



# FINAL REPORT 2015

For Public Release

## *Part 1 - Summary Details*

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

CRDC Project Number: **CSP1302**

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**Project Title:** Assisting cotton industry diversification in coastal NQ & tropical Australia

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**Project Commencement Date:** 1-July-12 **Project Completion Date:** 30-September-15

**CRDC Program:** 1 Farmers

## *Part 2 – Contact Details*

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**Date Submitted:** \_\_\_\_\_

## ***Part 3 – Final Report***

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

### ***Background***

#### **1. Outline the background to the project.**

The Burdekin region of coastal north Queensland and other areas of tropical Australia provide a significant opportunity for Australian cotton industry stabilisation and contribution to drought proofing. The research that preceded this proposal made significant progress toward the development of a production package for the wet season that incorporates strategies for managing seasonal variability. The focus of this project was to continue and extend upon research work conducted in predecessor projects "The development of sustainable cotton farming systems for coastal north Queensland" and "Completion of Burdekin cotton feasibility study". The wet season in the monsoon tropics is a unique environment for cotton production in Australia. Hence, to reliably achieve this potential requires an agronomic production package tailored to and validated under local conditions rather than the accepted norms of southern production.

A changed political landscape now permits commercial cotton production in the Gulf region of NQ, the Kimberley and Pilbara of WA and the top end of the NT. A key objective this project was to provide expert knowledge to assist cotton investment decisions, validate the Burdekin production package for new wet season growing areas, extend past research to dry season cotton growing areas and support implementation of sustainable and economic production practices for those regions. The knowledge gained from this and predecessor projects was also relevant to cotton regions with climates not typical of the older industry (e.g. CQ and southern NSW) hence this project also supported relevant research and delivery activities in these regions.

### ***Objectives***

#### **2. List the project objectives and the extent to which these have been achieved.**

There were five objectives

##### **1. Production systems package to account for climatic variability and soil type in the Burdekin.**

Gaps identified in the previous project were successfully addressed. N management experiments showed delayed release fertilisers applied pre planting could increase N fertiliser uptake efficiency 33 to 96% compared with urea on clay soils and avoid the need for in-crop application which is very risky due to poor trafficability in the wet season. Genotype screening was constrained by the transition to Bollgard III and it being practical to only screen Bollgard II in tropical Australia. The suitability of a later maturing high turnout variety was confirmed. The impact of 30 and 60% reduction in solar radiation for two weeks using shade cloth at first flower, mid flowering and cut-out was successfully measured. Knowledge of the mechanisms for crop recovery from these severe events provided insight into management practices that could minimise this production risk in tropical Australia.

##### **2. Cotton rotations linked with grain and sugar farming systems.**

The Joint venture rotation experiments with Sugar Research Australia and QDAF with support from GRDC and SRDC have clearly demonstrated the benefits of breaks with crops of cotton and grain crops (soybean, maize, mungbean). Sugar yields of plant crop and 1<sup>st</sup> ratoon increased 11 to 15% following 17 month break of cotton and or grains. While sugar yields were the same following cotton, soybean or mungbean in a short 6 to 9 month break. There are two more ratoons to harvest from this experiment. The experiment also highlighted the importance of managing the transitions between the crops, previous crop stubble and nutrient tie up. There has been great interest in this experiment in the farming community with large turnouts at field days and updates (separate to cotton specific events in section 4).

Nitrogen loss as field runoff water was measured in the final year of the project (2015) in field length (1000m) replicated plots to compare new N fertiliser management practices developed in this project

with previous management and the benchmarking measurements taken by Dr Paul Grundy in 2010. Delayed release fertilisers significantly reduced N in runoff water compared to urea but losses still occurred particularly following large rainfall events soon after planting.

### **3. Specialist cotton support for other regions in tropical Australia and CQ.**

This objective was achieved. Outside the tropics specialist support was provided to: 1) Paul Grundy's Emerald project via climatic analysis, experimental design and data interpretation has contributed to a change to a 4 to 6 week earlier sowing date for cotton which reduced the climatic risks associated with summer rainfall and heat stress common during boll growth and maturity at the traditional October sowing time; 2) southern NSW as contributions to growth regulator trial design and two visits which included speaking at a grower workshop at Griffith on 20 February 2014, the Cotton grower of the year field day at Hillston March 2015 and to Auscott Ltd company staff at Narrabri NSW in September 2012.

In tropical Australia (not Burdekin) the project made in-kind contribution to the Flinders and Gilbert Agricultural Resource Assessment (FGARA) conducted by CSIRO and funded by the Office of Northern Australia. Stephen Yeates' northern knowledge and experience was used to contribute to 2 chapters and as a reviewer on several others. The outcome of this study was cotton was identified as a potential irrigated crop, in 2015 the Queensland Government supported the release of irrigation water from both catchments for crop / forage production and two cotton proposals have followed. A second activity related to FGARA was to establish experiments in the Gilbert catchment to validate NORpak-Burdekin and the APSIM-OZCOT model in the region. Good progress with validation of NORpak-Burdekin for Pix management and crop nutrition. For OZCOT-APSIM soil characterisation commenced, progress with rooting depth simulation on sandy loams and leaf area prediction.

### **4. Building the capacity to produce cotton in the Burdekin.**

Achieved via well attended (25 to 35) seasonal updates and field walks every year at cotton experiments. Attendance by farmers, agribusiness and bankers with results emailed to attendees. Replicated experiments conducted in partnership with local growers and information provided to rural and local media.

### **5. Disseminate research to industry and the wider scientific community.**

Achieved via press releases some organised by INCITEC that went to all rural media. Presentations at 'Decision Makers Forum' 2014 cotton conference, Cotton industry nitrogen review Goondiwindi August 2014, 'Agronomy Community' forum Townsville March 2014, September 2013 Invited plenary speaker 9<sup>th</sup> Brazilian Cotton Congress, November 2014 Northern Australia Food Futures Conf, Darwin NT, Community forum and field walk at Georgetown June 2013, Australian cotton research conference September 2015.

## ***Methods***

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

#### **Objective 1.1:**

#### ***N Management on heavy clays***

N fertiliser efficiency and management experiments focused on the 'worst case' scenario for N availability to cotton identified by the previous project. That is where cotton followed cane (3 to 6 weeks after cane harvest) on heavy clay soils. Previous work (Grundy 2012) found to produce acceptable yields and prevent offsite contamination of leached N requires management to be reliant on timely in-crop applications of N fertiliser which can be very difficult to achieve during wet weather on clay soils. Fertilisers that delay the oxidation of N in fertiliser to soluble NO<sub>3</sub><sup>-</sup> could reduce early wet season losses and assist in synchronising fertiliser mineralisation with crop demand and avoid in-crop application.

#### Aims:

1. To further evaluate delayed oxidisation N fertilisers as pre-sowing options for wet season cotton on clay soils.
2. Measure the timing of cotton demand for N in this environment to assist with selection of fertiliser options that synchronise  $\text{NO}_3^-$  mineralisation with demand.
3. Validate and calibrate pre-planting N fertiliser requirement calculation from NORpak-Burdekin
4. Repeat the benchmarking run-off water analysis conducted by Paul Grundy in 2010 to measure if the changed N management has reduced N concentrations.

All experiments were located on heavy 'Baratta' clay soils near Clare 35 km west of Ayr. The 2013 and 2014 experiments were on Jeff Marson's farm Cuson Rd and the 2015 experiment in a 9 ha paddock on Mitchell Rd owned by Dal Santo Farming. The collaborating farmers managed these crops including planting and fertiliser application. Crops were furrow irrigated. Non nitrogen fertiliser was applied pre-sowing and consisted of 34 P, 81 K, 37 S, 23 Ca, 3 Zn kg/ha banded 10 cm inside the plant line as 'INCITEC 48218'. Other crop husbandry practices were as per NORpak-Burdekin (Grundy et al. 2012). Management specific to each experiment is shown in Table 1.

**Table 1:** N experiment details.

| Experiment Details               | Year Sown                 |                           |                            |
|----------------------------------|---------------------------|---------------------------|----------------------------|
|                                  | 2013                      | 2014                      | 2015                       |
| Date sugar of harvest            | 20/11/12                  | Fallow previous year      | 31/10/14                   |
| Date of pre sowing N Application | 21/12/12                  | 19/12/13                  | 17-23 Dec 2014             |
| Row Spacing                      | 1.52m bed x 2 rows        | 1.52m bed x 2 rows        | 1.6m bed x 2 rows          |
| Sowing date & Variety            | 12/1/13 SC71BRF           | 1/1/14 SC74BRF            | 15/1/15 SC74BRF            |
| Plant population                 | 7.9 plants/m <sup>2</sup> | 8.5 plants/m <sup>2</sup> | 12.5 plants/m <sup>2</sup> |
| Plot dimensions                  | 40m x 3 beds              | 40m x 3 beds              | 1000m x 3 beds             |
| Replications                     | 4                         | 4                         | 3 (Zero N unreplicated)    |

#### Measurements:

*Soil Measurements:* Soil cores for nitrogen status, organic carbon and other nutrient availability were taken as near as practicable to sowing with 4 to 6 cores taken per experiment to the maximum depth possible (50 to 90 cm). Soil was also cored to 90 cm near picking and opportunistically when conditions allowed (not too wet) around crop cut-out for available soil  $\text{NO}_3^-$  and  $\text{NH}_4^+$ . For each plot the surface 30 cm was sampled in three locations and samples combined while one core was taken below 30cm.

*Plant Measurements:* Cotton biomass accumulation, partitioning of biomass, fruit numbers and N uptake were measured on 4 occasions prior to flowering, early flowering, cut-out and 30 days after cut-out (20 to 60% open bolls). Plant height and node number were measured at least fortnightly on 5 plants / plot as was NAWF (nodes above white flower). Maturity was measured by picking open bolls from 3m of from in each plot at weekly intervals. Lint yield hand-picked from between 8 and 13m<sup>2</sup> from centre 2 rows per plot in 2013 and 2014. In 2015 hand harvested 8x4m<sup>2</sup> areas per plot 100 m apart from head ditch to tail drain. Apparent N fertiliser uptake efficiency was calculated for each treatment as  $(\text{kg N uptake} - \text{kg N uptake from zero N control}) / \text{kg N applied} * 100$ .

*Other measurements:* Daily rainfall was measured in a standard rain gauge and other meteorological data by an automatic station located at each experimental site.

#### Treatments:

The nitrogen fertiliser treatments used in each season are shown in Tables 2, 3, and 4.

*N Fertiliser formulations used:*

Urea: Control fertiliser for these experiments. Urea is commonly used but rapidly oxidised to  $\text{NO}_3^-$ , hence easily leached from the field or root zone in the tropical wet season.

ENTEC®: The active ingredient in ENTEC is 3,4-dimethyl pyrazole phosphate (DMPP). ENTEC is added to non  $\text{NO}_3^-$  fertilisers, it works by preventing Nitrosomonas bacteria in the soil from oxidising soil  $\text{NH}_4^+$  to  $\text{NO}_3^-$ . Due to high temperatures the half-life of DMPP is expected to be < 4weeks<sup>-1</sup> in tropical soils.

Polymer Coated Urea: The polymer coating delays the mineralisation of urea. These products are being more widely used in Australia and internationally prevent N fertiliser losses and synchronise  $\text{NO}_3^-$  availability with crop demand. Less expensive forms are being manufactured in China.

EasyN®: This is a liquid N fertiliser (42.5% N) that contains mainly  $\text{NH}_4^+$  which is stabilised with acid. Liquid N fertilisers are increasingly popular in the tropics due to operational advantages during the wet season. Growers can apply in-crop N to soil surface through a boom spray and apply N large areas quickly without the trafficability constraints of soil incorporation.

Dunder®: This was a grower requested treatment, it is made for the sugar industry by the milling company Willmar pty ltd. Dunder is applied as a high volume liquid (3000 lt/ha) consisting of acidified urea mixed with cane biomass left over from sugar milling. Other nutrients are included in the mixture. This is widely used by cane growers and N in this form is claimed to oxidise slower than urea fertiliser.



Dunder® application: Left incorporated; Right surface applied. In the 2014 experiment Dunder was incorporated.

**Table 2:** Treatments in 2013

| N Treatment                        | Pre-sowing N<br>(kg N/ha) | In-crop N 35 DAS<br>(kg N/ha) | In-crop N 55DAS<br>(kg N/ha) | Total N<br>(kg N/ha) |
|------------------------------------|---------------------------|-------------------------------|------------------------------|----------------------|
| Zero                               | 0                         | 0                             | 0                            | 0                    |
| Urea Low (U150N)                   | 150                       | 0                             | 0                            | 150                  |
| Urea High (U300N)                  | 300                       | 0                             | 0                            | 300                  |
| Entec® Urea (ENU) Low              | 150                       | 0                             | 0                            | 150                  |
| ENU High                           | 300                       | 0                             | 0                            | 300                  |
| Polymer coated urea (Poly150N)     | 150                       | 0                             | 0                            | 150                  |
| Urea (pre sow)+ EasyN® (Ezy) 35DAS | 150                       | 120                           | 0                            | 270                  |
| ENU (pre sow) + EN-EasyN® 35DAS    | 150                       | 120                           | 0                            | 270                  |
| Urea (pre sow) + EasyN® 55DAS      | 150                       | 0                             | 120                          | 270                  |
| Urea (pre sow) + EasyN® 35&55DAS   | 150                       | 120                           | 50                           | 320                  |
| Unlimited N                        | 300                       | 120                           | 120                          | 540                  |

**Table 3:** Treatments in 2014

| N Treatment | Pre-sowing N | In-crop N 29 DAS | Total N |
|-------------|--------------|------------------|---------|
|-------------|--------------|------------------|---------|

|                             | (kg N/ha) | (kg N/ha) | (kg N/ha) |
|-----------------------------|-----------|-----------|-----------|
| Zero                        | 0         | 0         | 0         |
| Urea                        | 240       | 0         | 240       |
| Entec® Urea                 | 240       | 0         | 240       |
| Polymer coated urea         | 240       | 0         | 240       |
| Poly+ENU 3:1                | 240       | 0         | 240       |
| Poly+ENU 1:1                | 240       | 0         | 240       |
| Poly+ENU 1:3                | 240       | 0         | 240       |
| Poly + Urea 3:1             | 240       | 0         | 240       |
| Dunder®                     | 240       | 0         | 240       |
| ENU pre-sow + EN-EzyN 29DAS | 120       | 120       | 240       |
| Urea pre-sow + EzyN 29DAS   | 120       | 120       | 240       |
| Unlimited N                 | 240       | 220       | 460       |

**Table 4:** Treatments in 2015.

| <b>N Treatment</b>         | <b>Pre-sowing N<br/>(kg N/ha)</b> |
|----------------------------|-----------------------------------|
| Zero                       | 0                                 |
| Urea                       | 270                               |
| Entec® Urea (ENU)          | 270                               |
| Polymer coated urea (Poly) | 270                               |
| Poly+ENU 1:1               | 270                               |

### ***Genotype evaluation***

Replicated screening experiments were conducted in 2013 and 2014. Plots were 10m x 4 75cm rows with 4 replications and were hand sown with a push planter and hand-picked (7.5 m<sup>2</sup> from centre rows). The 2013 experiment was located in the same field as the nitrogen experiment that year and had the same management with N fertiliser as for the ENU (pre sow) + EN-EasyN® 35DAS treatment. The 2014 experiment was sown at 'Tonks Camp' and had the same management as the rest of the field. It was accepted that with the move to Bollgard III there would be a hiatus in the development of new material hence the emphasis was on getting further data on two promising experimental lines identified in the previous project in comparison with currently available cultivar. Ginning and fibre quality testing was conducted at ACRI Narrabri.

### **Objective 1.2: Solar radiation reduction experiments**

Due to shortages of irrigation water in temperate Australia cotton production is expanding to new regions in the tropics. Rainfall is higher in these regions and cloud cover during boll growth has reduced yields. Previous research (Grundy et al. 2012) found the impact of low radiation on yield and crop returns can be modulated by applying knowledge of how the crop compensates from periods of low radiation at different times during flowering and boll growth how management options (e.g. variety, N, water, growth regulators, row spacing) interact with this compensation. However intra seasonal rainfall and cloud cover can be highly variable in the tropics making it difficult to reliably achieve crop growth stage x cloud interactions in field experiments. It is possible simulate cloud cover by excluding a proportion of the solar radiation with shade cloth at selected growth stages.

The objective was to understand and investigate cotton growth and recovery in response to reduced radiation at different times during flowering and boll fill during the tropical wet season. The Namoi

valley in Australia (30°S) generally has high radiation during flowering and boll growth and has been a site for cotton physiology research for many decades so provided a good reference site.

Experiments were located at two sites, near Clare (19.4°S,) in the Burdekin irrigation area NQ in 2013 and 2014 and at the Australian Cotton Research Institute in the Namoi Valley (30°S), 16 km W of Wee Waa NSW in 2014. The Burdekin sites were in the same fields as the nitrogen experiments and all crop management was identical except nitrogen management which was: 2013 pre-sowing 150 Kg N (ENU)/ha + 120 kg N (EN-EzyN)/ha @ 35 DAS; 2014 120 Kg N (ENU)/ha + 120 kg N (EN-EzyN)/ha @ 29 DAS. Management at ACRI was as per best practice for the location.

Radiation was excluded by using installing ‘shade tents’ in the field. These were black shade cloth attached covering retractable gazebo’s 3m wide x 3 M long x 1.5 m high see photo. New shade cloth was used each season. Light interception was measured above and inside tents at solar noon to validate the manufacturer’s radiation interception.



Shade tents to simulate cloud at different growth stages (27 February 2014).

#### Treatments:

**Table 5:** Treatments for the Burdekin radiation reduction experiments. The Namoi experiment had fewer treatments these are marked \*and there were 4 replications. First flower was 12 March, 24 February and 20 December at the Burdekin 2013, 2014 and Namoi sites respectively.

| Genotypes | Growth Stage   | Shade                                | Replications |
|-----------|--|--------------------------------------|--------------|
| SC71BRF*  | No Shade*  | 60% radiation reduction for 2 weeks* | 3            |
| SC74BRF   | 1 <sup>st</sup> Flower*                                | 30% radiation reduction for 2 weeks  |              |
|           | 1 <sup>st</sup> flower + 2 weeks<br>Cut-out (NAWF <4)* |                                      |              |

#### Measurements:

Date of 1<sup>st</sup> square, 1<sup>st</sup> flower, cut-out. Fruit retention mapping before and after shading and at maturity. Maturity from 2.5 m of a centre row in each plot open bolls picked weekly. Yield from 2.5m 2<sup>nd</sup> centre row of each plot plus the total of maturity picks. Boll numbers were recorded. A sub-sample of seed cotton from each plot was sent to ACRI to be ginned and HVI testing.

#### **Objective 2.1: Joint venture cotton/sugar/grain rotation experiments.**

The objective is to measure the effect of different cotton and grain crop sequences on sugarcane production. The replicated experiment is located on a farm on heavy clay near Clare. Five rotation sequences commenced in December 2011, three where cotton, mungbean and soybean grown during

a short (6-9 month) break between sugar crops and two were 17 month sequences of these crops grown between sugar crops. Sugar was planted in 2013 following these sequences. The experiment will terminate after the 3 cane ratoon is harvested in 2017.

**Objective 2.2: Monitoring cotton insects and weeds as affected by rotation sequence.**

Weed issues were monitored in the first year and found few problems with the RMP developed for NORpak-Burdekin. As notified in May 2014 six monthly report this activity was scaled back due to: 1) the rotation experiment being planted to sugar and SRA taking over responsibility; 2) Increased workload in the N fertiliser efficiency research.

**Objective 2.3: Nitrogen loss in runoff water from cotton**

Total N in runoff water from rainfall and irrigation was sampled from the 2015 pre-sowing N fertiliser comparison described above. Three replications were sampled from the Polymer, ENTEC and Urea N treatments with the single replicate of the zero N and the 1:1 ENTEC:Polymer treatment sampled.

Sampling methods were as recommended by Grundy (2012) with samples were taken early in irrigation events and opportunistically from rainfall runoff. Collection of samples was manual, runoff water was taken from the furrow approximately 50 m from the tail drain and above any back up water. During irrigation events intake water was also collected.



Sampling early runoff on 21 Jan 2015 10:15 am during a break between rainfall events.



Sampling late in runoff event on 21 Jan 2015 14:45 pm late in the runoff event. Note the difference in water clarity from the earlier sampling.

Irrigation water was sampled at sowing (watering up), at the first in-crop irrigation (3-March) and 2 weeks later when visual differences between the treatments were obvious and the crop was near to maximum N up-take for all treatments.

Unfiltered nutrient samples (TN) were collected in 60 mL Sarstedt polypropylene vials, with filterable nutrients filtered on-site through a syringe with sterile, pre-rinsed filter modules (Sartorius MiniSart

0.45 m cellulose acetate) into six 10 mL Sarstedt polypropylene vials. Nutrient samples were immediately placed on ice or refrigerated upon collection and frozen within 2 hours of sampling. Water samples were analysed for at the Australian Centre for Tropical Freshwater Research laboratory (James Cook University). Samples for TN were digested in an autoclave using an alkaline persulfate technique and the resulting solution analysed for NO<sub>x</sub>-N by segmented flow auto-analysis using an ALPKEMFlow Solution II.

**Objective 3.1: Specialist support for CQ and other non-tropical regions.**

The main activity has been to provide support for Paul Grundy's project 'Strengthening the Central Highlands Cotton Production System'. A detailed climatic analysis and plan for research was done in early 2013. Contributions to design, measurements and interpretation of data have followed. Presentations at industry meetings and field days at least twice per year have followed.

**Objective 3.2: Specialist support for other tropical regions.**

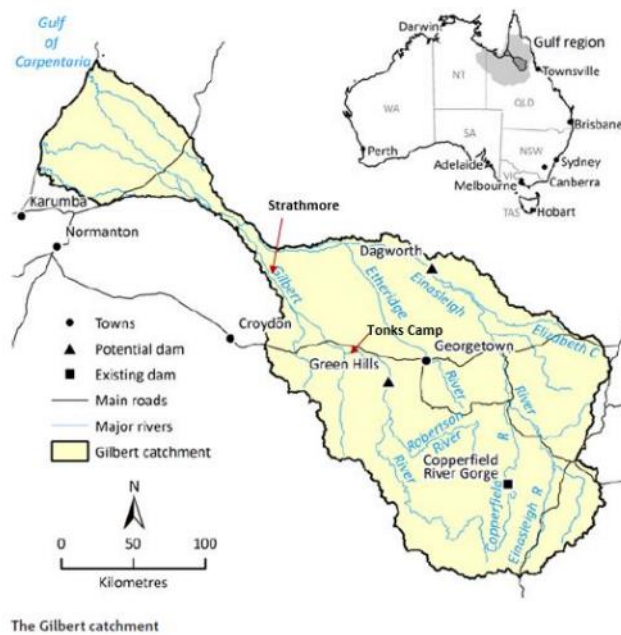
Collaboration with the Flinders Gilbert Agricultural Resource Assessment (FGARA) in the Gulf of Carpentaria commenced in September 2012 (Petheram et al. 2013). This CRDC project was asked to provide expert advice on cotton adaptation and production feasibility in the catchments.

The FGARA assessments quickly identified knowledge gaps for cotton that could make an irrigation investment unviable such as:

- What is the likely yield and quality of cotton grown in the late wet season?
- How much seasonal variability is there in yield?
- What are the consequences of inaccurate prediction of the irrigation water requirement of individual crops?

The later of these is critical because an error in prediction would mean having water to grow a sufficient area of crop to sustain processing infrastructure and a failed investment due lack of crop area. For example a proponent for sugar cane development in the Gilbert catchment, has assumed a requirement for 6 ML/ha of irrigation water while the FGARA modelling has estimated closer to 15 ML/ha. The cotton simulation model has not been validated for prediction of the crop water balance in these growing conditions (climate, soil type). A median irrigation requirement of 3.5 ML/ha was estimated (Webster et al. 2013; Hughes et al. 2013). In the case of cotton an error of just 1ML/ha above this estimate would reduce the median area that could be grown each season by 29%!

A further challenge for gaining state and local support for cotton proposals was lobbying by a proponent for a sugar development claiming the climate of the Gilbert catchment is unsuitable for cotton. Evaluations were established on 'Tonks Camp', owned by Grant Randal, 50 km west of Georgetown in 2013 and 2014 then at Strathmore Station in 2015 (Fig. 1).



**Fig 1:** The Gilbert Catchment and dam sites identified in the FGARA study. Shown is the location of cotton evaluation sites at Tonks Camp and Strathmore Station.

### ***Tonks Camp 2013 and 2014***

Validation studies had the following aims:

1. To demonstrate whether cotton can be grown in the region.
2. Validate cotton growth model OZCOT / APSIM for climatic risk assessment and prediction of inputs e.g. water
3. Validation of production package at Burdekin (NORpack-Burdekin).
4. Identify any tailoring required for the above and other unknowns.

Tonks Camp is a small freehold property developed for irrigation and grows seed crops and forages. The soil was a deep sandy loam. Due to the small size of the trials (0.5 ha in 2013, 1 ha in 2014) the crop was furrow irrigated from 'lay flat' fluming. This was easier for to manage than including the trial with other crops in one of the larger overhead irrigated fields.

Three commercial varieties Sicot 71BRF, Sicot 74BRF and Siokra 24BRF were sown in mid-January. The row spacing was 90 cm. All other management followed NORpak-Burdekin Guidelines (Grundy et al. 2012). It was not cost effective to machine pick the cotton so 11 areas (10m<sup>2</sup>) were hand-picked from each variety covering the length and width of the field. To estimate machine harvested yields 4% was deducted from hand-picked seed cotton yields. Fibre quality and gin turnout was measured from a 300 g sub sample taken from each harvested plot and sent to ACRI, Narrabri NSW

Due to the isolation of the site and commitments in the Burdekin the research team were only able to visit at 2 to 4 week intervals during the growing season. Hence the data collected was the minimum possible for the validations. The grower was required to record irrigation dates and volumes where possible and was shown how to do basic crop monitoring for pests, fruit retention and crop vigour. Data was emailed to researchers. An automatic weather station was located at the site this was provided by the FGARA project.



Right: 22/10/12 plastic sheeting for drained upper limit calculation. Left Tonks Camp, March 2013, arrow shows cotton trial.



16/5/13 – Soil sampling for crop lower limit and depth of roots



Left - 24/4/13 –Biomass partitioning Grant Randal, Brendan Fry (neighbour) and Perry Poulton CSIRO. Right- Sampling near maturity.

**Measurements:**

Above ground biomass was partitioned into vegetative and reproductive components 1st squaring, 1<sup>st</sup> flower, cut-out and 60-80% open bolls. Three areas were sampled from each variety. Insect scouting, crop nutrition decisions and plant vigour monitoring were as per NORpak-Burdekin (Grundy et al. 2012). Boll weights were measured from bolls picked from 3 groups of 5 plants for each variety. To meet the requirements of the OZCOT-APSIM model the soil was characterised for plant available water. This was done in collaboration with the CSIRO staff in the FGARA study (Webster et al. 2013). Depth of roots was measured when taking soil cores to measure the crop lower limit of water extraction.

**Strathmore Station 2015**

The 2015 season was the first in a longer term partnership between this project and its successor, QDAF and the management of Strathmore Station and to evaluate potential irrigated and dry land crops prior to their development of new irrigated and dryland farming land. A condition of

partnership, negotiated by QDAF, was in return for the input by the RD&E providers findings are to be made publically available.

The FGARA report (Petheram et al. 2013) released in December 2013 provided a catalyst for Strathmore and others interested in irrigation development in the Gilbert Catchment to pursue development plans. Strathmore is the largest single pastoral lease title in Queensland covering nearly 1,000,000 ha. In late 2014 Strathmore obtained permits to clear 60,000 ha on suitable soils for dryland and irrigated cropping. About half of this area was cleared by August 2015. They are interested in cotton as a potential crop for about 15,000 ha earmarked for irrigation development. Strathmore propose to capture water from a creek system (Dismal Ck) on the property where there is a natural barrier that can be sealed to store water on farm. The proposed storage is close to land suitable for irrigated cropping.

The broad aim of the partnership is to assess crop potential and farming system options that can inform investment before irrigation development commences.

The specific objectives for Stephen Yeates and projects CSP1302 / 1516FRP079A were:

- Agronomic expertise for growing irrigated cotton in the tropics
- Mentoring and training of station staff employed to assist the project
- Application of the OZCOT-APSIM to assess climatic and resource availability impacts on cotton production and crop rotation options following model validation and where required enhancement for local conditions.
- Continued validation and tailoring of NORpak-Burdekin
- Provide recommendations for irrigation application systems suitable for the local soils.
- Identify likely inputs required to grow cotton e.g. fertiliser, water requirement, pest management.

Greg Maison and Gareth Jones QDAF and Tony Webster CSIRO (Cairns) were responsible for the other crops evaluated (soybean, mungbean, sorghum and maize) which had similar objectives to cotton shown above. QDAF also had the lead role in the wider promotion of the project results e.g. local catchment management and other interest groups, field days, Qld Government internally and media. Strathmore provided staff for day to day management, development of the research site, most farming equipment, inputs for growing crops and accommodation on site for the R&D team.

### Methods:

The first season was quite challenging as it has required development of a 16 ha paddock only cleared the previous wet season and grown one dryland sorghum crop. Hence stumps and roots remained with an irrigation system and perimeter fencing to be installed prior to planting in early January 2015. The paddock was split so dryland and irrigated crops could be evaluated (Table 6). The deep loam soils may permit opportunistic dryland cropping of cotton.

**Table 6:** Crop areas (ha) sown in 2015

| Crop     | Irrigated | Dryland | Total |
|----------|-----------|---------|-------|
| Cotton   | 1.9       | 3.8     | 5.7   |
| Soybean  | 0.7       | 1.7     | 2.4   |
| Mungbean | 0.5       | 2.7     | 3.3   |
| Maize    | 1.1       | 0.0     | 1.1   |
| Sorghum  | 0.8       | 0.0     | 0.8   |
| Refuge   | 0.2       | 0.1     | 0.3   |
| Total    | 5.2       | 8.4     | 13.6  |



Location of trial site 7 km down stream from the homestead.

Three commercial varieties Sicot 71BRF, Sicot 74BRF and Siokra 24BRF were sown January 15 & 16. Row spacing was 1m hills. The crop was managed using NORpak-Burdekin. Soil tests indicated that N was the only nutrient required, 180 kg/ha was applied in-crop as Easy-N 39 DAS. Three soil characterisation ponds were established to measure the volumetric drained upper limit. Crop lower limits were measured in-situ for all crops grown.



The field was cleared the previous season many large tree roots remained below the soil surface creating problems when ripping, cultivating and hilling up for irrigation.



Left: Dryland area at sowing, drilled into nutgrass cover! Right preparing hills in irrigated area, tree roots broke many shear pins and the tool bar.



Simple fluming was used to irrigate the site. QDAF applied for a special permit to extract river water to irrigate the site.

**Objective 4: Building cotton production capacity in the Burdekin and NQ.**

The main methodology has been to use action learning with growers test farming cotton and associated service providers. Hence all research was these farmers' fields and associated field days and research updates centred on these fields.

**Objective 5: Disseminate research to industry and wider community.**

Dissemination of research was strongly linked to activities above. In addition as described in Section 1 there has been wider presentation of results at a range of cotton and other forums in the traditional cotton growing areas, northern Australia combined with media releases to rural press.

## Results

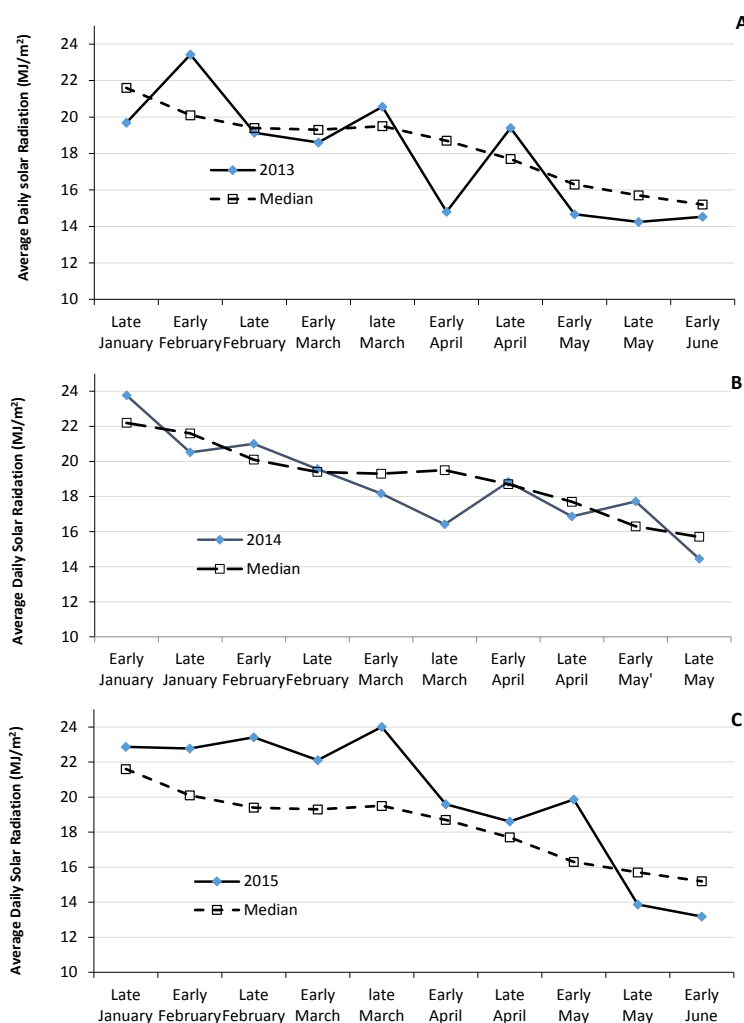
### 4. Detail and discuss the results for each objective including the statistical analysis of results.

#### Objective 1.1. Wet season crop management experiments

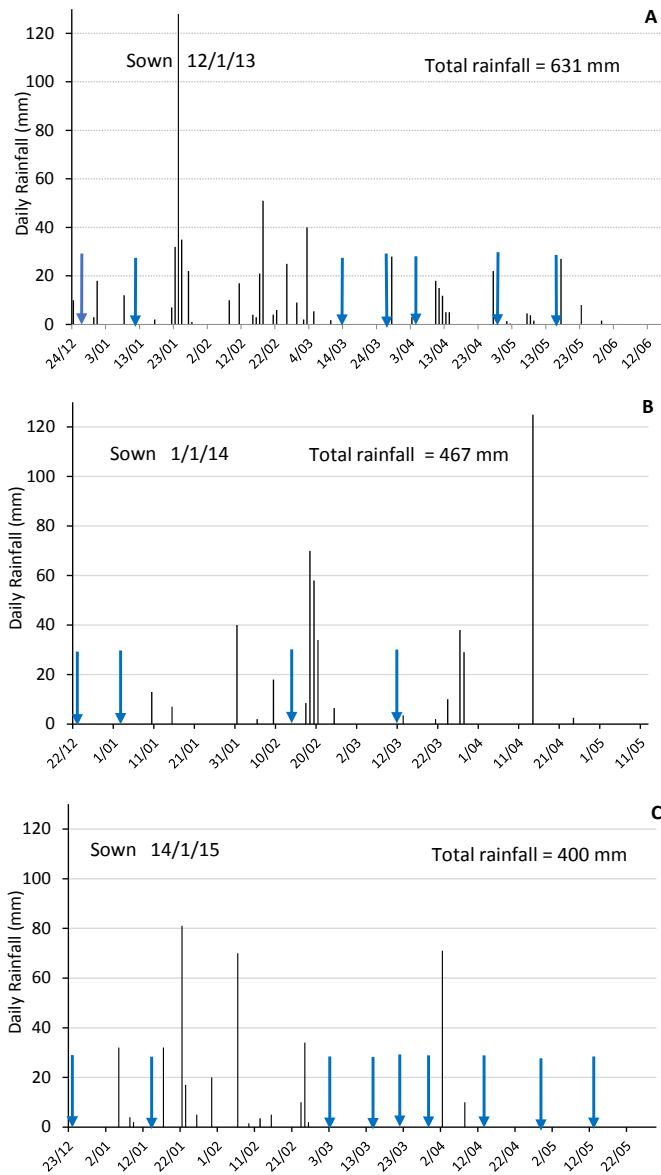
##### *Cotton N fertiliser management on clay soils - Burdekin 2013-2015*

##### Climate:

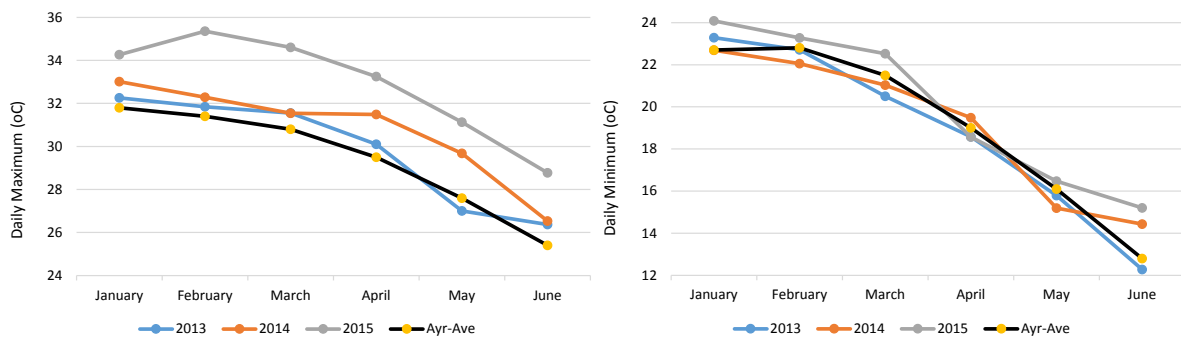
Figures 2 and 3 show the solar radiation and rainfall received for the experimental sites. Solar radiation during boll growth in March – May is critical for cotton yield in the Burdekin and large rainfall events early in growth can leach  $\text{NO}_3^-$  from soil into the furrow to be lost in runoff (Grundy 2012). 2013 was characterised by average or above radiation until late April or much of the flowering boll filling period with the exception of a cloudy period in early April in 2013; May was cloudy (Fig.2A). Seasonal conditions were favourable to N loss as cyclone Oscar produced 270 mm rainfall over 4 days shortly after crop emergence (Fig 3A). Temperatures were near average in 2013 (Fig 4). 2014 was sunny and dry until first flower in late February, radiation was below average for March and a large rainfall event combined with low radiation coincided with crop cut-out in late March (Figs. 2B and 3B). Maximum temperatures were above average in April and May (Fig 3). 2015 was one of the driest years on record in the Burdekin consequently solar radiation and maximum temperatures were above average (Figs 2C, 3C, 4). A significant rainfall event occurred on 21 and 22 January 6 days after sowing and ‘watering up’ hence the soil was wet and there was significant runoff.



**Fig 2:** Fortnightly daily solar radiation for the growing season compared with the long term median. Growing seasons: A) 2013; B) 2014; C) 2015



**Fig 3:** Growing season daily rainfall: A) 2013; B) 2014; C) 2015. Arrows show irrigation dates.



**Fig 4:** Growing season monthly average daily maximum and minimum temperatures.

Pre-sowing soil N, pH and organic carbon:

The very low available soil N status in 2013 and 2015 reflects the previous cropping history of the fields (Tables 7, 8 & 9). Both fields were sown shortly after four years of sugar cane and there was very little rainfall between burning, cutting the cane, cultivation and pre-irrigation. The field in 2014 had been weed fallow since a cotton crop 18 months previously and had higher available N. Soil organic carbon was consistent with past seasons on these soils.

**Table 7: 2013**

| Depth (cm)          | NO <sub>3</sub> <sup>-</sup> (kg/ha) | NH <sub>4</sub> <sup>+</sup> (kg/ha) | NO <sub>3</sub> <sup>-</sup> + NH <sub>4</sub> <sup>+</sup> (kg/ha) | pH (H <sub>2</sub> O) | OC (%)      |
|---------------------|--------------------------------------|--------------------------------------|---|-----------------------|-------------|
| 0-15                | 2.1 ± 0.39                           | 16.3 ± 2.15                          | 18.4 ± 1.96   | 7.3 ± 0.09            | 0.95 ± 0.02 |
| 15-30               | 1.7 ± 0.30                           | 10.9 ± 3.13                          | 12.6 ± 2.95   | 7.5 ± 0.11            | 0.80 ± 0.03 |
| 30-45               | 1.1 ± 0.36                           | 6.4 ± 1.25                           | 7.5 ± 1.30  | 7.7 ± 0.60            | 0.61 ± 0.03 |
| <b>Total (0-45)</b> | <b>4.9 ± 0.41</b>                    | <b>33.6 ± 3.2</b>                    | <b>38.5 ± 3.19</b>  |                       |             |

**Table 8: 2014**

| Depth (cm)          | NO <sub>3</sub> <sup>-</sup> (kg/ha) | NH <sub>4</sub> <sup>+</sup> (kg/ha) | NO <sub>3</sub> <sup>-</sup> + NH <sub>4</sub> <sup>+</sup> (kg/ha) | pH (H <sub>2</sub> O) | OC (%)      |
|---------------------|--------------------------------------|--------------------------------------|---|-----------------------|-------------|
| 0-15                | 16.7 ± 4.50                          | 6.0 ± 0.58                           | 22.7 ± 4.59   | 7.7 ± 0.21            | 0.67 ± 0.03 |
| 15-30               | 20.3 ± 1.43                          | 6.3 ± 0.39                           | 26.6 ± 1.50   | 7.6 ± 0.20            | 0.67 ± 0.02 |
| 30-45               | 9.3 ± 2.04                           | 5.7 ± 1.18                           | 15.0 ± 3.22   | 7.2 ± 0.10            | 0.60 ± 0.02 |
| <b>Total (0-45)</b> | <b>46.4 ± 2.26</b>                   | <b>17.9 ± 0.39</b>                   | <b>64.3 ± 2.09</b>  |                       |             |

**Table 9: 2015**

| Depth (cm)          | NO <sub>3</sub> <sup>-</sup> (kg/ha) | NH <sub>4</sub> <sup>+</sup> (kg/ha) | NO <sub>3</sub> <sup>-</sup> + NH <sub>4</sub> <sup>+</sup> (kg/ha) | pH (H <sub>2</sub> O) | OC (%)      |
|---------------------|--------------------------------------|--------------------------------------|---|-----------------------|-------------|
| 0-15                | 7.3 ± 2.59                           | 8.9 ± 0.39                           | 16.2 ± 2.33   | 6.7 ± 0.09            | 0.74 ± 0.02 |
| 15-30               | 4.9 ± 2.49                           | 9.1 ± 0.65                           | 13.9 ± 1.98   | 6.5 ± 0.13            | 0.84 ± 0.05 |
| 30-45               | 1.4 ± 0.42                           | 6.1 ± 0.29                           | 7.5 ± 0.65  | 6.3 ± 0.11            | 0.82 ± 0.07 |
| <b>Total (0-45)</b> | <b>13.5 ± 4.6</b>                    | <b>24.1 ± 0.45</b>                   | <b>37.7 ± 4.5</b>   |                       |             |



N deficiency symptoms were expressed early and were severe: Left 10/2/13 – 29DAS; Right 8/4/13 - 86DAS

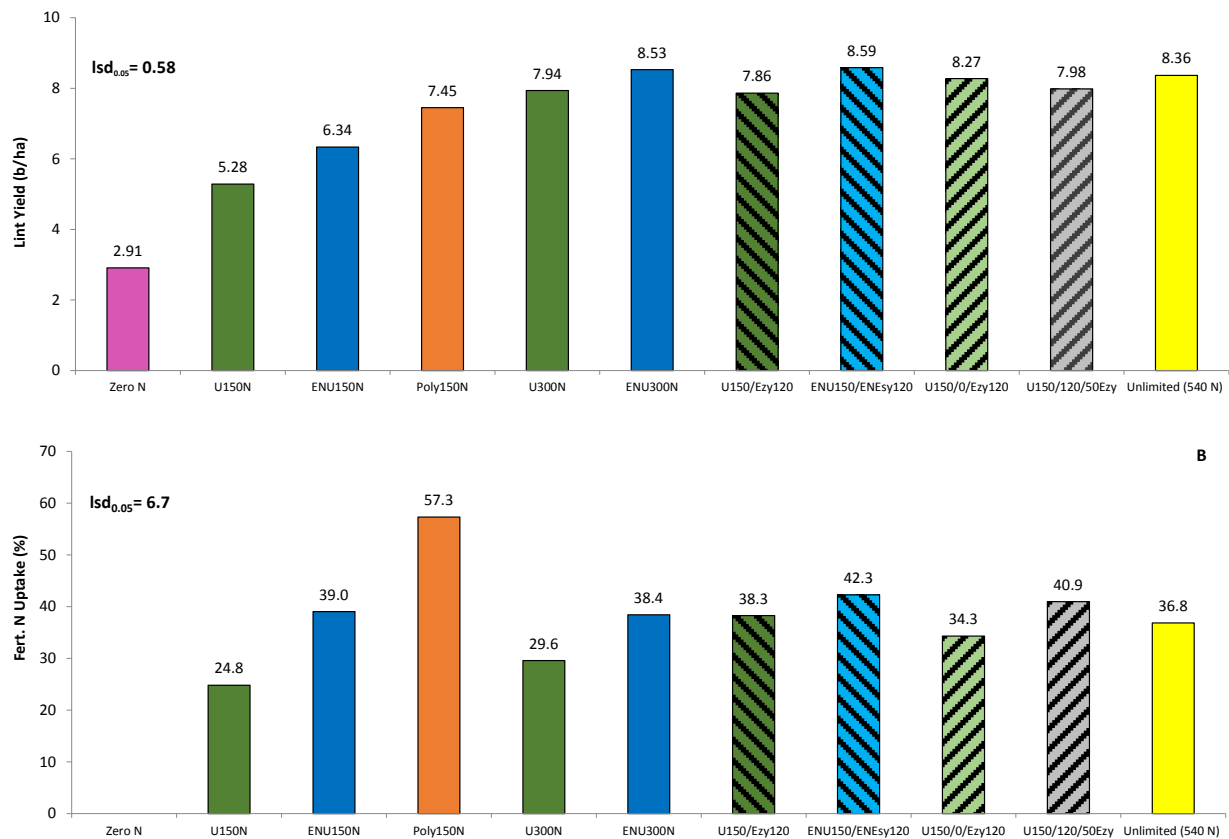
Soil available N at maturity

Available soil N to 90 cm at maturity was very low and similar to previous years (Yeates 2012, Final Report CRDC00031). N as NO<sub>3</sub><sup>-</sup> was < 2 kg N/ha in 2013 and 2015 and <6.5 kg N/ha in 2014, while NH<sub>4</sub><sup>+</sup> N was < 30, < 13 and < 50 kg/ha in 2013, 2014 and 2015 respectively and there was no difference between fertiliser treatments and the zero N control. The only exception being the unlimited N treatment which had 10 to 25 kg/ha more N as NO<sub>3</sub><sup>-</sup> N and NH<sub>4</sub><sup>+</sup> N than the other treatments.

## Yield and apparent N uptake efficiency:

2013

Figure 5A shows for the same rate of N fertiliser banded prior to sowing the delayed mineralisation products significantly increased yield and N fertiliser uptake efficiency compared with urea. The polymer coated urea was the most effective as only 150 kg of N/ha was required to produce the same yield statistically as 300 kg N/ha of urea. The fertiliser uptake efficiencies reflected the yields with the uptake of urea N being < 30% while the polymer coating increased the uptake efficiency to 57% (Fig. 5B).



**Fig 5:** Effect of N rate, fertiliser type and timing in 2013 on: A) Lint Yield; B) Apparent N fertiliser uptake %.

In-crop application of N either at 30 days after sowing or at first flower again produced good yields (Fig. 5A). ENTEC® (EN) treated urea applied at sowing plus EN treated EasyN® applied 30 days after sowing produced significantly higher yield than the same fertiliser combination without treatment with ENTEC. Higher rates of N with a proportion applied 55 DAS (flowering) did not improve yield and delayed maturity. The unlimited N rate provided no yield advantage above the recommended N rate.



Impact of excessive N applied after flowering on fruit retention and development, 4/4/13 (82 DAS):  
 Left high yielding treatment (ENU pre-sow + EN-EzyN 29DAS); Right Unlimited N

**2014**

Visual differences between treatments were not obvious 29 DAS when in-crop N was applied due to little rain to leach or denitrify fertiliser combined with higher soil N than past experiments. Cotton roots were well established at this stage and polymer coating still intact for release to coincide with maximum crop N uptake over the next 60 days.



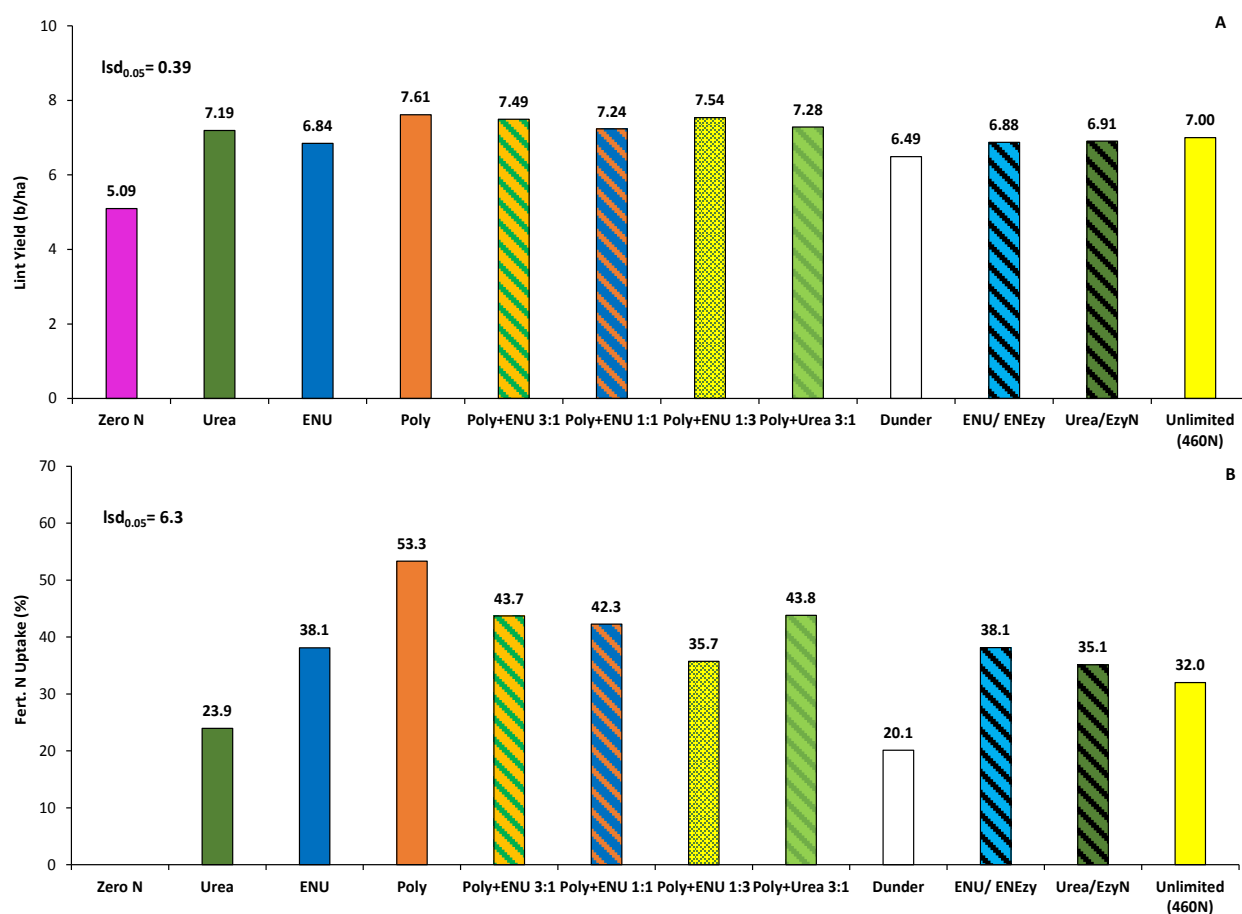
29 DAS when in-crop N applied



29 DAS - Left intact polymer coated urea granules applied pre-sowing; Right cotton roots below 25 cm.

Lint yields are shown in Fig. 6A. Low solar radiation combined with rain in late March coincided with cut-out and reduced yield potential. Higher soil available N than in past seasons increased the N uptake and yield of the zero N treatment. In fact the yield of the zero N was the highest for this treatment measured on a clay soil for the in the Burdekin (2010-2015).

However differences in fertiliser N uptake were large (Fig. 6B). Uptake percentages were similar to 2013 with pre-sowing urea having the lowest efficiency and the polymer and Entec® treatments having the highest. Pre-sowing applied polymer coating or Entec® were again at least as effective as split application of N (sowing plus in-crop). The 100% Polymer treatment being the standout for yield and N uptake efficiency. The lower N uptake efficiency of the Polly / ENU 1:3 treatment is hard to explain.



**Fig 6:** Effect of N rate, fertiliser type and timing in 2014 on: A) Lint Yield; B) Apparent N fertiliser uptake.

Below: March 18 2014 (77 DAS) eight days prior to rain and cloud. Polymer coated urea was near cut-out with high fruit retention. Visual differences in N uptake between treatments.



Polymer Coated Urea 240 kg



Dunder 240 kg N/ha



Urea 240 kg



Zero N



ENTECC® Urea 240 kg

2015

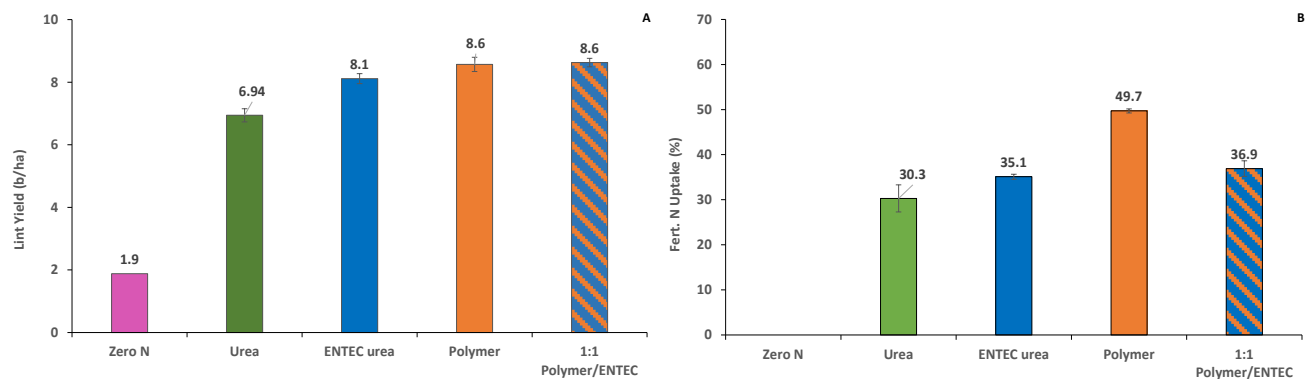
The poor yield of the zero N treatment was indicative of the low N status of the field (Fig.7A). Sunny conditions enabled the yields of the ENTEC and polymer coating treatments to reflect their greater N uptake (Fig. 7B). The fertiliser N uptake % of the polymer only treatment was again very high compared with other treatments.



March 6 2015: Visual differences at early flowering 51 DAS.

N was lost in runoff water during the post sowing rainfall event on 21 and 22 of January (Fig. 3A). It is probable management prior to sowing contributed to N loss. A combination of three weeks between fertiliser application and sowing and the field being wet on three occasions between fertilisation and establishment (pre-irrigation for 24 hours due to dry soil and 1000m field, watering up and 30 mm rain on 4/1/15) and high temperatures would have increased the oxidisation of all N fertilisers prior to this rainfall event.

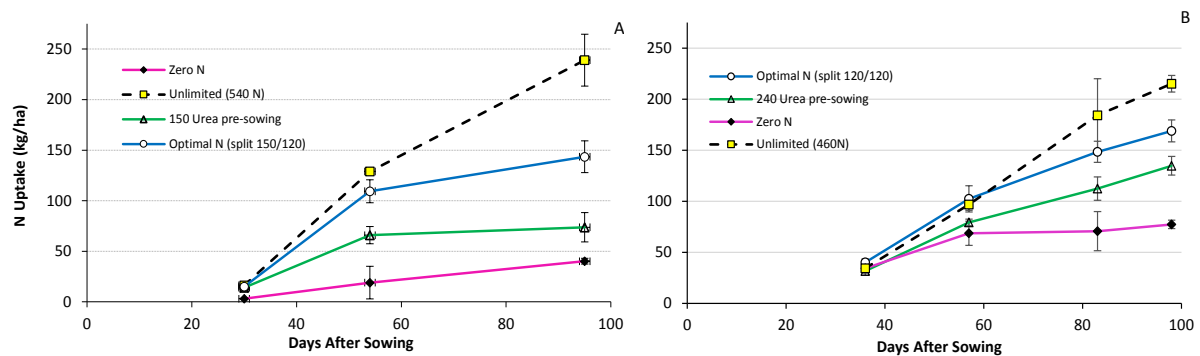
It is possible the irrigation on March 3<sup>rd</sup> was a little late, and reduced the yield potential of the high N uptake treatments. While the crop did not show any leaf wilting, it was very hot and humid but dry the week prior, fruit retention was high and internodes had shortened toward the top of the plant. This prevented the crop having sufficient biomass to support the high boll demand later in the month so cut-out was early.



**Fig 7:** Effect of N rate, fertiliser type and timing in 2015 on: A) Lint Yield; B) Apparent N fertiliser uptake. Bars show  $\pm 1$  standard error.

### Seasonal crop N uptake

Fig 8 shows in the first 30 to 40 days after sowing fertiliser treatment had little effect on crop N uptake and only 10 to 20% of N in the optimal treatment taken up. The crop uptake was rapid after 40 days with the duration of uptake dependent on the N treatment.



**Fig 8:** Crop N uptake over time showing fertiliser rate timing effects for A) 2013 and B) 2014. Bars are  $\pm 1$  se. NB show here is N uptake until peak 90 to 100 DAS.

### Conclusions:

Over three seasons the delayed N oxygenation products ENTEC<sup>®</sup> treated and polymer coated urea significantly increased apparent N fertiliser uptake by 33% and 96% respectively compared with untreated urea when applied pre-sowing. The greater N uptake translated into higher lint yield than urea in all seasons using polymer coating and two seasons using the ENTEC treatment. The ENTEC yield was not significantly different to urea in 2014. The magnitude of the yield increase over urea from using these products was due to factors other than N such as solar radiation.

Applying ENTEC and polymer coated urea had at worst the same N fertiliser uptake efficiency and lint yield as the recommended management option before this work commenced that was splitting N between sowing and in-crop application. Applying in-crop N after early flowering (55 DAS) delayed maturity and did not increase yield.

The method for calculating N fertiliser rates prior to sowing recommended in NORpak-Burdekin were confirmed in this study (NB not the 150kg N/ha rates used in 2013) as the unlimited treatment had no yield advantage and was later maturing.

Cotton uptake of N was only 10% - 20% of maximum 30 to 40 DAS. Most uptake occurred between 30 and 90 DAS and confirms the need for fertiliser N to be oxidised during this period to synchronise  $\text{NO}_3^-$  availability with crop demand. The polymer coating appears to have achieved this. The crop N uptake efficiency using the ENTEC treatment was lower and more variable and the protection provided by the product may have been affected by the time, climate and management between fertiliser application and planting.

### Genotype Screening.

Yield, turnout and fibre properties are shown in Tables 10 and 11. In 2014 one replication was lost to 2,4-D damage. Neither of the experimental lines were consistently better than Sicot74BRF for yield or fibre quality. As was the case in 2012 late season cloud reduced the yield of Siokra24BRF in 2013.

**Table 10:** 2013 – Burdekin on clay sown 5/1/13

| Variety / Line            | Yield (b/ha) | Relative Yield | TO (%)      | Length (in)   | Strength     | Micronair    |
|---------------------------|--------------|----------------|-------------|---------------|--------------|--------------|
| Sicot 71 BRF              | 8.4          | 100            | 39.4        | 1.24          | 28.7         | 3.80         |
| Sicot 75BRF               | 8.2          | 97             | 41.0        | 1.25          | 29.9         | 3.90         |
| EX102BRF                  | 8.1          | 97             | 40.6        | 1.22          | 30.7         | 3.64         |
| EX208BRF                  | 8.0          | 96             | 39.0        | 1.28          | 31.1         | 4.00         |
| Sicot 74 BRF              | 7.6          | 90             | 41.7        | 1.25          | 29.5         | 3.98         |
| Siokra 24 BRF             | 6.5          | 78             | 38.1        | 1.23          | 28.2         | 3.83         |
| <i>lsd<sub>0.05</sub></i> | <b>1.11</b>  |                | <b>0.93</b> | <b>0.0464</b> | <b>1.357</b> | <b>0.175</b> |

**Table 11:** 2014 – Gilbert River on sandy loam sown 9/1/14

| Variety / Line            | Yield (b/ha) | Relative Yield | TO (%)      | Length (in)  | Strength    | Micronair   |
|---------------------------|--------------|----------------|-------------|--------------|-------------|-------------|
| EX208BRF                  | 10.3         | 118            | 43.4        | 1.24         | 34.3        | 4.16        |
| Sicot74BRF                | 10.0         | 116            | 44.3        | 1.30         | 33.5        | 4.03        |
| EX102BRF                  | 9.3          | 107            | 43.7        | 1.23         | 33.7        | 3.41        |
| Siokra24BRF               | 8.8          | 102            | 41.2        | 1.26         | 32.0        | 3.97        |
| Sicot71BRF                | 8.7          | 100            | 41.1        | 1.23         | 32.3        | 3.83        |
| Sicot75BRF                | 8.7          | 100            | 42.9        | 1.30         | 33.4        | 3.87        |
| <i>lsd<sub>0.05</sub></i> | <b>1.14</b>  |                | <b>1.27</b> | <b>0.049</b> | <b>2.21</b> | <b>0.31</b> |

### Objective 1.2. Solar radiation reduction experiments

Sown are key results from these experiments. The work is in the process of being written for a paper and presentation at the 6<sup>th</sup> World Cotton Research Conference.

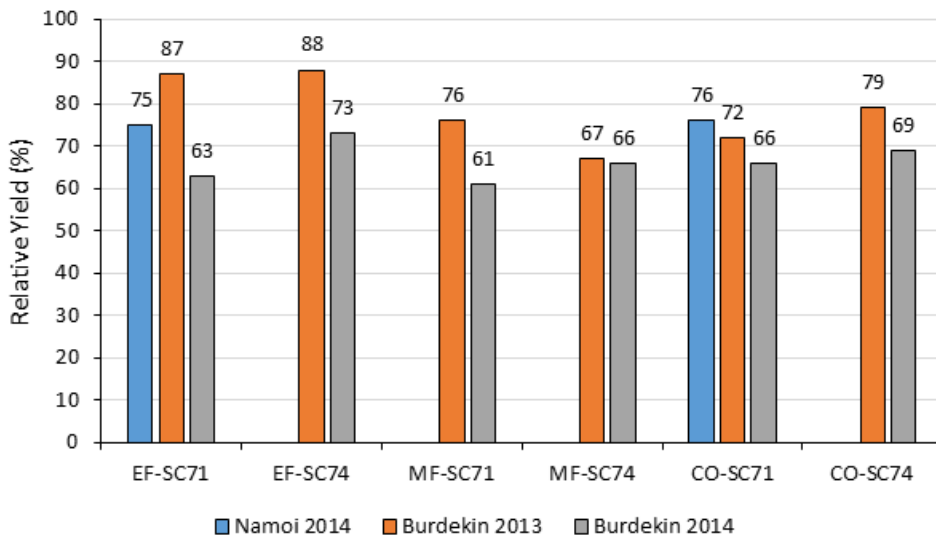
Not surprisingly 60% shade reduction significantly ( $p < 0.05$ ) reduced lint yield compared to the unshaded control in all experiments, growth stages and genotypes. Yield reductions were less with 30% shade. Yield not significantly different from unshaded in 2013 following 30% shade early in flowering. The Burdekin experiments has significant ( $p < 0.05$ ) main effects for shade percentage, growth stage and the interaction of these factors. The variety main effect was significant in 2013.

The unshaded control yields (Table 12) varied between locations and seasons reflecting the growing conditions for each experiment (e.g. seasonal solar radiation, temperature, evaporative demand and previous cropping history). Hence to compare sites and seasons the yields of shaded treatments are presented as percentages of their respective unshaded control (Fig. 9).

**Table 12:** Lint yields of unshaded treatments (kg/ha).

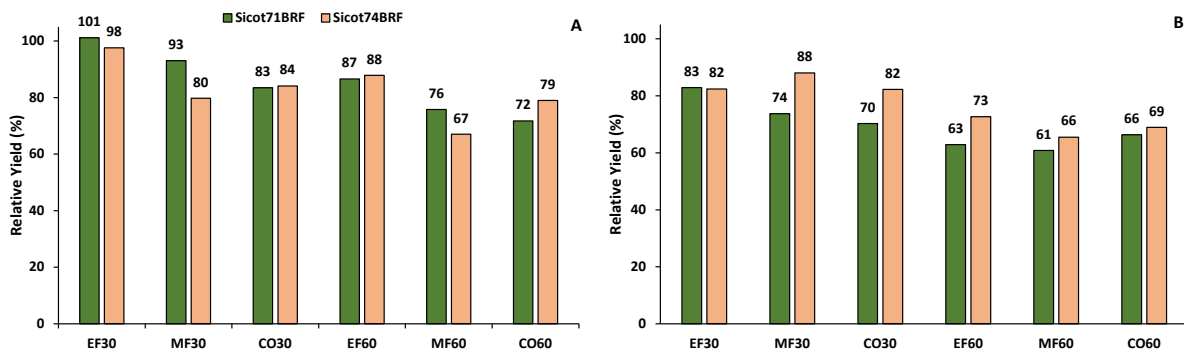
| Experiment    | Sicot 71BRF | Sicot 74BRF |
|---------------|-------------|-------------|
| Namoi 2014    | 2633        | NT          |
| Burdekin 2013 | 2088        | 1930        |
| Burdekin 2014 | 1975        | 1975        |

Figure 9 shows irrespective of location or unshaded yield the reduction in yield due shading was very large. At the Namoi site there yield reductions equated to 1.7% per day similar to water deficit at the same growth stages at this location. At the Burdekin relative yields were lower in 2014 than 2013 and may reflect very low solar radiation in late flowering (Figs. 2A, 2B). Of most interest for practical application of this data for the tropics was to identify treatments where relative yield was highest and variation in relative yields between seasons and genotypes greatest. This occurred early in flowering for both cultivars and at cut-out for SC74.

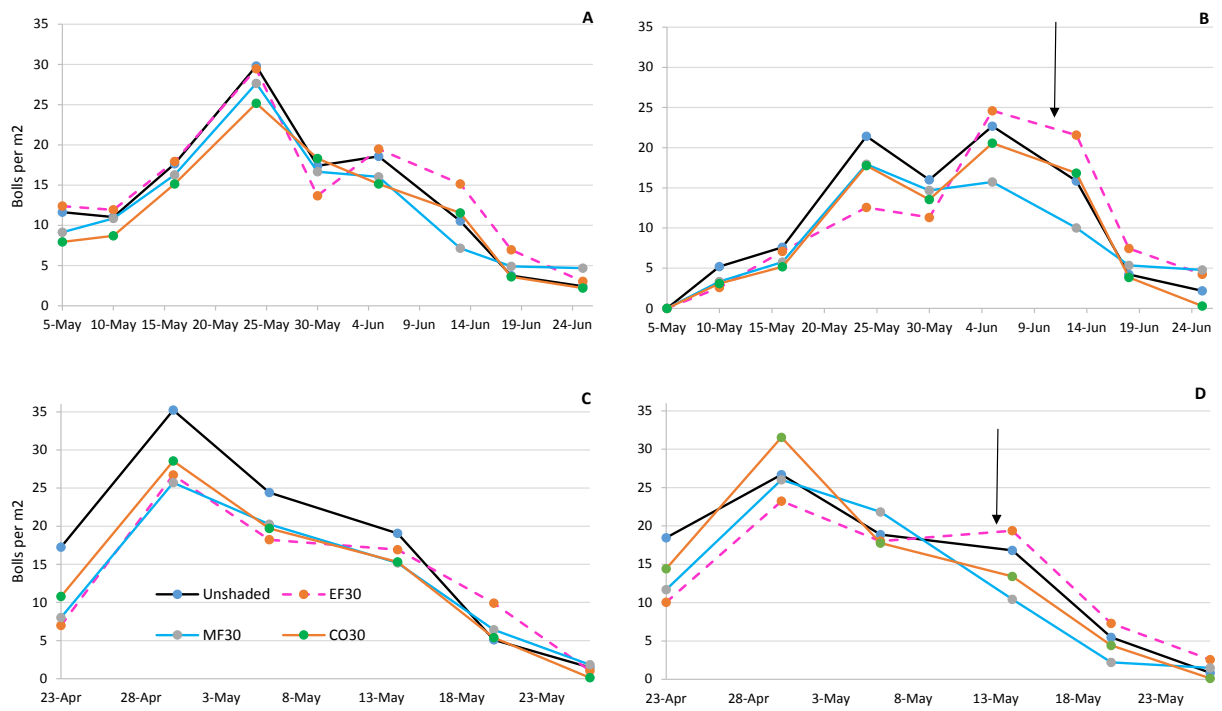


**Fig 9:** Lint yields relative to unshaded control for each experiment when solar radiation reduction was 60%. Where EF, MF and CO are shading at first flower, mid flowering and cut-out.

Figure 10 shows relative yields for all shading treatments at the Burdekin. Seasonal differences in the unshaded solar radiation following each period of shading can explain the treatment differences. 2013 had average or above solar radiation during the first month of flowering (March) and except for the first week of April below average solar radiation for the remainder of the season (Fig. 2). This favoured full yield recovery, particularly Sicut71BRF which has a shorter fruiting cycle, when moderately shaded (30%) early in flowering. In 2014 solar radiation was below average for March or most of the flowering period and near average for April and early May. When radiation was reduce by 30% this favoured the longer fruiting cycle variety Sicut74BRF (Fig. 11).



**Fig 10:** Lint yields relative to unshaded showing genotype, growth stage and radiation reduction effects following 14 days of shading at the Burdekin: A) 2013,  $l_{sd_{0.05}} = 13.9$ ; B) 2014  $l_{sd_{0.05}} = 13.6$ . Where 30 and 60 are radiation reduction % and growth stages are as show in Fig R1.



**Fig 11:** Effect of 30% shade during flowering on open boll numbers per date of maturity: A) SC71BRF-2013; B) SC74BRF-2013; C) SC71BRF-2014; D) SC74BRF-2014. Arrow indicates compensation from bolls that flowered later.

**Conclusions:**

These experiments will provide essential data to analysis that assist in the quantification of low radiation risk to cotton production in green-field sites in tropical Australia. The severity of the radiation reduction applied in these experiments represents a worst case scenario for most potential locations and an extreme event for the Namoi. Knowledge of the mechanisms for crop recovery from these sever events provides insight into management practices that could minimise this production risk. For example just the data shown above indicates sowing date selection to avoid low radiation periods later in flowering and a mixture of varieties with short and long fruiting cycles could be beneficial in climates where the timing of low radiation events is variable.

**Objective 2.1.** Impact of rotations with cotton on sugar yield.

Table 13 shows, contrary to popular belief, the later planting of sugar cane after cotton in a short fallow did not reduce total yield by harvest of the 1<sup>st</sup> ratoon. There were significant sugar yield increases by a 17 month break of cotton and grain crops. This experiment has two more seasons before final sugar yields will be measured and a comparative economic analysis can be made between the rotation options.

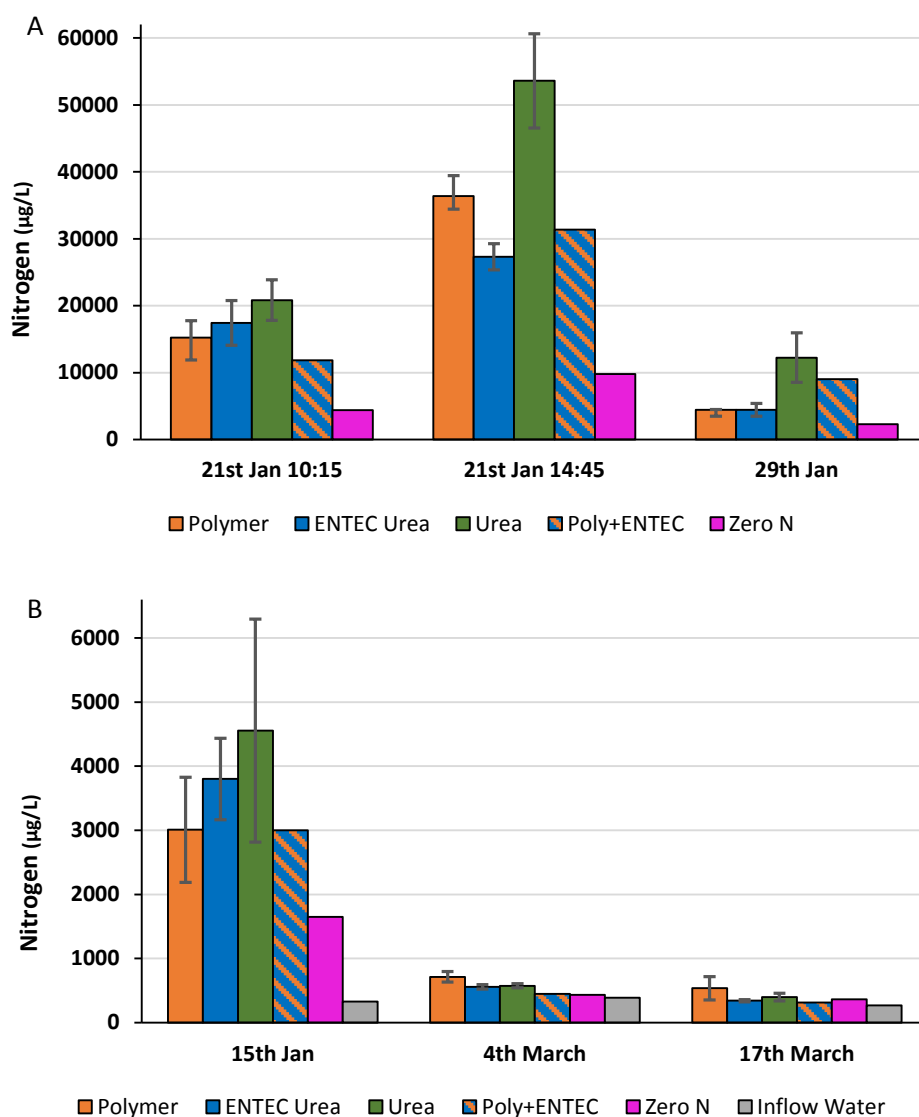
**Table 13:** Plant and 1<sup>st</sup> ratoon sugar yields (t/ha) following break crops of 6 to 17 month duration. Yields are also expressed as a proportion of the common 7 month soybean break (data from Barry Salter SRA McKay).

| Length of Break<br>(Months) | Sugar Cane<br>Planting Month | Fallow Crop    | Plant<br>Yield (t/ha) | % Soybean | 1st Ratoon<br>Yield (t/ha) | Total<br>Yield (t/ha) | Total<br>% Soybean |
|-----------------------------|------------------------------|----------------|-----------------------|-----------|----------------------------|-----------------------|--------------------|
| 6                           | April                        | Mung           | 24.3                  | 106       | 25.8                       | 50.1                  | 102                |
| 7                           | May                          | Soybean        | 22.9                  | 100       | 26.2                       | 49.1                  | 100                |
| 9                           | July                         | Cotton         | 23.4                  | 102       | 25.9                       | 49.3                  | 100                |
| 17                          | April                        | Soy-Maize-Mung | 30.3                  | 132       | 26.4                       | 56.7                  | 115                |
| 17                          | April                        | Cot-Maize-Mung | 26.8                  | 117       | 27.7                       | 54.5                  | 111                |



### Objective 2.3. Nitrogen loss in runoff water from cotton

Rainfall volumes when samples were taken are shown in Fig 2C. Fig 12 shows the total filterable N concentrations for each treatment in rainfall (A) and irrigation (B) water runoff. The most significant rainfall events were received on 21 January one week after planting and watering up. Two water samples were taken: the first during a break in rainfall after 32 mm had fallen; the second after a further 49 mm had fallen (Fig. 12A).



**Fig. 12:** Total filterable N concentrations in runoff water from A) rainfall and B) irrigation.

Consistent with Grundy (2012) N concentrations in runoff water were highest after large early season rainfall events when the crop was young and had taken up only a small amount of available N from the soil (Fig 12A). The Zero N treatment shows the contribution to runoff N from non-fertiliser sources was also high in this situation, reflecting the mineralisation of soil N prior to crop up-take.

Fig. 12A also shows although all fertiliser types produced N in runoff water following rainfall, urea produced higher N concentrations at all sample dates.

The concentration of N in irrigation runoff water was much lower than in rainfall runoff (Fig 12B); less than 10% of the maximum in rainfall runoff on 21 Jan 15:45 pm (Fig 12A). As expected the 'watering up' irrigation (Jan 15) produced the greatest N concentration in irrigation runoff water from all

treatments with urea producing the highest concentrations (Fig. 12B). Pre-irrigation on 23 December 2014 after fertiliser was applied would have initiated the N mineralisation process prior watering up 22 days later.

Post flowering irrigations on March 4 and 17 had low N concentrations for most treatments were similar to the source water applied (Fig 12B). The slightly higher N concentrations in runoff from the polymer treatment suggest some fertiliser N was still being mineralised from that treatment up to March 17.

The concentrations of N in runoff water presented here need to be put into context of the whole N budget of the crop and soil at this site. By far the greatest N loss in runoff would have been during the rainfall event occurred on January 21<sup>st</sup> 2015 when 32 mm of rain falling prior to the 1<sup>st</sup> sampling at 1015am and 49 mm between the first and 2<sup>nd</sup> sampling at 14.45 pm. Assuming all the rain received ran off the field this equals 320000 and 490000 litres/ha for each event. When these volumes are multiplied by the concentrations of N in runoff water the total N leaving the field / ha was calculated as 33, 19, 23 and 6 kg /ha for urea, ENTEC, polymer and zero N fertiliser respectively. In contrast the March 4<sup>th</sup> irrigation event would have runoff 0.11 kg N /ha from the polymer treatment and 0.065 kg N / ha from the zero N treatment. A total of 270 N/ha of fertiliser nitrogen was applied to each treatment and there would have been at least 20 kg/ha of mineralisation to NO<sub>3</sub> during the growing season. Given that the highest apparent fertiliser uptake efficiency's was 30.3, 35.1, 49.7 % for urea, ENTEC and Polymer respectively it is clear a significant amount of N fertiliser was lost to other mechanisms.

### **Conclusions:**

The pattern of N concentration in runoff water was similar for all fertiliser treatments (including zero N) to those measured by Grundy (2012) with concentrations highest (tenfold) following rainfall early in the growing season than from later irrigation events. ENTEC and polymer coated urea had average N concentrations 36 and 39 % lower than the urea control following the peak loss events (early season rainfall and irrigation in January 2015). However a simple estimation of the N balance suggests causes other than runoff water account for the majority of the fertiliser N not taken up by the crop.

### **Objective 3.1: Specialist support for CQ and other non-tropical regions.**

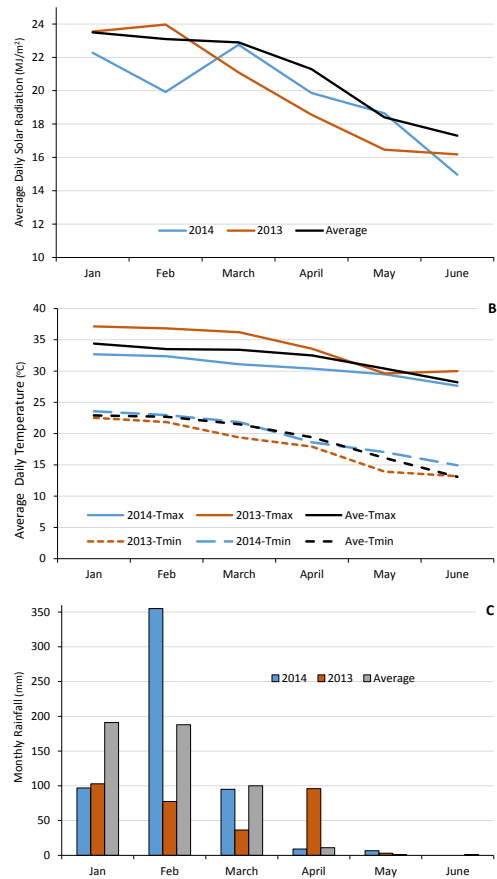
Detailed climatic review presented to industry at Emerald in April 2014. A similar analysis was done for the Theodore region and presented to industry by Paul Grundy in June 2014. Early sowing experiments established. Presentations at industry meetings and field days at least twice per year have followed. The specific results and outcomes of this work are in the reports of Paul Grundy's project.

As discussed above some assistance with experimental design of growth regulator experiments and presentations on cotton physiology were made in southern NSW and in the Namoi.

### **Objective 3.2: Specialist support for other tropical regions.**

#### ***Tonks Camp***

Figure 13 shows the 2013 season was dry (lowest 10%) with higher maximums than average so fruit retention was high and crop development rapid. Solar radiation was a little lower during flowering and boll filling (March to May). The 2014 season was wet and cloudy during February which stimulated early vegetative growth and enhanced the shedding of early squares, favourable radiation and temperatures favoured crop growth during March and April. Maximum temperatures were cooler January to April.



**Fig 13:** Growing season climate at Tonks Camp for 2013 and 2014: A) Solar Radiation; B) Temperature; C) Rainfall. Long term averages for Georgetown are shown.

Unfortunately the 2014 crop was impacted by boom contamination with 2,4-D in February. The crop was managed so the least affected areas could grow out of the damage. Twenty two harvest areas of 7.2m<sup>2</sup> were hand-picked from least damaged areas



Cotton at time of 2-4 D damage 12 February 2014 (30 DAS). Damage was severe in places.

Yields were encouraging considering these were first attempts in an isolated and untested location (Table 14). Fibre quality was excellent. Crops reached picking maturity in mid-June only 5 months (150 days from sowing) in both seasons.

**Table 14:** Yield and fibre quality. NB turn outs are an estimate of commercial values calculated as small gin turnout multiplied by 0.93.

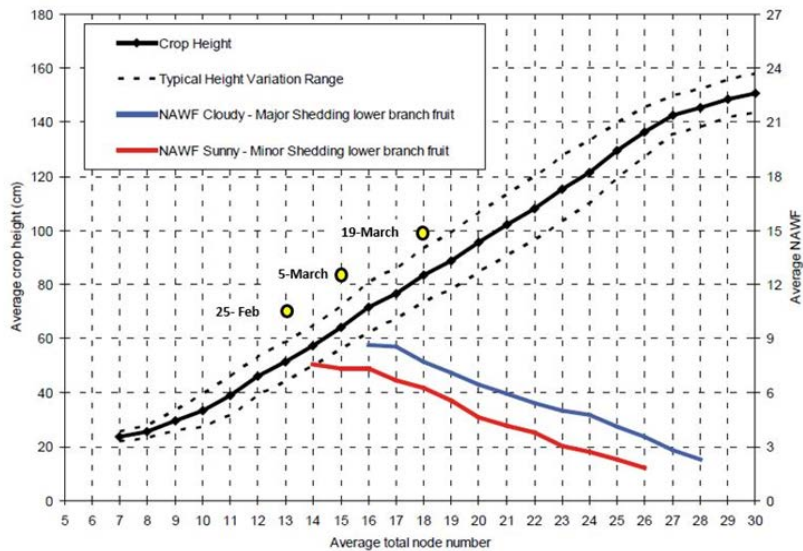
| Variety     | Yield<br>(b/ha) | Turn Out<br>(%) | Length<br>(in) | Strength<br>(g/txt) | Micronair  |
|-------------|-----------------|-----------------|----------------|---------------------|------------|
| <b>2013</b> |                 |                 |                |                     |            |
| SC71BRF     | 10.1 ±0.01      | 38.4 ±0.16      | 1.24 ±0.02     | 31.7 ±0.20          | 4.27 ±0.09 |
| SC74BRF     | 9.4 ±0.40       | 40.6 ±1.16      | 1.28 ±0.02     | 32.2 ±0.38          | 4.06 ±0.10 |
| SC24BRF     | 10.1 ±0.38      | 39.3 ±0.84      | 1.27 ±0.02     | 30.8 ±0.86          | 3.83 ±0.16 |
| <b>2014</b> |                 |                 |                |                     |            |
| SC71BRF     | 9.2 ±0.31       | 40.7 ±0.60      | 1.23 ±0.17     | 32.3 ±0.26          | 3.83 ±0.05 |
| SC74BRF     | 10.6 ±0.23      | 43.6 ±0.61      | 1.30 ±0.08     | 33.5 ±0.90          | 4.03 ±0.09 |
| SC24BRF     | 9.9 ±0.18       | 41.4 ±0.63      | 1.26 ±0.26     | 32.0 ±0.46          | 3.97 ±0.03 |

Generally NORpac-Burdekin was transferable to the Gilbert River in these seasons, particularly crop vigour monitoring for Pix®, insects and irrigation management, nitrogen rates and timing. No Pix® or insecticide was applied in 2013. One application of Pix (400 ml/ha) and two insecticide applications were required (mirids and western flower thrips) in 2014.

Managing the recovery from the 2,4-D damage in 2014 while challenging, was highly successful where damage was moderate and was an excellent test for the practices derived in the Burdekin. An example of the validation of NORpak for crop vigour monitoring in this situation is shown in Fig. 14. Crop height was excessive for the stage of crop development due to combination of cloudy wet conditions during February, a well-drained soil, and the need to grow the crop out of 2,4-D damage. Pix® treatment needed to be modest and was aided by drier conditions during March permitting irrigation to be delayed to that expansive vegetative growth could be suppressed without affecting fruit production or retention.

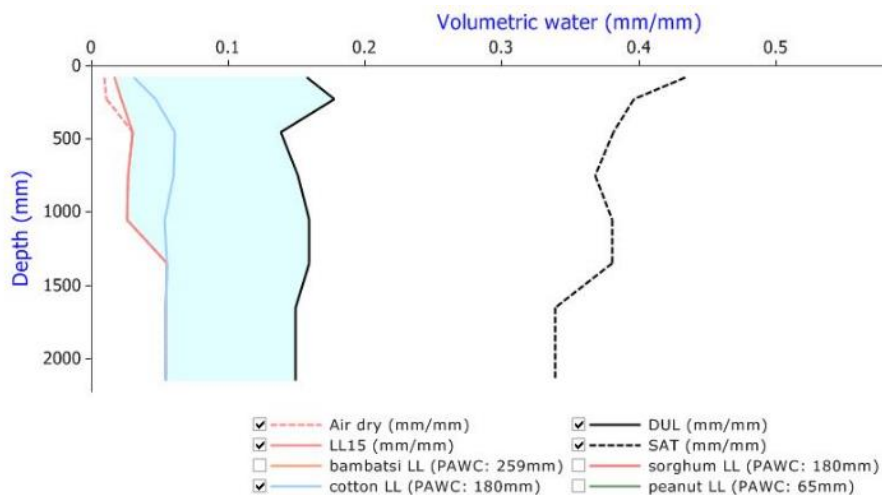


15<sup>th</sup> April 2014 (94 DAS): Boll load where 2, 4-D damage was minimal and where the crop had grown out of the damage (Grant Randall grower).



**Fig 14:** NORpak-Burdekin validation of crop vigour management 2014. Shown is the restoration of the height v node balance for Sicot71BRF during early flowering following wet humid conditions and the need to grow out following early 2,4-D damage.

The soil at the site is one of the dominant soils in the Gilbert catchment deemed suitable for agricultural development and was successfully characterised for APSIM modelling. The volumetric water properties and the crop lower limit and plant available water measured cotton are shown in Fig 15.



**Fig 15:** Volumetric moisture content by soil depth for sandy-loam, including the crop lower limit (LL) and plant available water content (PAWC) for cotton.

The key implication of the soil characterisation for modelling and cotton production in this environment is the greater than expected available soil water due the rooting depth of 2.2 m and the rapid rate of root elongation. The greater plant available water means that a larger volume rainfall can be stored in the soil during the wetter months when the crop is young saving irrigation water during the early dry season. The OZCOT model simulated a shallower (1.6m) and slower rate of root elongation hence a lower plant available soil water. Yields were under predicted due to the model falsely simulating water stress.



12-2-13 (40DAS) – roots to at least 50 cm.

Unfortunately it was not possible for the grower to reliably measure the irrigation water applied to the field in these experiments. The water deficit was replaced by irrigation but due to the need to run water to other fields simultaneously the volume applied to the field was not measured. As was the case in the Burdekin the model did not account for the more rapid pre-flowering canopy development and climate induced square shedding.



Picking June 2013



Near picking June 2014, Left to right Grant Randal, Glen and Val

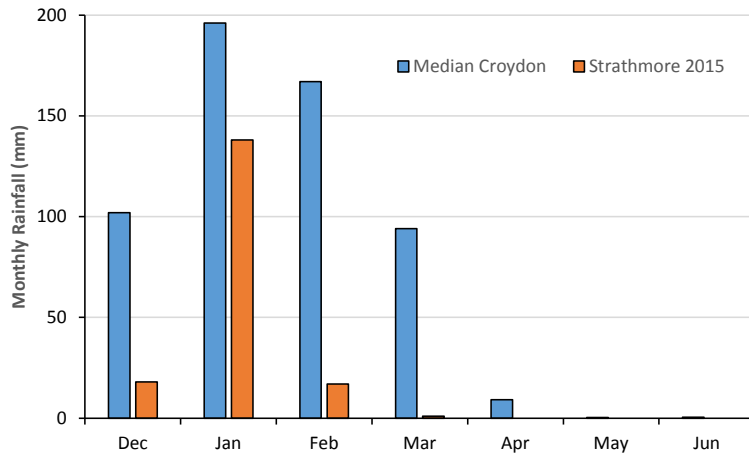
*Conclusions:*

The 2013 & 2014 cotton evaluations in the Gilbert Catchment were successful first attempts and demonstrated good yields and fibre quality were possible with many of the husbandry practices developed at the Burdekin transferable.

The need for enhancement of the OZCOT model in the prediction of root development and early leaf area development was identified. These parameters are essential to the calculation of crop water requirement and yield for potential investors and government supported resource assessment studies in green field sites in northern Australia. These model deficiencies prevented an accurate simulation of cotton potential yields and water requirements in the FGARA study (Petheram et al. 2013).

**Strathmore Station**

The driest wet season on record (Fig. 16) combined with delays in getting a permit to extract water from the river bed sand meant the irrigated crops were without water for significant periods during February and March ( Squaring to peak flowering). Most rain occurred in the first week of January prior to land preparation and planting. There was insufficient rainfall during February and March to fill the soil profile to provide a buffer while waiting for a permit to use bed sand water to irrigate. Subsidence of soil in areas where large trees were removed contributed to field variability.



**Fig 16:** Monthly rainfall 2015 vs median at Croydon, 50 km WSW.



Left 4/3/15 pumping river water; Right 25/3/15 excavating bed sand to pump water; pictured Ben Langford, Strathmore Station.



Slumping of soil where large trees were removed. Ironically these areas were the least water stressed during March and many were sufficiently large and uniform to take hand harvested yields.

A delay in getting a permit to extract bed sand water prevented crops being irrigated. Between 16/2/15 and 25/3/15 only 1 short irrigation (using surface water) was applied on 4/3/15. Consequently the crop was severely water stressed during the squaring to peak flowering period.



24/3/15: Sever drought stress due to no irrigation water or rain.



25-3-15: Left - Crop recovery 1 day after irrigation; Right – shedding of lower fruit was common.



25-3-15 – Dryland cotton!



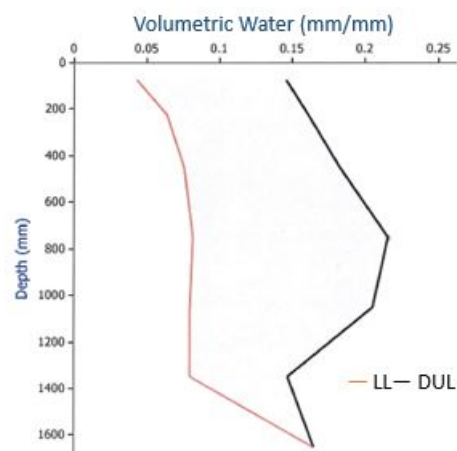
20-6-15 Maturity – yield recovery occurred via ‘top crop’ (photos Greg Maison QDAF).

Yields reflected the field variability and crop water stress (Table 15). As expected yields were highest where soil water was more available near tail drains and in tree stump hollows. Fibre quality was good considering the drought stress.

**Table 15:** Yields and quality Strathmore Station. Standard error of the means are shown.

| Variety | Yield Range (b/ha) | Turnout (%) | length (in) | Strength   | mic        |
|---------|--------------------|-------------|-------------|------------|------------|
| SC71BRF | 7.3-9.4 ±0.36      | 40.4 ±0.59  | 1.22 ±0.17  | 32.2 ±1.07 | 3.85 ±0.33 |
| SC74BRF | 6.9-8.2 ±0.35      | 43.3 ±0.76  | 1.24 ±0.20  | 34.0 ±0.80 | 3.69 ±0.11 |
| SC24BRF | 5.5-8.7 ±0.81      | 37.8 ±0.10  | 1.29 ±0.20  | 33.5 ±0.46 | 4.20 ±0.20 |

Soil characterisation commenced in 2015 (Fig. 17). The importance of rainfall during January - March when the root system is establishing to the crop water balance was highlighted. Rainfall was insufficient to drain below 1600 mm in the cropped area at that time. Hence root penetration only reached 1600mm. When irrigation started in late March the root system was fully developed and drainage would have wet the soil below the roots. Clearly further research is required to optimise irrigation efficiencies on these soils.



**Fig 17:** cotton volumetric plant available water range in 2015, where DUL = drained upper limit, LL- crop lower limit.

## Conclusions and future work:

Despite these 'pioneering' challenges useful data was collected and local staff got valuable experience. The site will be in a crop ready state next season including irrigation permits.

In 2016 monitoring of this remote site will be enhanced by a real time satellite link to field sensors and cameras. QDAF have funded a base station tower to relay data via Wi-Fi to the homestead and to the R&D via satellite as there is no mobile reception on Strathmore. Measured or monitored will be soil water (to 2.2 m in cotton) using capacitance probes, meteorological data, crop growth and pests via movable cameras and the water pump and irrigation delivery systems. In addition to data collection a key objective is to evaluate these technologies to assist isolated farms in managing high input irrigated crops.

### **Objective 4:** Building cotton production capacity in the Burdekin and NQ.

Distribution of NORpak-Burdekin has continued at a range of forums and in response to requests for information. Results were also distributed by email. Field days and research updates have been conducted every season with good attendance. Some examples follow:

A presentation and cotton field walk was conducted at Georgetown on 20 June 2013. With new irrigation licences a possibility in the future, the invitation to present came from the local community as part of effort to provide information on potential irrigated crops for the region.



June 20 2013: About 30 people travelled to Grant Randal's property 'Tonks Camp' 56 km west of Georgetown NQ to view cotton, guar bean and forage crops.

A field day at the Burdekin N nutrition site, instigated by local growers, was held on May 12 2015. Twenty nine local growers, agribusiness and banking representatives attended. Local growers Wayne Dal Santo and Lyndsay Hall spoke as well as Stephen Yeates CSIRO and Rick Jones Queensland Cotton.



Burdekin May 12 2015

### **Objective 5:** Disseminate research to industry and wider community.

In addition to annual field days for this project at the Burdekin and Emerald, listed below are the invited presentations of outputs from the research reported here.

**Invited cotton research presentations and participation at significant meetings.**

- September 2015 – Speaker plenary – Australian Cotton Research Conference
- March 2015 – Speaker - Cotton Grower of year field day Hillston, NSW.
- November 2014 Speaker and organising committee member Northern Australia Food Futures Conf, Darwin NT.
- October 2014 – interviewed as part of ABC ‘Landline’ story ‘Wrapped up’ on CQ project <http://www.abc.net.au/landline/content/2014/s4124478.htm> shown 9/11/14.
- August 2014 Speaker 17<sup>th</sup> Australian Cotton Industry Conference and Decision Makers Forum, Gold Coast, Qld,
- August 2014 Speaker Australian cotton industry nitrogen review, Goodiwindi.
- March 2014 Presentation at Agronomy Community Forum, Townsville.
- September 2013 Invited plenary speaker 9<sup>th</sup> Brazilian Cotton Congress, Brasilia,
- June 2013 Cotton presentation at Community Forum and field day, Georgetown
- April 2013 Cotton presentation at Community Forum and field day, Richmond
- April 2013 Presentation of Emerald Climate Review. CRDC research planning and review.
- August 2012 Speaker 16<sup>th</sup> Australian Cotton Industry Conference Gold Coast, Qld,
- August 2012 Invited speaker ‘Hora do Algodão’ Conference, 9-10 August 2012, Chapada Dos Guimaraes, Mato Grosso, Brazil.

## *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: Production systems package to account for climatic variability and soil type in the Burdekin.**

The outputs were:

1. Management options that increased pre-sowing N fertiliser uptake efficiency on heavy clay soils by 33 to 96% and significantly increase yield in the tropical wet season.
2. At the Burdekin and the Namoi (reference site) the impact 60% reduction in solar radiation for two weeks using shade cloth at first flower, mid flowering and cut-out was quantified. The yield reduction per day of shading late in flowering was 1.7% per day or similar to water stress for the same stage at both locations. More importantly yield recovery was possible in tropical climates following 30 % solar radiation reduction early in flowering provided there was sufficient heat and radiation during the recovery phase.
3. Finalised genotype screening of promising Bollard II lines. The suitability of a later maturing high turnout variety was confirmed.

The outcomes were:

1. Greater confidence by farmers, financiers and investors that a key production risk, low N uptake efficiency on clay soils, has a practical solution. Sufficient data was collected to update the N management section of NORpak-Burdekin.
2. Adoption of the research approach used to mitigate wet season N fertiliser loss in cotton by other industries (sugar and Rice) in tropical Australia.
3. Provided a greater capacity to select best growing areas and management practices that could minimise production risk due to cloud induced low radiation at critical times during flowering and boll filling in tropical Australia.
4. Provided information on potential suitable ideotypes that will assist cultivar selection in the tropics for Bollgard III era.

#### **Objective 2: Cotton rotations linked with grain and sugar farming systems.**

The outputs were:

1. After two cycles of sugar cane (plant and 1<sup>st</sup> ratoon) the later planting of sugar cane after cotton in a short fallow (6 to 9 month) did not reduce total sugar yield. There were significant sugar yield increases following a 17 month break of cotton and grain crops.
2. Data that showed delayed oxidation nitrogen fertilisers ENTEC and polymer coated urea reduced N concentrations in runoff water by 36 and 39 % compared to the urea control following peak N loss events after early season rainfall and irrigation.

The outcomes were:

1. Farmer and sugar miller concerns about lower cane yields by adopting cotton have eased.
2. Greater confidence for regulators and the wider community that cotton farming will not contaminate the environment.

### **Objective 3: Specialist cotton support for other regions in tropical Australia and CQ.**

The outputs were:

1. In the central highlands of Queensland this project has contributed to research that has identified then demonstrated the climatic risk benefits of 4 to 6 week earlier sowing date for cotton. Earlier sowing stabilised yield by avoiding the climatic risks associated with summer rainfall and heat stress common during boll growth and maturity at the traditional October sowing time.
2. Significant technical contributions on cotton production to the Flinders Gilbert Agricultural Resource Assessment (FGARA) report that identified cotton as a potential irrigated crop for the catchments.
3. Progress in enhancing modelling tools to better assess climatic risks to potential investments at new tropical production sites (e.g. operational, yield, irrigation water supply, fibre quality). For example in the Gilbert Catchment, good progress with made with the validation of NORpak-Burdekin for Pix management and crop nutrition. For OZCOT-APSIM soil characterisation commenced, enhancement of water logging simulation following large rainfall events on clay soils, and rooting depth and leaf area prediction for loam textured soils.

The outcomes were:

1. Cotton growers in central Queensland having increased understanding of climatic risks and opportunities associated with different sowing dates and will adopt earlier planting as part of their production system.
2. An outcome of FGARA was support from the Queensland Government in 2015 for the release of irrigation water from both catchments for crop / forage production. This resulted in applications for land clearing (commenced on one property) and irrigation water for cotton on properties in each catchment (Stanbroke, Strathmore).
3. Involvement in the new Northern Australian Water Recourse Assessment that will quantify water, land and agricultural productivity in three catchment areas the Mitchell (N Qld), Fitzroy (Kimberley WA) and Darwin region (NT). The former two catchments were identified as having potential for cotton but required further analysis by the former Cotton CRC (see Yeates 2001).

### **Objective 4: Building the capacity to produce cotton in the Burdekin.**

The outputs were:

1. Farmers and consultants gained ongoing exposure to wet season cotton production and the application of NORpak-Burdekin via the R&D on N management for clay soils and radiation reduction which was conducted on their farms with their participation.

The outcomes were:

1. A small group of nine farmers and consultants now have sufficient knowledge and experience to grow cotton and assist new growers in the Burdekin. Without a gin production will be opportunistic in response to cotton prices in the short to medium term.

### **Objective 5: Disseminate research to industry and the wider scientific community.**

The outputs were:

1. Many opportunities to present research outputs throughout Australia and internationally (all invited) see results for Objective 5.

The outcomes were:

1. Confidence to further investigate cotton at large green-field sites in tropical Australia by investors and government agencies. Examples include: A new research partnership with potential cotton farming investors at Strathmore Station; Provision of climatic analysis and research data to Stanbroke Pty Ltd for a \$200m investment proposal to develop 17000 ha for

irrigated cotton in the lower Finders River; Enquires from Walin in the west Kimberley, KAI in the Ord, Fly Fox station in Roper River.

2. Linkages with cotton research and industry in Brazil that have provided direction for research in tropical Australia.

**Please describe any:-**

- a) **technical advances achieved (e.g. commercially significant developments, patents applied for or granted licenses, etc.);**

The finding that two 'under development' delayed N oxidisation fertilisers can provide a practical solution to leaching of  $\text{NO}_3^-$  and poor crop uptake of pre-sowing N fertiliser will be developed further by commercial fertiliser companies for use in cotton and other tropical crops.

The FGARA studies have led to the Qld Government announcing the release of significant volumes of irrigation water in these catchments in August 2015. Investment proposals for irrigated cotton by Stanbroke in the lower Flinders catchment near Normanton and on Strathmore station in the Gilbert Catchment have followed. The future CRDC project will provide technical support to these and other future cotton developments in tropical Australia.

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

None

- c) **required changes to the Intellectual Property register.**

None

### **Conclusion**

1. **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?**

- The major impact for the Australian cotton industry is there are now investment plans for large scale green-field developments in tropical Australia. The knowledge generated by this project and its predecessors combined with collaboration with the resource assessment studies in the Flinders and Gilbert catchments (FGARA) has made a significant contribution to government support for release of irrigation water and the subsequent investor interest in both catchments. Due to a changed political landscape there is now interest by investors in irrigated cotton in the Kimberley and NT and the proponents have requested technical information developed by this project and its predecessors.
- This project has contributed knowledge and climate analysis techniques generated at Burdekin on the impact of cloud and rainfall at different cotton growth stages on cotton to research that has led to a change to a 4 to 6 week earlier sowing date for cotton in the central highlands of Queensland. Earlier sowing stabilised yield by avoiding the climatic risks associated with summer rainfall and heat stress common during boll growth and maturity at the traditional October sowing time.
- The objective of completing the production package for the Burdekin was achieved. N management experiments showed delayed release fertilisers applied pre planting increased N fertiliser uptake efficiency 33 to 96% compared with urea on clay soils, increase yield and avoid the need for split application which is very risky due to poor trafficability in the wet season. Knowledge of the mechanisms for crop recovery from low solar radiation due to cloud provided insight into management practices that could minimise this production risk in

tropical Australia. These research outcomes are to be incorporated into the production package NORpak Burdekin.

- The delayed oxidisation N fertilisers provide evidence for regulators and the wider community that adoption of cotton farming will not increase environmental contamination. These fertilisers reduced N concentrations in runoff water by 36 and 39 % compared to the urea control following peak N loss events after early season rainfall and irrigation
- Good progress with extrapolation NORpak-Burdekin to the Gilbert catchment with validation of the package for sowing date Pix management and crop nutrition. Similar validation work to extrapolate the package beyond the Burdekin will continue in the new project.
- Negativity toward cotton in the Burdekin from sugar millers and growers has eased due to research in collaboration with Sugar Research Australia showing rotation with cotton will not reduce sugar yield.

### *Extension Opportunities*

#### **2. Detail a plan for the activities or other steps that may be taken:**

##### **(a) to further develop or to exploit the project technology.**

An update of NORpak-Burdekin to include new N management for heavy clays and recovery from cloud findings will be completed as soon as possible.

Presentation of key results from radiation reduction experiments at the World Cotton Conference in May 2016.

Continue the development of tools to assist investors in the selection and development of green-field cotton production sites in tropical Australia. These tools relate to identifying the best production system based on climatic risk, water requirement and availability, operational issues and infrastructure options.

Publication of key science findings in appropriate Journals.

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

As above

##### **(c) for future research.**

The new project more focused on filling knowledge gaps for potential investors (including Governments) and ensuring past research is made available.

#### **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)**

In addition to the publications listed below an update of NORpak-Burdekin will be produced and there will be refereed publication of the N management and solar radiation reduction experiments.

Petheram C., McKellar L., Holz L., Poulton P., Podger S., Yeates S., (2016). Evaluation of the economic feasibility of water harvesting for irrigation in a large semi-arid tropical catchment in northern Australia. *Agricultural Systems* 142, 84-89.

Yeates S.J., Strickland G.R, Grundy P.R., (2013) Can sustainable production systems be developed for

tropical northern Australia? *Crop & Pasture Science* 64, 1127-1140.

Yeates S, Grundy P, (2012). The essentials for successful cotton in the Burdekin' The Australian Cottongrower V33, No. 7 p49-51.

Tony Webster, Perry Poulton, **Stephen Yeates**, John Hornbuckle, Lisa Brennan McKellar, Brett Cocks, Johanna Gentle, Di Mayberry, Dean Jones, and Ainsleigh Wixon (2013) APSIM - Production Potential of Region, In: Agricultural productivity in the Flinders and Gilbert catchments, A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy

Justin Hughes, Perry Poulton, Cuan Petheram, Linda Holz, **Stephen Yeates**, Shaun Kim, Scott Podger, Michael Kehoe, Daniel Aramini, Peter Wilson, David McJannet, Arthur Read, David Rassam, Nathan Waltham, Damien Burrows, Lisa Brennan McKellar, Geoff Podger, John Hornbuckle, Seonaid Philip, Andrew Higgins, Marcus Barber, and Becky Schmidt (2013). Chapter 8: Green Hills dam and irrigated three-crop rotation. In: Petheram C, Watson I and Stone P (eds) Agricultural resource assessment for the Gilbert catchment. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment.

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

Not yet

## ***Part 4 – Final Report Executive Summary***

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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 major impact for the Australian cotton industry is there are now investment plans for large scale green-field developments in tropical Australia. The knowledge generated by this project and its predecessors combined with collaboration with the resource assessment studies in the Flinders and Gilbert catchments (FGARA) has made a significant contribution to government support for release of irrigation water and the subsequent investor commitments in both catchments. These investors are being supported technically by this projects successor. Due to a changed political landscape there is now interest by investors in irrigated cotton in the Kimberley and NT and technical information has been provided by this project.

The completion of research to fill key knowledge gaps in the wet season production package at the Burdekin (NORpak-Burdekin) underpinned contributions to FGARA and studies aimed at stabilising cotton production in the central highlands of Queensland. In the later studies this project has contributed knowledge and climate analysis techniques generated at the Burdekin on the impact of cloud and rainfall at different cotton growth stages on cotton. The outcome being a 4 to 6 week earlier sowing date for cotton in central Queensland that stabilised yield by avoiding unfavourable climatic conditions common with the traditional sowing date.

Replicated field experiments conducted during this project where located in farmers' fields and focused on knowledge gaps identified in the previous projects these where; 1) overcoming poor uptake of pre-sowing N fertiliser on clay soils during the wet season; 2) quantifying the impact of and recovery from low radiation during flowering and boll filling; 3) Validating NORpak-Burdekin and the OZCOT-APSIM simulation in new production areas (Gilbert River).

N management experiments showed delayed release fertilisers applied pre planting increased N fertiliser uptake efficiency 33 to 96% compared with urea on clay soils, increase yield and avoiding the need for split application which is very risky due to poor trafficability in the wet season. The new N fertiliser practices provide evidence for regulators and the wider community that adoption of cotton farming will not increase environmental contamination as N concentrations in runoff water were reduced by 36 and 39 % compared to the urea control following peak N loss events after early season rainfall and irrigation.

Knowledge of the mechanisms for crop recovery from low solar radiation due to cloud provided insight into management practices that could minimise this production risk in tropical Australia. At the Gilbert Catchment the superiority of the climate over the Burdekin was demonstrated and good progress with made with the validation of NORpak-Burdekin for Pix management and crop nutrition. For the OZCOT-APSIM model soil characterisation commenced, enhancement of water logging simulation following large rainfall events on clay soils, and rooting depth and leaf area prediction for loam textured soils.

Negativity toward cotton in the Burdekin from sugar millers and growers has eased due to research in collaboration with Sugar Research Australia showing rotation with cotton will not reduce sugar yield.

### **Acknowledgements:**

The interest and commitment to this work by the farmer collaborators (Jeff Marson, Grant Randal, Wayne Dal Santo, Ben Langford, Scott Harris and Peter Andersen) and other collaborators (Barry Salter SRA, Greg Mason, Gareth Jones and Mike Hanks QDAF, Rob Dwyer INCITEC) was exceptional and greatly appreciated.

Special thanks to:

The technical staff (mostly casuals) that have worked on this project over the three years in hot humid weather with many snakes and other reptiles: Cecelia Bonny, Tony Webster, Tracy King, Justin King and Gerry MacManus.

Barry Braden (AGnVet), John Marshal (CSD), Ric Jones (QC),

The CSIRO breeding team Greg Constable, Warwick Stiller and Kellie Cooper

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