first fruiting branch and fruit retention (Table 4).

Table 4: Node of 1st fruiting branch, fruit retention and leave area index (LAI)

Variety	Node of 1st Fruiting Branch	Fruit Retention at 1st flower (%)	LAI
SC714B3F	8.4	97	2.4
SC748B3F	8.4	97	2.1
SC746B3F	8.5	95	2.4
SC707B3F	8.5	96	2.2
$Lsd_{0.05}$	ns	ns	ns

The likelihood of high temperatures over the 2 to 4 weeks after first flower combined with high fruit retention on a small plant (plate 10) created a scenario where rapid demand for assimilate from bolls could reduce the flowering period, hence lower yield potential. Management was adjusted so irrigation was applied at weekly intervals for four weeks in attempt to extent the flowering period. This strategy was mostly successful (plate 11) although in hind-site three irrigations at weekly intervals may have produced a better balance between vegetative and reproductive growth.

Plate 10: Smallish high retention plants at first flower and first irrigation, 21 March 2018 (54 DAS).

Plate 11: 24 April 2018 irrigating at 7 day intervals from March 22 extended the flowering period during a period of very hot maximum and minimum temperatures.

Infiltration of irrigation water was not uniform, after 12 hours water had not infiltrating more than 5 to 10 cm inside the plant line in some areas of the field and to the centre of the bed in others. Frequent irrigation suited the areas where infiltration was incomplete and created excessive vegetative growth in areas where the beds were saturated (plate 12).

Plate 12: Crop at time of 1st irrigation and poor infiltration of irrigation area observed in about half the field.

Crop vigour and canopy management

A key objective of this work was to validate management practices developed for wet season cotton at the Burdekin and if required modify for Ord conditions. Managing the crop so plant height was in an optimal range as it developed nodes was the objective. At the Burdekin this relationship successfully produced a canopy where leaf area (light penetration into the canopy) and fruiting site development could be managed to respond to changes in within season growing conditions such as the need to compensate from cloud induced fruit shedding and premature canopy closure. Timing of irrigation, monitoring of fruit retention, growth regulator treatment, timing of nitrogen application and weather forecasts are the management tools used to maintain the optimum plant height as main stem nodes are produced.

Figure 5 shows the progression of plant height with main-stem node development for two varieties similar to those grown previously at the Burdekin. Irrigation and growth regulator management keep both varieties on the Burkekin 'optimal' line.

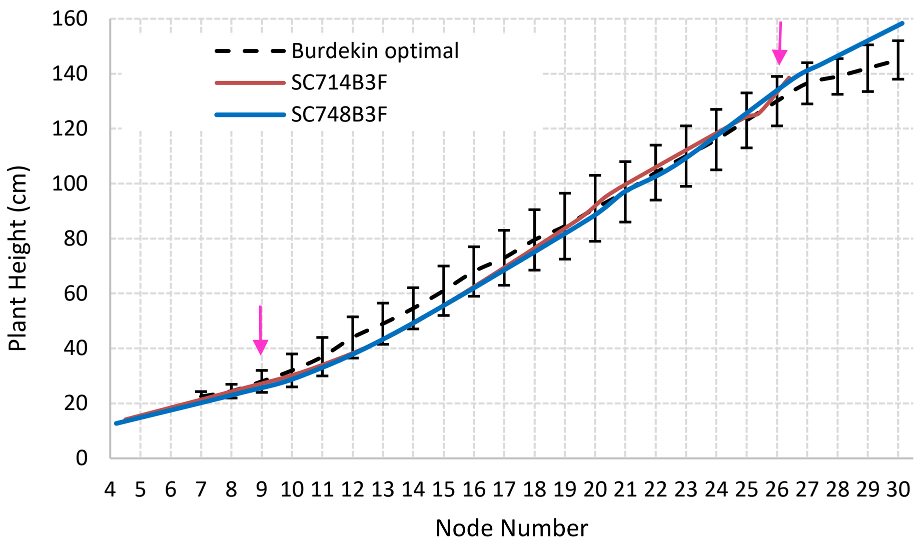

Fig 5: Crop vigour validation CERES farm 2019 compared with the Burdekin optimal (Grundy et al 2012). Pink arrows indicate timing of Mepiquat Chloride (Pix) treatment.

Soil water extraction

Research at the Burdekin and Gilbert found root exploration varies in response rainfall prior to flowering. Thus it is critically important to know the depth of roots to schedule irrigations to avoid stress, particularly the first irrigation. Fig 6 shows in 2018 little extraction was measured below 50 cm for the first six weeks after first irrigation (21 March) and when extraction below 50 cm was not replenished by irrigation.

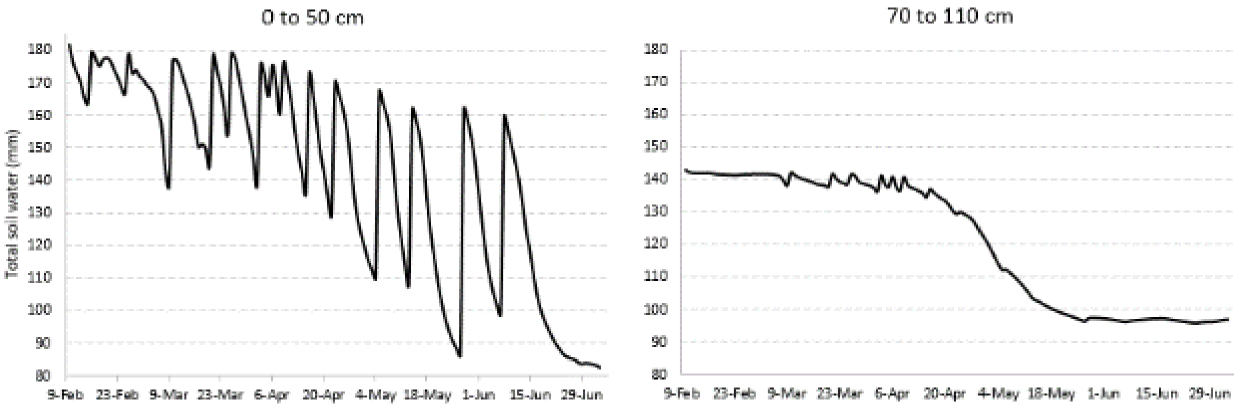

Fig 6: Average capacitance probe measurement of soil water for 0 to 50 cm and 70 to 110 cm depth.

Model validation and variety parameterisation

This is a work in progress. Over the two seasons at the Ord River and at Strathmore in 2017 there was no differences in parameters measured between the Bollgard II varieties SC71BRF and SC74BRF were not significantly different to their equivalent Bollgard 3 varieties SC714B3F and SC748B3F. However all varieties evaluated had significantly greater rates of leaf area development, specific leaf area and maximum leaf area per site (up to 30% for all parameters) than the OZCOT model parameters. Rooting front expansion was greater than the existing model in these soils and climate. The above differences partially explain errors in simulation of net photosynthesis fruit shedding due to physiological and soil water availability.

Yield and Quality

Yields were slightly above expectation considering the high temperatures and uneven infiltration of irrigation water (Table 5). Only SC707B3F had a significantly lower lint yield, due to poor lint %. SC714B3F and SC707B3F produced higher seed cotton yield, lower gin turnout, the same or lower lint yield and matured earlier than the others (Table 5). The hand-picked yields of the Bollgard II were not significantly different to their equivalent Bollgard 3 variety of SC714B3F and SC748B3F and are not presented.

Gin turnouts were lower than for the same varieties grown in southern Australia a result consistent with wet season planted cotton in elsewhere in tropical Australia e.g. Gilbert, Burdekin, lower Flinders.

Table 5: Seed cotton yield, Lint%, machine and hand-picked yield of the Bollgard 3 varieties

Variety	Seed Cotton Ex picker T/ha	Lint %	Machine Picker Yield b/ha	Adjusted Hand Yield* b/ha
SC714B3F	**5.74**	**38.6**	**9.8**	**10.1**
SC748B3F	**5.57**	**41.0**	**10.1**	**10.3**
SC746B3F	**5.33**	**42.0**	**9.9**	**10.1**
SC707B3F	**5.90**	**37.0**	**9.3**	**9.7**
$Lsd_{0.05}$	0.21	1.32	0.49	0.28

* 11.7 % was deducted from hand yield to approximate picker & commercial gin yield – losses = 7.7% gin + 4% picker

Hand picking a small area of each plot and adjusting for picker and commercial gin efficiencies gave good estimates of plot yield. Hand picking was also an accurate measure of within field yield variability which ranged from 7.7 to 11.8 bales /ha

In response to favourable climate late in flowering all varieties produced a high proportion of yield on later pollinated flowers toward the top of the plant or on vegetative branches. The longer flowering cycle varieties SC748B3F and SC746B3F produced the highest proportion of yield on late pollinated flowers (Table 6).

SC707B3F was 7 to 13 days earlier maturing than the other varieties and may have a place in late planting situations.

Table 6: Maturity date and within plant yield maps.

Variety	Maturity Date	% of Yield on Fruiting Branches		
		1 to 8	9 to 12	13+
SC714B3F	21-June (± 5)	42.5	18.9	27.8
SC748B3F	28-June (± 5)	27.5	18.6	43.7
SC746B3F	26-June (± 2)	25.0	16.6	47.0
SC707B3F	15-June (± 8)	46.0	13.5	30.0
$Lsd_{0.05}$		8.38	ns	11.29

Plate 13: Favourable weather from late April produced a large bolls at the top of the plant.

Fibre quality measured from commercially ginned cotton exceeded or equalled the market 'basis' for all parameters (Table 7) a small premium was received for the majority of bales produced. A reliably clear and dry boll opening period ensured excellent colour. More favourable temperatures when top bolls developed may have contributed to lower micronaire in the later maturing varieties. The comparison with laboratory ginned samples provided a correction factor for future evaluations in tropical Australia can't be commercially ginned for either scale or biosecurity reasons.

Table 7: Commercially ginned fibre quality with laboratory gin in brackets.

Variety	Colour	Staple	Len Inches	Strength	Micronaire
SC714B3F	**11-2**	**37**	**1.14 (1.22)**	**28.5 (30.4)**	**4.5 (4.4)**
SC748B3F	**11-2**	**38**	**1.18 (1.31)**	**28.9 (32.1)**	**4.2 (4.2)**
SC746B3F	**11-2**	**37**	**1.16 (1.26)**	**29.7 (31.4)**	**4.2 (3.8)**
SC707B3F	**11-2**	**37**	**1.15 (1.23)**	**28.0 (31.9)**	**4.5 (4.4)**
Basis	31	36	1.125	26 to 28	3.5 to 4.9
$Lsd_{0.05}$ (lab gin)			0.042	0.86	0.28

Plate 14: Top picking at CERES farm on July 15 2018. Bottom left Matt Grey and son of CERES Farm. Bottom right: local spectators of the cotton pick!

Conclusions Ord 2018:

- Confirmed sweet spot climatically for boll growth, avoidance of boll rots and colour discounts is Late March to May. Therefore need to plant late January to early February on well drained soils.
- Monthly maximum temperatures 3°C above the April long term average favoured the development of later pollinated bolls hence for all varieties a significant proportion of yield was formed near the top of the plant, i.e. above fruiting branch 12 or on vegetative branches.
- Fibre quality was above basis
- Long flowering cycle high gin turnout varieties were slightly higher yielding.
- Variety SC707B3F about 2 weeks earlier may have place in later planting, more seasons of testing required to confirm.
- Validation of Burdekin practices reaffirmed management of the transition from wet to dry season (particularly irrigation timing) is critical at the Ord River!
- Local agronomists and farmers got first-hand experience with monitoring, growing and management of late wet season planted cotton.

Bollgard 3 efficacy on cluster caterpillar, *Spodoptera litura* Ord River 2017 & 2018

Summary of Results:

Visual differences in leaf damage between varieties expressing different Bt proteins were obvious in these evaluations.

Although having much greater mortality than non-Bt cotton or Bollgard II, Bollgard 3 mortality was incomplete and variable (56 to 96%) depending on growth stage of leaves and their age. However larval fitness cost was sever and there was little growth of larvae feed on Bollgard 3 leaves. It was concluded there would be little chance of survival in the field. The 2017 report is presented in Appendix G.

Plate shows leaf damage on non BT cotton by *Spodoptera litura* and larvae.

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

Objective 1: Continue established and develop new R&D partnerships for new region cotton development.

The outputs were:

1. The existing partnership at Strathmore Station continued and was included in the CRC for Developing Northern Australia project proposal with the Ord River (see section 2.1.)
2. A small irrigated cotton evaluation was conducted at Strathmore in 2017. Unfortunately unreliable irrigation supply at the site reduced the quality of data collected.
3. A R&D new partnership was established with the Ord River with commercial entities ORDCO, NACRA and KAI and a funding proposal to support cotton farming system submitted to the Developing Northern Australia CRC.
4. Collaboration with NAWRA (Northern Australia Water Resource Assessment) was also established and continued until the project was completed in July 2018 when the final report was released.

The outcomes were:

1. Success with the CRC for Developing Northern Australia proposal. An expanded RD&E program commenced in 2018 at Strathmore and the Ord River including field experiments and training of local agronomists.
2. A new larger irrigated R&D site is under development by Gulf Farming at Strathmore Station for the 2019 cotton season. This site has reliable water supply from an on-farm storage and uniform alluvial soil.
3. Of relevance to the cotton industry the NAWRA projected identified new opportunities for irrigated cotton from ground water away from the Fitzroy River WA (less politically sensitive) east of Fitzroy Crossing.

Objective 2: To provide agronomic and technical support for commercial and government activities / enquires regarding cotton production in northern Australia.

The outputs were:

1. Produced report for the TIM's committee for the tropical Australia Bollgard 3 resistance management plan that identified all regions with a realistic potential to grow cotton within 10 years, the likely growing season and pest issues for each region and produced a map so distance between regions could be measured (Appendix C).
2. Technical support was provided via soil characterisation and modelling analysis to dryland cotton cropping on two properties in the Gilbert Catchment Qld identified the most suitable soil characteristics and optimal sowing window to produce reliable yield (reports in Appendices A, B &D).
3. A tropical cotton workshop and climate analysis to identify the climatic sweet spot for boll filling at the Ord River WA with local growers, service providers and the KAI the company expanding the irrigation scheme.
4. Provided agronomic, climatic and other technical support to many commercial (local and international) and government agencies (listed in section 2.2) including with written reports / analysis (see Appendices E, F)

5. Instigated bioassay studies over two seasons to confirm the efficacy of BG3 (Vip3A protein) on the major wet season cotton pest *Spodoptera litura* (section 4 & Appendix G)

The outcomes were:

1. Tropical registration of Bollgard 3 with sowing windows and resistance management tailored to intra-regional abiotic and biotic risks.
2. The best dryland crops in 2018 were grown on soil types with the characteristics identified in these analysis (well drained, deep uniform loamy-sand texture, minimal surface crusting). Hence increased confidence in growing dryland cotton provided the more suitable soils are used. The intended area planted in the Gilbert to dryland in 2019 will increase on both properties to a total > 4000 ha.
3. A partnership established to investigate cotton in 2017 at the Ord. Securing funding from for the CRC-P project "Developing sustainable cropping systems for cotton, grains and fodder" expanded R&D activities in 2018 (see Objective 1). Results from research and test farming of 350 ha in 2018 were very promising with yields > 11 b/ha and above basis fibre quality when planted in the February sweet spot. Land development has commenced at Carlton Hill and planning for gin construction in late 2020 initiated by the developers.
4. Outcomes were variable. Maryborough Sugar will proceed with 400 ha of wet season planted cotton at Mareeba in 2019 but are now more aware of the potential climatic risks and management challenges so have adjusted management plans and input costs so a positive gross margin is possible in the worst case scenario of a 6 b/ha yield. A similar outcome at the Burdekin appears likely. Most of the other enquiries have not progressed to date many due to time required to get access to land and water prior to development of green field areas in topical Australia or a due to a greater appreciation following climatic analysis presented to them that not all of tropical Australia has the best climate for cotton.
5. Bioassay studies concluded there would be little chance of *Spodoptera litura* survival in the field.

Objective 3: Continuation of support to established CRDC Projects.

The outputs were:

1. Contributed to DAQ1401 – "Strengthening the Central Highlands Cotton Production System" by climatic analysis, experimental design, data interpretation and analysis. Presented at annual field days, review meetings & final report.

The outcomes were:

2. Contributed to a 20 to 30% yield increase with August sowing, majority adoption of the practice and an ongoing crop monitoring program.

6. Please describe any:-

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

Investment in commercial production using husbandry and monitoring practices developed directly from or inspired by this and past R&D e.g. Burdekin and Emerald

b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and

Refinement of climatic sweet spot analysis for tropics.

c) required changes to the Intellectual Property register.
None

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

Impact:

- This project has provided many of the essential knowledge foundations required for the expansion of cotton production into the Australian tropics in the near future. What started as feasibility assessments with commercial partners at the Ord River and Gilbert River have rapidly moved to new cotton industry development (both catchments changing from sugar as the preferred base crop to cotton). Although the timeframe to achieve a stable new industry in each region will also be driven by external factors e.g. necessary government approvals, capital raising and infrastructure planning.

- Enhanced modelling capacity ensuing from this project will contribute to faster, more accurate and efficient feasibility assessment in other new areas. It is important to also recognise a negative feasibility assessment is likely to prevent a failed investment which could be damaging to the cotton industries wider licence to operate.

- Significant increase in skills / knowledge (from a low base) in the agricultural and non-agricultural communities in cotton production and the cotton industry generally in tropical Australia.

- Contribution to the early sowing opportunity in CQ.

- Greater knowledge and tools to support cotton feasibility assessments elsewhere in tropical Australia in the near future.

Key messages for the existing cotton industry in southern Australia are:

- Patience, deep cotton and local knowledge, locally developed production practices, proven crop performance including offsite impacts, support from the community and government are required.
- Biosecurity will be paramount to the sustainability of tropical cotton production including impacts north to south within Australia and the reverse.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken: (a) to further develop or to exploit the project technology.

This will happen via a future CRDC project, the recently funded CRC project, RD&E partnerships in development (e.g. with NT) and the evolution of new opportunities e.g. post NAWRA at the Fitzroy WA. A key objective for all new projects is to continue the development of local human capacity in tropical cotton skills.

(b) for the future presentation and dissemination of the project outcomes.

Presentation of key results at stake holder reviews and other forums are planned and have commenced. Publications will be written and when sufficient information is available a NORpak wet season for the Ord and Gilbert.

(c) for future research.

It is inconceivable any future research will not have delivery / extension milestone.

9. A. List the publications arising from the research project and/or a publication plan.

(NB: Where possible, please provide a copy of any publication/s)

New journal and industry publications are planned when sufficient quality data is available from these new cotton development sites

Yeates S, Grundy P, (2016). Balancing canopy management using mepiquat chloride with recovery from biotic and abiotic stress in the Australian tropics. World Cotton Research Conference -6, Goiania, Brazil, May 1-6, 2016.

Paytas M, Yeates S, Bange M, (2016). Management options for cotton growth in variable solar radiation regions: yield recovery in response to reduced radiation during flowering. World Cotton Research Conference -6, Goiania, Brazil, May 1-6, 2016.

Ash A, Cossart R, Ham, C, Laing A, MacLeod N, Paini D, Palmer J, Poulton P, Prestwidge D, Stokes C, Watson I, Webster T, and Yeates S (2018) Agricultural viability: Fitzroy catchment. A technical report from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments, CSIRO, Australia.

Ash A, Laing A, MacLeod N, Paini D, Palmer J, Poulton P, Prestwidge D, Stokes C, Watson I, Webster T, and Yeates S (2018) Agricultural viability: Mitchell catchment. A technical report from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments, CSIRO, Australia.

PR Grundy, SJ Yeates & KL Bell (2019). Cotton production and variable solar radiation during the tropical monsoon season. I – Yield, lint quality and intra-canopy boll distribution and II- Biomass accumulation, partitioning and RUE. In review

B. Have you developed any online resources and what is the website address?

Not yet

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

The key impact of this project for the Australian cotton industry was via the provision many of the essential knowledge foundations that assisted the rapid transition from a feasibility assessment with commercial partners at the Gilbert River to new cotton industry development at the Gilbert and the Ord Rivers (the later changing from sugar to cotton as the preferred crop). The move to cotton as the base crop for the expanded irrigation area at the Ord River was unexpected when the project started.

Tropical registration of Bollgard 3 with sowing windows and resistance management tailored to intra-regional abiotic and biotic risks was supported via expertise that identified all regions with a realistic potential to grow cotton within 10 years, the likely growing season and pest issues for each region and produced a map so distance between regions could be measured. This project also facilitated and supported efficacy studies of Bollgard 3 (VIP3A) on *Spodoptera litura* a key wet season pest in much of tropical Australia as there was no evidence of prior testing of this species. Following two years of screening it was concluded there would be little chance of survival of *Spodoptera litura* in the field.

A partnership was established to investigate cotton at the Ord River WA in 2017 following a workshop requested by local farmers and Ord expansion proponents on the prospects for growing cotton as a base crop. The workshop coincided with the impending registration of Bollgard 3 technology, the opportunity to develop well-drained levee soils on the west bank of the Ord suitable for wet season planted cotton and a climatic sweet spot analysis (conducted by this project) identifying mid-wet season as the optimal planting time. Securing funding from for the CRC-P project "Developing sustainable cropping systems for cotton, grains and fodder" (an objective of this CRDC project) expanded R&D activities in 2018. Results from research in 2017 & 2018 and test farming of 350 ha in 2018 were very promising with yields > 11 b/ha and above basis fibre quality when planted in the February 'sweet spot'. Land development has commenced at Carlton Hill in October 2018 and planning for gin construction in late 2020 initiated by the developers.

Provided Technical support via soil characterisation and modelling analysis to two properties investigating dryland cotton cropping in the Gilbert Catchment Qld. The most suitable soil characteristics and optimal sowing window to produce reliable yield were identified. The best dryland crops in 2018 were grown on soil types with the characteristics identified in these analysis (well drained, deep uniform loamy-sand texture, minimal surface crusting).

This project contributed to DAQ1401 – "Strengthening the Central Highlands Cotton Production System" by climatic analysis, experimental design, data interpretation and analysis to support the August sowing opportunity. Presented at annual field days, review meetings & final report. The industry impacts of this project are now well documented.

Provided agronomic, climatic and technical support to many commercial and government agencies. Some will proceed with cotton in 2019 but are now more aware of the potential climatic risks and management challenges and have adjusted plans so a positive gross margin is possible in the worst case scenario (e.g. at Mareeba and the Burdekin). Other enquiries have not progressed due to time required for development or due to reassessment following climatic and resource analysis presented to them.

Acknowledgements:
The work described above would not have been possible without the interest, support and commitment by of the following:

ORDCO: Penny Goldsmith, David Cross, Tommy Palmer
CERES Farm: Matt and Mel Grey & team
KAI: Jim Engleke, Luke Mackay and staff
Strathmore / Gulf Farming: Ron Greentree, Scott Harris, Charlie Pedersen, Peter Andersen, Tony Harrison and staff.
QDAF: Paul Grundy, Lance Pendergast.
WADPIRD: Geoff Strickland, John Moulden
CSIRO: David Johnston, Perry Poulton, Paul McLennan and Kellie Copper
NACRA: Deb Pearce

References:

Grundy P., Yeates S, Grundy T., (2012). NORpak Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. Cotton Catchment Communities Cooperative Research Centre.

Appendix A: **Monitoring dryland cotton in 2015/16 wet season at Strathmore Station, Gilbert River, NW Qld.**

By Stephen Yeates (CSIRO), Lucas Delai (visiting Brazilian student), Lance Pendergast (QDAF).

1. Yield and fibre quality.

The crop (40 ha) was sown in mid- January 2016 by Gulf Farming who partner Strathmore Operations in developing dryland and irrigated cropping on the beef property Strathmore Station 126 km WNW of Georgetown. The cotton was grown in a paddock cleared in 2014 then panted to dryland sorghum in 2015. The field required cultivation prior to planting to remove sucker regrowth from roots of cleared vegetation. No fertiliser or insecticide was used. The crop was not commercially picked.

Due to patchy establishment yields were hand-picked from the centre row of three good even rows in 4 areas of 5m length on June 2nd 2016. Fibre quality and gin turnout was measured by CSIRO at Narrabri. To give an estimate of machine picked and commercially ginned yield hand-picked yields were reduced by 10%. The yields were promising given rainfall was well below average except for March (Table A1).

Plate A1: Hand picking uniform areas of cotton.

Table A1: Yield and Fibre quality 2016

	Average	Range
Yield (b/ha)	4.02	3.53 - 4.28
Lint %	40.5	38.8 - 41.6
Boll size (g)	2.95	2.63 – 3.32
Bolls / m	80	64 - 92
Fibre Length (in)	1.16	1.12 - 1.18
Strength (g/txt)	30.3	28.9 - 32.3
Micronair	4.24	4.21 - 4.27

- The harvested areas were in small depressions and water may have benefited from runoff from the adjacent scalded areas
- It is recommended soil cover in the form of a cover crop mulch combined with zero tillage will increase plant establishment in these hard setting soils.

2. Soil and root depth

The soil was very dry and compacted below 60 cm and was too hard to sample below 120 cm, however we found roots at this depth. By comparison the roots were found to 220 cm in a sandy-loam at 'Tonks Camp' a farm 80 km up river from this site (see Yeates 2015).

It was clear there is a need to identify the deeper soils at Strathmore and minimise soil surface crusting for reliable production of dryland cotton.

Ron Greentree (Gulf Farming) in dryland cotton crop at Strathmore Station (Gilbert R. NW Qld) on 12/4/16

Lucas Dalai in Dryland cotton on 12/4/16

Soil sampling 12/6/16 Lucas Delai and Tony Harrison (Gulf Farming)

Yeates S (2015). Assisting cotton industry diversification in coastal NQ & tropical Australia. Final Project Report CSP1302, Cotton Research & Development Corporation, 45pp, Narrabri, NSW.

Appendix B: **First attempt at simulating possible dryland cotton yields at Strathmore Station, Gilbert River, NQ Qld.**

By Stephen Yeates and Perry Poulton, CSIRO, October 2016

Three simulation analysis were were conducted: i) the effect of sowing date and available soil N on likely yield variability when grown on a best case soil in the region a deep not crusting well drained alluvial; ii) four soil depth x soil organic carbon x soil surface crusting scenarios; iii) predict the proportion of seasons when planting was possible for a range of planting windows using a simple panting rule. Historic climatic data from 1957 to 2016 was used. Detailed methodology, APSIM-OZCOT model settings and soil characterisation data are given in section 4.

1. Effect of sowing date and available N assuming a deep non crusting soil

This analysis indicates likely yield variability given the same pre planting starting conditions each season. That is what could 'next seasons' crop yield? Sorghum stubble is retained from previous wet season then on September 1st each season available soil water is set at 10% as is organic carbon (OC) and soil NO_3^- and NH_4^+ (for deep soil from 'Tonks Camp in the Gilbert Catchment).

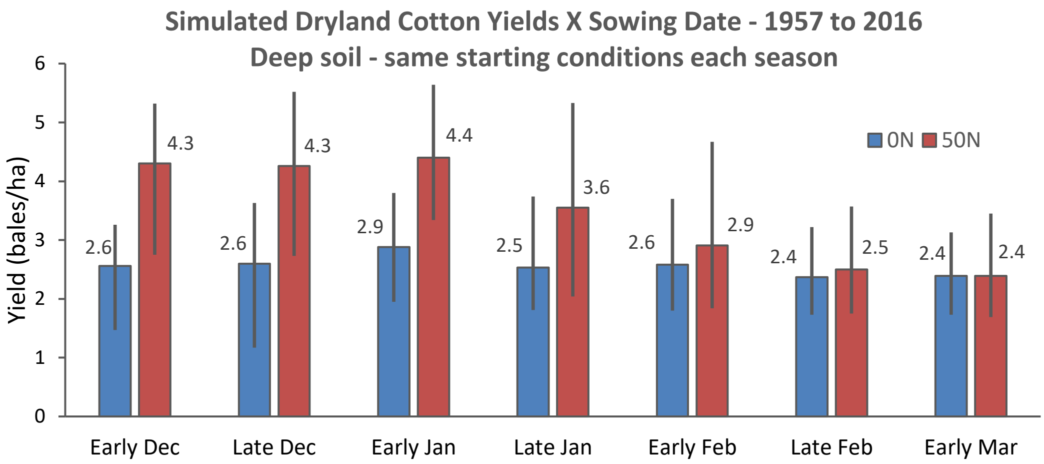

Figure B1: Simulated (APSIM-OZCOT model) average cotton yields and their range (bars = 10 to 90% of seasons) for the seasons when soil water permitted planting (not too wet or dry). Assumes a deep sandy loam soil, with 2 t/ha sorghum stubble retained from the previous season and soil available N is at the higher end for this region (see Appendix). Applying 50 kg N as fertiliser (50N) 30 days after sowing is compared with no N fertiliser (0N).

Key Points:

- Planting during December and early January appears more favourable for yield when more nitrogen is available to the crop.
- Soil water deficit reduces yield potential when sown after mid-January
- Early December planting will have a greater risk of rain at maturity that could discolour lint in possibly 10% of seasons, there are fewer planting opportunities (see Table B1) and early season water stress is more likely.
- The soil characterisation and weather data used is the best available. The appendix has the soil characterisation, meteorological data and management used in this analysis.
- The model assumes pests and weeds do not reduce yield, nutrients other than N are not limiting and there is an even plant stand.
- The model needs to be validated before to have good confidence in the response to N fertiliser in this environment as the model was developed at Narrabri. So try some N fertiliser strips this season if possible.

2. The effect of soil depth and available N on yield.

Compared are 4 soil scenarios: a deep (1.8 to 2m) sandy loam with above average organic carbon for the region (best soil); shallower (1.2m) sandy loam with higher (HOC) and lower (LOC) organic carbon and soil N (from soil analysis); a shallower soil prone to surface crusting with low organic carbon (worst soil). The soil characterisations are based on sampling at Tonks Camp and at Strathmore (more needed).

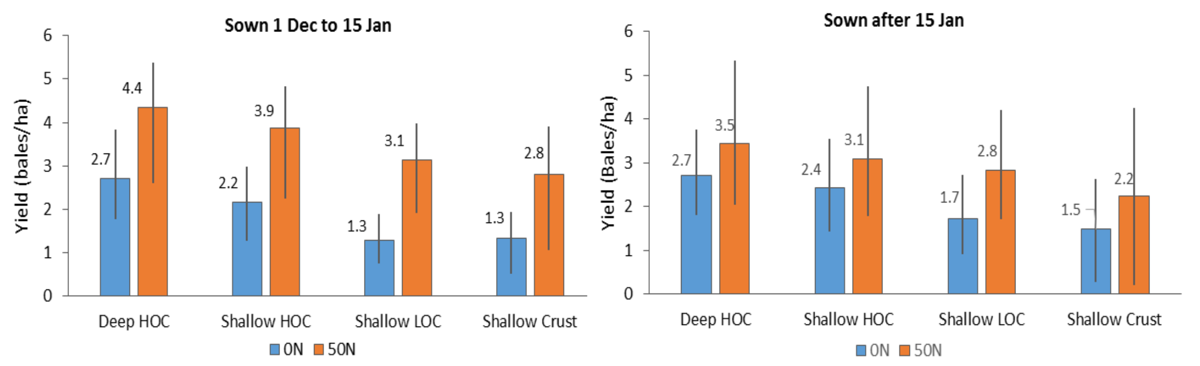

Figure B2: Simulated (APSIM-OZCOT model) average cotton yields and their range (bars = 10 to 90% of seasons) for different soil organic carbon and nitrogen concentrations for the seasons when soil water permitted planting (not too wet or dry).

Key Points:

- Shows the impact of soil available N and water on potential yield. Collecting soil data from more fields this season would improve this analysis.
- We tried 100 kg N fertiliser/ha and only the best soil (Deep HOC) produced a yield increase (average of 0.8 b/ha) compared to 50kg N /ha. Indicates insufficient N may be overriding the benefit of greater water in this soil.
- The model needs to be validated to have any confidence in the response to N fertiliser in this environment as the model was developed at Narrabri. N fertiliser strips this season are recommended.

3. Percentage of seasons when planting occurred.

Table B1 shows the number of seasons when planting occurred on the sandy loam soil with and without crusting for the sowing windows simulated in Figures 1 and 2 using the simple planting rule shown in section 4.

Note the crop is planted only on the first day in the window when the planting rule is met. We need to refine the rule to calculate the number of planting days possible in a window each season and for other soil types.

Table B1: Percentage of seasons when planting was possible on at least 1 day.

Sowing Window	No crust	Crust
Early December	50	40
Late December	57	43
Early January	67	55
Late January	75	67
Early February	70	62
Late February	68	60
Early March	63	52
Dec 1 to Jan 15	93	92
Jan 16 to March 15	98	98

4: Strathmore Dryland Simulations – Settings

4.1 Available soil water

Based on a river levee soil characterised at Tonks Camp in 2013 and Strathmore Station 2015 see Yeates (2015).

Table B2: Likely best soil: Deep sandy-loam higher organic carbon. Runoff Curve No. = 80

Depth (cm)	BD (g/cc)	Air Dry (mm/mm)	LL15 (mm/mm)	DUL (mm/mm)	SAT (mm/mm)	Cotton CLL	Cotton PAWC	Mung CLL	Mung PAWC	SWCON
0-15	1.42	0.009	0.031	0.157	0.434	0.031	18.9	0.031	18.9	0.9
15-30	1.71	0.011	0.047	0.177	0.35	0.047	19.5	0.047	19.5	0.7
30-60	1.56	0.03	0.061	0.138	0.381	0.061	23.1	0.061	23.1	0.7
60-90	1.6	0.027	0.06	0.151	0.368	0.06	27.3	0.075	22.8	0.7
90-120	1.56	0.026	0.053	0.159	0.38	0.053	31.8	0.118	12.3	0.7
120-150	1.56	0.055	0.055	0.159	0.38	0.055	31.2	0.155	1.2	0.7
150-180	1.67	0.054	0.054	0.149	0.339	0.08	20.7	0.149	0	0.7
180-220	1.67	0.054	0.054	0.149	0.339	0.147	0.8	0.149	0	0.7
Total							173.3		97.8	

Table B2: Poor soil: Shallow, Low organic carbon, surface crust. Runoff Curve No. = 90

Depth (cm)	BD (g/cc)	Air Dry (mm/mm)	LL15 (mm/mm)	DUL (mm/mm)	SAT (mm/mm)	Cotton CLL	Cotton PAWC	Mung CLL	Mung PAWC	SWCON
0-15	1.42	0.009	0.031	0.157	0.434	0.031	18.9	0.031	18.9	0.4
15-30	1.71	0.011	0.047	0.177	0.35	0.047	19.5	0.047	19.5	0.7
30-60	1.56	0.03	0.061	0.138	0.381	0.061	23.1	0.061	23.1	0.7
60-90	1.6	0.027	0.06	0.151	0.368	0.06	27.3	0.075	22.8	0.7
90-120	1.56	0.026	0.075	0.159	0.38	0.075	25.2	0.118	12.3	0.7
Total							114		96.6	

4.2 Starting N conditions each growing season (1957 to 2016) used in simulations for Fig B1.

Previous crop – sorghum 2t/ha of stubble cover C:N ratio = 80. Soil OC and available NO^-_3 and NH^+_4 as shown in Table 4C:

Table 4C:

	Higher N			Low N		
Depth (cm)	OC %	NO3 kg/ha	NH4 kg/ha	OC %	NO3 kg/ha	NH4 kg/ha
0-15	0.8	16	7.1	0.55	5.6	4.1
15-30	0.5	9	4.1	0.5	4	4.2
30-60	0.3	5	5	0.3	4.2	4.1
60-90	0.2	1	0	0.2	1	0
90-120	0.1	1	0	0.1	1	0
120-150	0.1	1	0	0.1	1	0
150-180	0.1	0	0	0.1	0	0

Yeates S (2015). Assisting cotton industry diversification in coastal NQ & tropical Australia. Final Project Report CSP1302, Cotton Research & Development Corporation, 45pp, Narrabri, NSW.

Appendix C: **Tropical regions Bollgard 3 RMP – initial background March 2016**

Stephen Yeates CSIRO & Paul Grundy (QDAF).

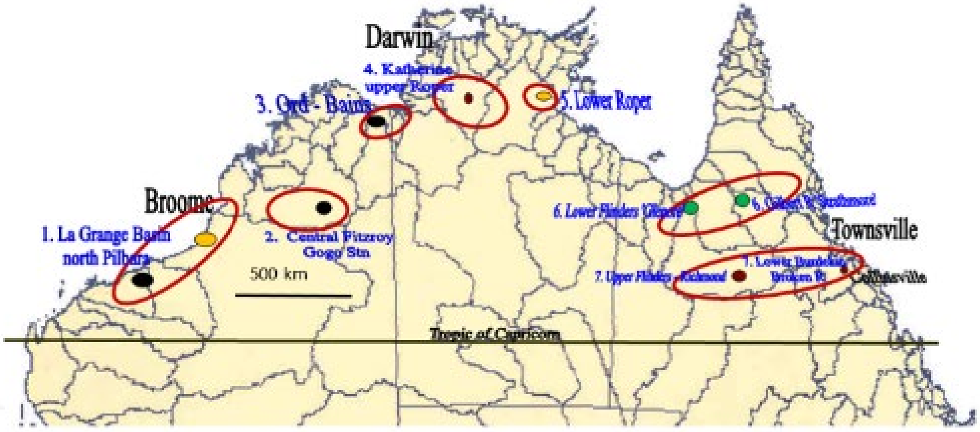

Fig. 1: Likely tropical cotton growing regions outside of the current BG3 RMP.

Where development time ● = now, ● = 3 to 5 years, ● ≥ 5 years, ● opportunistic small areas now or > 5 years

Table C1: Preferred sowing windows estimate without analysis of Heliothis generations.

Number	**Region**	**Preferred sowing window**	**Issues**
1	La Grange/N Pilbara	April - May	Time frame for land and water access
2	Central Fitzroy (Camballin to Fitzroy Crossing)	December – February, May?	Night temps, water, trafficability
3	Ord / Bains	Feb – Early May	Trafficability and season length
4	Katherine-Daly / upper Roper / Stuart Plateau	Feb to E – May	Cold nights, season length, small scale
5	Lower Roper	March to May	Trafficability , water
6	Lower Flinders / Gilbert	January to May	Water, trafficability, season length
7	Upper Flinders / Lower Burdekin & Broken	December to February	Trafficability, cold, season length, small scale in short term

Suggested Approach

Northern Australia window from 1 December to 30th May. Within this period a 6 week planting window that can commence at any time in that window within each production region. Each region is very well spaced and therefore should be able to be treated separately. Pigeon peas to be used throughout and kept over as trap crop similar to CQ. Planting window can be reset if less than 10% is sown to take into account weather interruptions that can occur due to the wet season.

Appendix D: **Forest Home Gilbert River dryland cotton support 2018.**

Provided technical support and NORpak to Ken and Brendan Fry 'Forest Home Station' 60 km west of Georgetown in the Gilbert catchment who planted 130 ha dryland and irrigated cotton in mid-January and early-February 2018 on deep alluvial soil.

A slightly above average wet season up to mid-March setup a good dryland cotton crop on these soils. A rain depression then delivered 500 mm over 3 days from 26 March to 28 March, filling the soil profile. The depth of soil water extraction by cotton roots was measured by soil cores to 1.5 m and 3 m were taken on May 2nd and May 28th. This data is essential for assessing the long term prospects for dryland cotton grown on these soils.

Plate D1: Dryland cotton 'Forest Home' Georgetown 6 April 2018. Left Brendan Fry 'Forest Home', Right Grant Randal 'Tonks Camp'.

Plate D2: Forest Home dryland cotton 2 May 2018 Paul Grundy (QDAF) sampling for soil water to 1.8 m.

Plate D3: 28/5/18 Paul McLennan (CSIRO) sampling to 3m for deeper soil water!! The first 120 cm was taken by pneumatic rig the rest by hand core!

Soil water was measured in the plant line and between the rows and averaged. Cores were taken in areas of good and poorer crop vigour. To calculate volumetric moisture content (VMC) the bulk density measured for a similar soil on the adjacent farm 'Tonks Camp' was used.

Results:
It was dry for 5 weeks prior to sampling on May 2 and VMC to 60 cm was near to the crop lower limit measured previously at 'Tonks Camp'. Plant available water and active roots were present from 60 to 180 cm. Table D1 shows the average VMC below 60 cm for the two sampling dates. It is clear the dryland cotton was extracting soil water to between 210 and 240 cm.

Table D1: Volumetric water percentage by soil depth and standard deviation in brackets.

	VMC (%)	
Depth (cm)	2-May	31-May
60 to 90	13.5 (0.50)	11.2 (0.68)
90 to 120	16.7 (0.70)	13.5 (0.74)
120 to 150	20.6 (0.76)	14.9 (0.22)
150 to 180	24.4 (0.50)	13.6 (0.36)
180 to 210	NT	10.7 (0.35)
210 to 240	NT	17.4 (0.38)
240 to 270	NT	39.4 (1.87)
270 to 300	NT	30.6 (0.25)

More rigorous characterisation of these soils for cotton is planned for the future. Assuming the bulk density and drained upper limit is similar to the soil at 'Tonks Camp' then the plant available water to 2.2 m should between 180 and 240 mm; desirable for dryland cotton.

Appendix E: **Mareeba climate for cotton**

By Stephen Yeates CSIRO 6/6/18

The growing season for cotton in the tropics is different to traditional growing areas in Australia. Cotton can't be planted in the spring because flowering and boll maturity would occur during the peak of the wet season in January – March. Flower shedding, boll rot and discoloration of lint would be common.

Cold night temperatures (<12° C) from May to August can down grade fibre quality, reduce yield and delay maturity. The extent of these impacts depends on the number of cold nights and the stage of fruiting. Cotton will not be affected by a few cold nights particularly during early flowering and late boll filling. Could nights during flowering combined with dew or wet leaves from irrigation can lead to Alternaria leaf spot infection which is very difficult to control and will reduce yields.

A quick climatic analysis follows:

Rainfall:

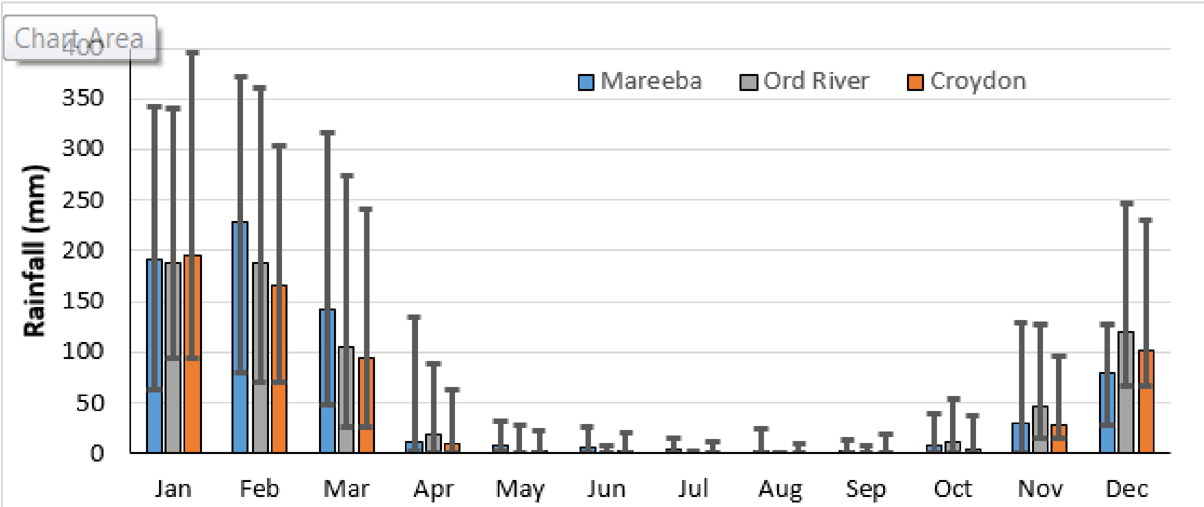

Fig E1: Mean monthly rainfall at Mareeba Airport data (most recent) from BOM is compared with the Gilbert River (Croydon) a similar latitude to Mareeba where good cotton yield and quality has been grown in recent trials sown during January and the Ord River where dry season cotton was evaluated. Bars show the range in 10 to 90 % of seasons.

Fig E1 shows the extreme variability in rain fall during the wet season months. Mareeba is wetter in February - March and drier in December than Croydon or the Ord River.

Solar Radiation:

Fig E2 below overlaps the average monthly daily solar radiation for the traditional October to April growing season at St George with a December to June growing season at Mareeba, Croydon and the Burdekin.

Mareeba has lower daily solar radiation during flowering and boll filling than the other tropical sites. Based on experience with January sown cotton at the Burdekin the deficit in solar radiation during flowering and boll filling compared to St George is likely to be reflected in lower yield potential.

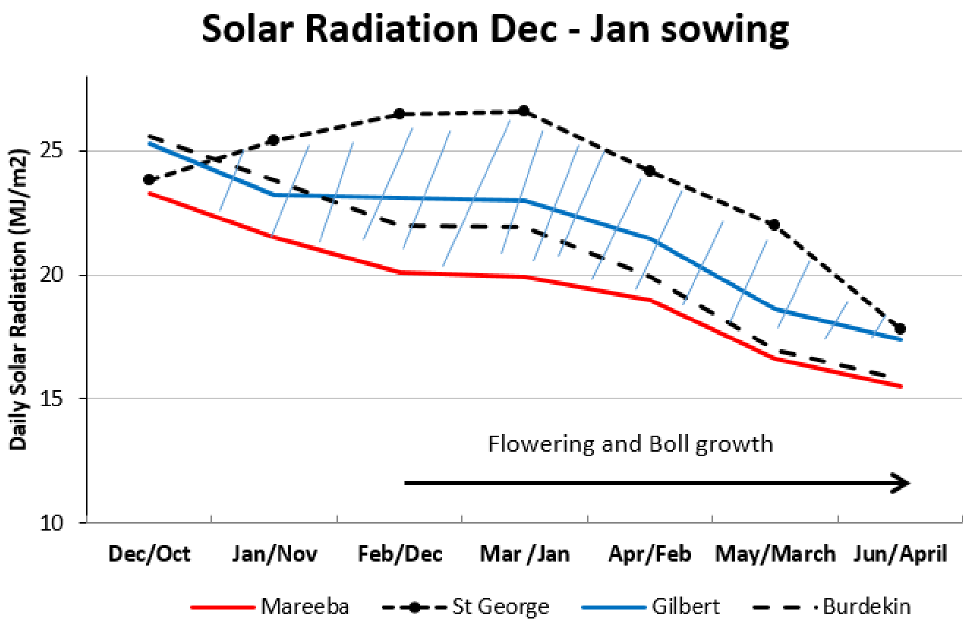

Fig E2: Monthly average solar radiation for the tropical growing season (December to June) at Mareeba, Gilbert River and the lower Burdekin compared with the high yielding St George region in southern Queensland with an October to April growing season.

Temperature:

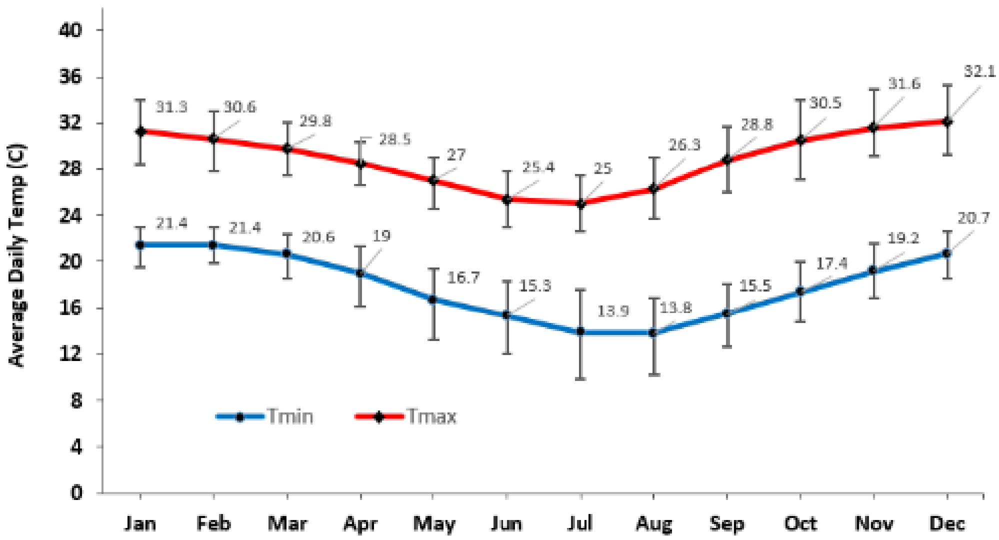

Fig Ex: Mean monthly temperatures at Marrebeand their range in 10 to 90 % of seasons (bars)

Mareeba temperatures are generally mild and farvorable for cotton. Only minimums during June to August could be problematic.

Potential Growing Season:

The Table E1 shows predicted the time for key growth stages using degree day sums developed in the Burdekin and Ord River. These differ from the values used in southern Australia. Planting dates from December 1 to May 15 are compared.

Table E1: Predicted mean dates for critical groth stages. Physiological risk periods are coloured as follows.

Flower shedding & boll rot	**Fibre colour grade**	**Cold nights**

Sow Date	1st Square	1st Flower	1st Open Boll	Pick
1-Dec	E-Jan	L-Jan	E-Apr	E-June
1-Jan	E-Feb	E-Mar	E-May	E-July
15-Jan	M-Feb	M-Mar	L-May	E-Aug
1-Feb	E-Mar	E-Apr	**M-Jun**	M-Sep
1-Mar	E-Apr	**E-May**	**E-Aug**	M-Oct
1-Apr	M-May	**L-June**	**L-Sep**	M-Nov
1-May	L-June	**E-Aug**	M-Oct	E-Dec
15-May	E-July	**M-Aug**	E-Nov	M-Dec

NB there will be at least a 2 week range in these dates due to variability in temperature and boll retention.

Based on the above January or possibley early May are potential panting times for irrigated cotton. A more detailed analysis is required to tease this out. For Dryland cotton a late December – early January planting could work as water will be the limiting factor.

Appendix F: **Burdekin dry season climate for cotton - November 2018**

1. **Growing season length**

   Season length was predicted using the Degree Day Sum (DDS) of 2243 calculated from planting to picking for June 1 and August 1 planting dates using historical temperatures for Ayr from 1957 to 2017.

   - June 1 to December 31 - Median DDS 2234 (lowest 10% < 2115, highest 10% > 2402)
   - August 1 to January 31 - Median DDS 2259 (lowest 10% < 2154, highest 10% > 2369)

Note: The measured DDS sowing to picking at Burdekin = 2243, base = 12°C

2. **Likely late growing season rainfall**

   - Figure F1 shows at the Ayr half monthly rainfall varies significantly between seasons the median increases rapidly from early December to late January when it peaks until mid- February. The wettest 10% of seasons exceed 150 mm per half month from late December until early March
   - At Ay the median rainfall volume for the first half of December is similar to the last half of March as is the variability.
   - At Emerald half monthly rainfall is lower and less variable than Ayr from January to March. Median rainfall in December at Emerald is similar to Ayr; importantly there is less variation at Emerald.

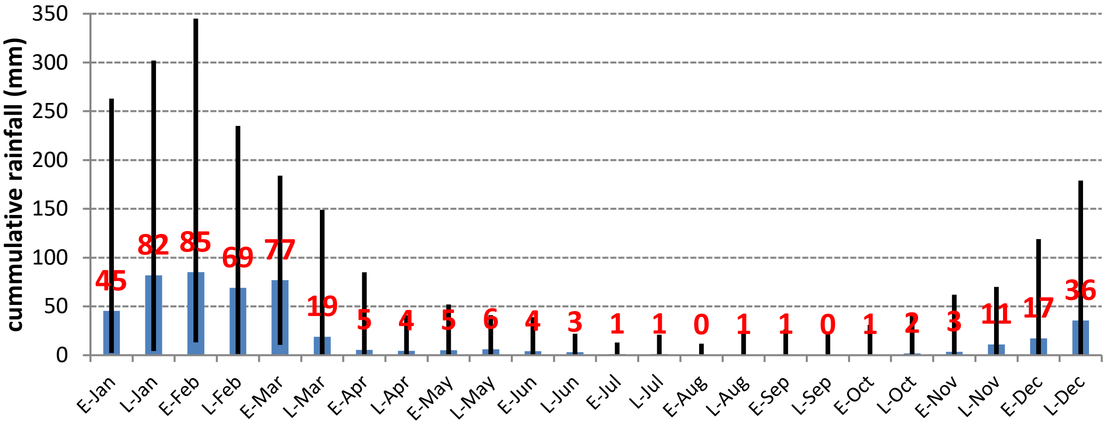

Fig.F1: Half monthly median rainfall (50% of seasons 1957 to 2017’) for Ayr shown as blue bars and the range for 10 to 90% of seasons – black bar.

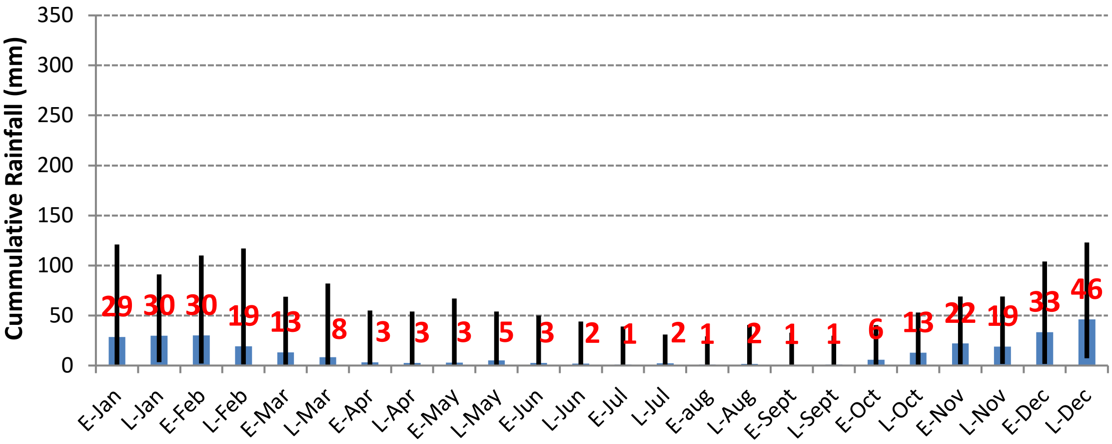

Fig.F2: Half monthly median rainfall (50% of seasons 1957 to 2017) for Emerald shown as blue bars and the range for 10 to 90% of seasons – black bar.

3. Cold shocks – minimums < 12°C

Cold shocks can occur from May to September being most frequent from late June to early August (Fig F3). The Clare – Dalbeg area is colder than Ayr. Ayr can expect 35 (range 8 to 70) cold shocks per season much greater than the 14 cold shocks at the Ord River.

Cold night temperatures (<12° C) from May to August can down grade fibre quality, reduce yield and delay maturity. The extent of these impacts depends on the number of cold nights and the stage of fruiting. Cotton will not be affected by a few cold nights particularly during early flowering and late boll filling. Could nights during flowering combined with dew or wet leaves from irrigation can lead to Alternaria leaf spot infection which is very difficult to control and will reduce yields.

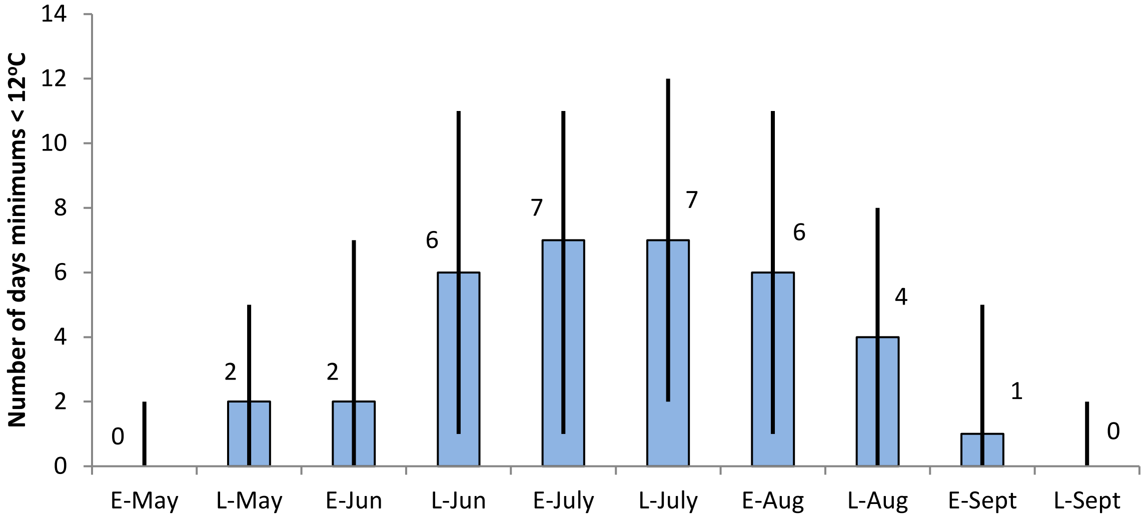

Fig. F3: The median number of minimum temperatures < 12°C at Ayr. Bars show range for 10 to 90 % of seasons.

Appendix G: **Leaf bioassay to determine the efficacy of Bollgard II® and Bollgard III® cotton varieties against cluster caterpillar, Spodoptera litura 2017.**

By John Moulden and Geoff Strickland WA Department of Primary Industries and Regional Development Durack Drive Kununurra WA 6743

Aim: To determine the survivorship of neonate larvae of the lepidopteran pest *Spodoptera litura* (Lepidoptera: Noctuidae), the cluster caterpillar, feeding on old and young leaves of Bollgard II® and Bollgard 3® cotton varieties.

Summary:

Young and old leaves of a Bollgard II and a Bollgard 3 cotton variety were fed to neonate larvae of *Spodoptera litura* in a laboratory bioassay. Bollgard II provided poor control of larvae, which were able to accumulate almost as much individual and total biomass as larvae fed on a non-insecticidal cotton variety (the control). Larval development was retarded to the extent that pupation did not occur in larvae fed Bollgard II by the time the control larvae were commencing pupation.

The Bollgard 3 cotton variety, while providing a much greater level of larval control, did not give total control, with one larva of 25 alive 17 days after feeding on young Bollgard 3 leaves commenced. Nevertheless, this level of activity against *Spodoptera* larvae probably provides an acceptable level of field control of this pest.

Background:

The larvae of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) were often the most important pest of cotton (*Gossypium hirsutum* L. (Malvaceae)) at Kununurra, Western Australia (WA), during the 1960s, until *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) developed resistance to insecticides (Wilson 1974, Michael and Woods 1980). Until then, *Helicoverpa armigera* was considered a minor pest in cotton but the increased populations after the evolution of resistance led to the eventual collapse of the cotton industry in northern WA in 1974 (Michael and Woods 1980).

The recent availability of Bollgard 3® cotton varieties containing the Vip3 gene in addition to those already incorporated into Bollgard 2® varieties has not only increased confidence in controlling *Helicoverpa armigera* but may make a return to a wet season cotton production model feasible. There are several reasons why an early planting date is desirable, including avoiding end of dry season storms, maturing the crop in conditions of relatively high temperatures and solar radiation, and the opportunity it may present to plant a second non-cotton crop following cotton in the same season.

Limited activity of Bollgard 2 cotton on *Spodoptera* was demonstrated by Spafford *et al* (2007). Anecdotal evidence to date suggests that Bollgard 3 varieties may be active against *Spodoptera* in the field. This would be a major contribution to achieving effective control of most of the major late wet season caterpillar pests without resort to chemical applications. There is however little experimental evidence to support this claim.

Method:

Cotton leaves were collected from a trial planted at Ceres Farm, Kununurra on 3 February 2017. Old leaves (mature leaves close to the bottom of the plant) and young leaves (the topmost fully open leaves) were collected and transferred in ziplock bags in an esky with a cooler brick to the laboratory at Kununurra Research Station where the bioassays were conducted. Leaves were replaced every two days with freshly picked leaves for the first 7 days. Thereafter leaves were replaced with either fresh leaves or leaves which had been stored in the refrigerator at 4ºC for a maximum of 3 days. The varieties used in the bioassay were 71RR (Roundup Ready® with no insecticidal genes, control), 71BRF (Bollgard II containing Roundup Ready® traits and producing Cry1Ac and Cry 2Ab proteins) and 714B3F (Bollgard3 containing Roundup Ready® traits and producing the Cry1Ac, Cry2Ab and Vip3A proteins).

Newly hatched *Spodoptera* larvae were collected from the field from a leaf of the cotton variety 71RR. Eclosion had just occurred as the larvae had not moved off the leaf on which the egg mass had been laid. This was not seen as the preferred method of obtaining neonates; however, of the approximately 30 egg masses collected from 71RR plants, all either failed to hatch in the laboratory or were

parasitised by wasps. There was no evidence of virus infection in the field-collected neonates, which were subsequently used in the bioassay.
Whole leaf bioassays were performed in 15cm diameter round clear plastic takeaway containers containing a 0.9% agar layer of approximately 1cm depth. Leaves were inserted by the trimmed petiole into the agar in the tubs. Large "old" leaves were trimmed around the edges before inserting into the agar. In the treatments involving young leaves, two leaves were put into each tub at each leaf change. The containers were covered with press-fit plastic lids and kept on the laboratory bench at approximately 28ºC under a 12:12 fluorescent light regime for the duration of the experiment.
Five neonate larvae were used in treatment and each treatment was replicated 5 times.
Survival was recorded 4 days after initiation of the bioassay and thereafter every 3-5 days. Surviving larvae were weighed after 12 days and again 5 days later.
The bioassay was concluded on May 22nd when the last larva in the Bollgard3/old leaf treatment died.

Results

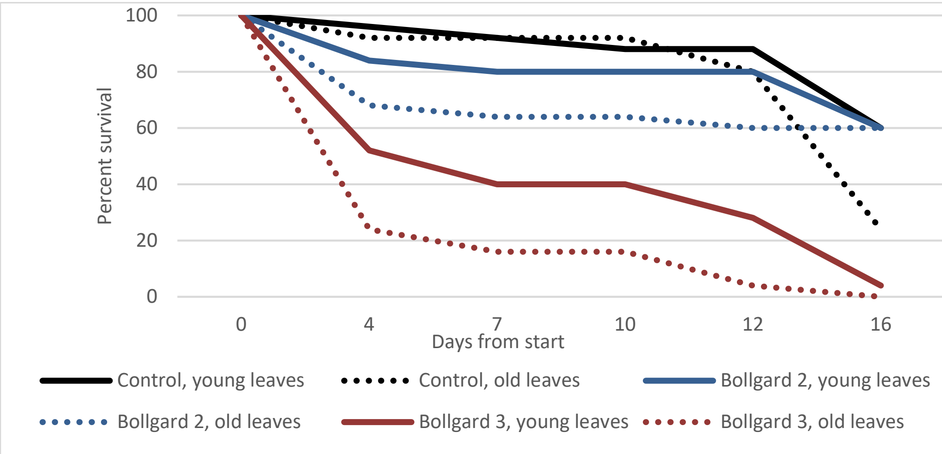

Figure G1. Percent survival of *Spodoptera* larvae on Roundup Ready only, Bollgard 2 and Bollgard 3 cotton varieties.

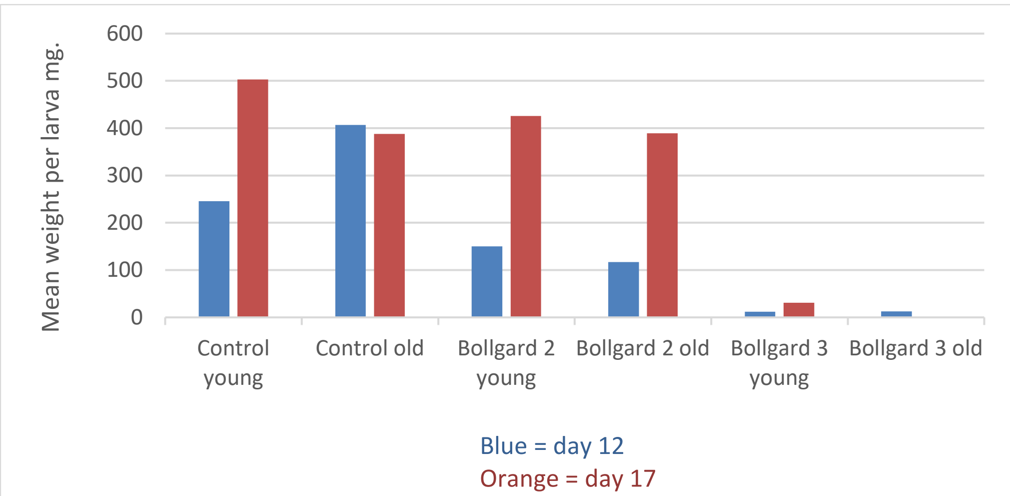

Figure G2. Mean weight per *Spodoptera* larva surviving to day 12 and day 17.

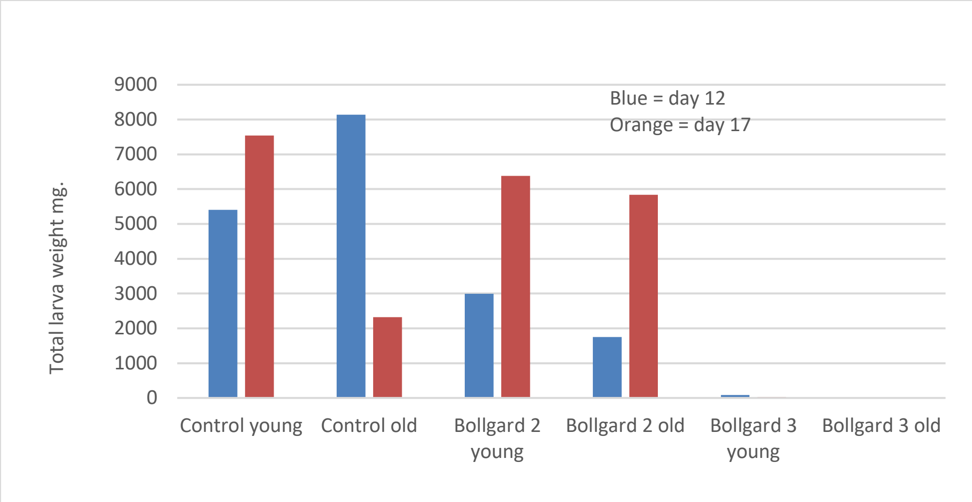

Figure G3. Total weight of all larvae surviving at day 12 and day 17. Five larvae were placed in each replication of each treatment, a total of 25 larvae per treatment.
Survival and larval weight

Genetics	Leaf age	Treatment no.	Date						
			9 May	12 May	15 May	17 May		22 May	
			Alive	Alive	Alive	Alive	Total wt mg.	Alive	Total wt mg.
“ Conventional”	Young	1	5	5	5	5	1437	2	1071
		2	5	4	4	4	1139	4	2133
		3	5	5	5	5	1140	3	1280
		4	4	4	3	3	681	3	2000
		5	5	5	5	5	1008	3	1060
	Old	16	3	3	3	3	1394	1	535
		17	5	5	5	5	2304	0	
		18	5	5	5	3	1626	0	
		19	5	5	5	4	1463	3	1103
		20	5	5	5	5	1356	2	688
Bollgard 2	Young	11	5	5	5	5	840	2	780
		12	3	2	2	2	313	2	1159
		13	4	4	4	4	693	4	1609
		14	4	4	4	4	607	3	1387
		15	5	5	5	5	545	4	1448
	Old	26	3	3	3	3	431	3	1248
		27	3	3	3	2	143	2	540
		28	3	2	2	2	307	2	1033
		29	4	4	4	4	445	4	1254
		30	4	4	4	4	429	4	1760
Bollgard 3	Young	6	3	3	3	1	8	0	
		7	3	1	1	0		0	
		8	3	3	3	3	45	0	
		9	1	1	1	1	28	1	31
		10	3	2	2	2	10	0	
		21	0	0	0	0		0	

	Old	22	1	0	0	0		0	
		23	2	2	2	0		0	
		24	2	1	1	0		0	
		25	1	1	1	1	13	0	

Discussion.

Some mortality was seen in all treatments 4 days after initiating the bioassay. Survival in the controls remained above 80% until day 12 when further rapid mortality occurred, possibly due to excessively humid conditions prevailing in the containers. By day 17 some larvae on both young and old leaves had pupated while a few had died during pupation.

Bollgard II did not provide exceptional levels of control of *Spodoptera* larvae when these were presented with either young or old leaves, and interestingly mortality did not increase as rapidly at day 12 as it did in the controls. Larvae were actively consuming both young and old leaves of Bollgard II throughout the bioassay as shown in Figure 3. However, no larvae had reached pupation by the end of the bioassay.

While resulting in much higher mortality, for the duration of the bioassay, Bollgard 3 did not provide complete control of *Spodoptera* larvae when these were presented with young or old leaves. Bollgard 3 cotton is clearly unpalatable to *Spodoptera* larvae. Complete mortality of larvae exposed to old Bollgard 3 leaves occurred by day 17, while one larva fed young Bollgard 3 leaves remained alive on day 17. This larva weighed 13 mg. and had not progressed past the second instar. Thus, while it may be theoretically possible for *Spodoptera* to survive on young foliage of Bollgard 3 cotton varieties, significant damage to the plant is unlikely. This is clearly illustrated by Figure 3, total larval biomass.

Reference:

Spafford, H., Strickland G. and Fairhead, J. (2007). A whole leaf bioassay to determine the efficacy of two Bollgard II® cotton varieties against cluster caterpillar, *Spodoptera litura* (Lepidoptera: Noctuidae)