



# FINAL REPORT 2006

*Due by 30th September 2006.*

## *Part 1 - Summary Details*

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

**CRDC Project Number:**  
**OR Cotton CRC Project Number:**           **1.02.10**

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**Project Title:** Irrigation scheduling for drip irrigated  
Bollgard II<sup>®</sup> cotton in the west Kimberley.

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**Project Commencement Date:** May 2005    **Project Completion Date:** Dec 2005

**CRDC Program:**  
**OR CRC Program:**                           **The Farm**

## *Part 2 – Contact Details*

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**Administrator:** Ms Annette Long  
**Organisation:** WA Department of Agriculture & Food  
**Postal Address:** Locked Bag 4, Bentley Delivery Centre, WA 6983  
**Ph:** (08) 9368 3414    **Fax:** (08) 9368 2186    **E-mail:** along@agric.wa.gov.au

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**Principal Researcher:** Ms Noeleen Edwards  
**Organisation:** WA Department of Agriculture & Food  
**Postal Address:** PO Box 5502, Broome, WA 6725  
**Ph:** (08) 9194 1422    **Fax:** (08) 9192 2946    **E-mail:** nedwards@agric.wa.gov.au

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**Supervisor:** Geoff Strickland, Cotton Project Manager  
**Organisation:** WA Department of Agriculture & Food  
**Postal Address:** Locked Bag 4, Bentley Delivery Centre, WA 6983  
**Ph:** (08) 9368 3756    **Fax:** (08) 9368 3808    **E-mail:** gstrickland@agric.wa.gov.au

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**Signature of Research Provider Representative:** - \_\_\_\_\_

### **Background**

Winter grown cotton in the west Kimberley (near Broome) has produced exceptionally high yields (>10 bales/ha) and premium quality fibre. Crops are irrigated daily, according to a formula based on “crop factors” and daily evaporation. However, the crop factors are estimates derived from other areas and may not represent efficient water use. Generally, crops near Broome have required 9 ML/ha applied water compared to about 6 ML/ha for similarly grown crops on drip irrigation at Katherine (NT).

There is a clear need to accurately define the irrigation requirements of Bollgard II<sup>®</sup> cotton grown in a winter production system in the west Kimberley.

### **Objectives**

To compare three rates of irrigation based on evapotranspiration / crop factor scheduling, at three phases of Bollgard II<sup>®</sup> crop growth.

### **Methods**

#### **Treatments:**

Three rates of irrigation were assessed at three crop development phases. The irrigation treatments were:

1. \*Standard irrigation
2. Standard irrigation minus 30%
3. Standard irrigation plus 30%

(\* Standard irrigation replaces water lost daily according to the formula crop factor X evapotranspiration. Crop factors vary with accumulated “day degrees” (DD), which are calculated daily by using the formula:

$$DD = \frac{(T_{max} - 12) + (T_{min} - 12)}{2}$$

DD starts accumulating daily from crop emergence.

Crop factors (CF) and accumulated DD are: CF is 0.35 from DD=0 to DD=500; increasing gradually from CF 0.35 to CF 1.15 from DD=500 to DD=800; maintained at CF 1.15 from DD=800 to DD=1400; reduced gradually from CF 1.15 to 0.35 from DD=1400 to DD=2100).

The three phases of crop growth were defined as:

1. Emergence to first flower
2. First flower to 4 nodes above white flower ( 4 NAWF)
3. 4 NAWF to last irrigation

#### **Design and layout:**

There were a total of 27 treatments possible from the combinations of three irrigation rates and three growth stages described above. The matrix of the 27 treatment combinations is shown in Table 1.

A randomised complete block experiment with four replications was used to evaluate the treatment combinations. The layout of the experiment in relation to other activities in the paddock is shown in Figure 1.

**Table 1.** Summary of the irrigation treatments.

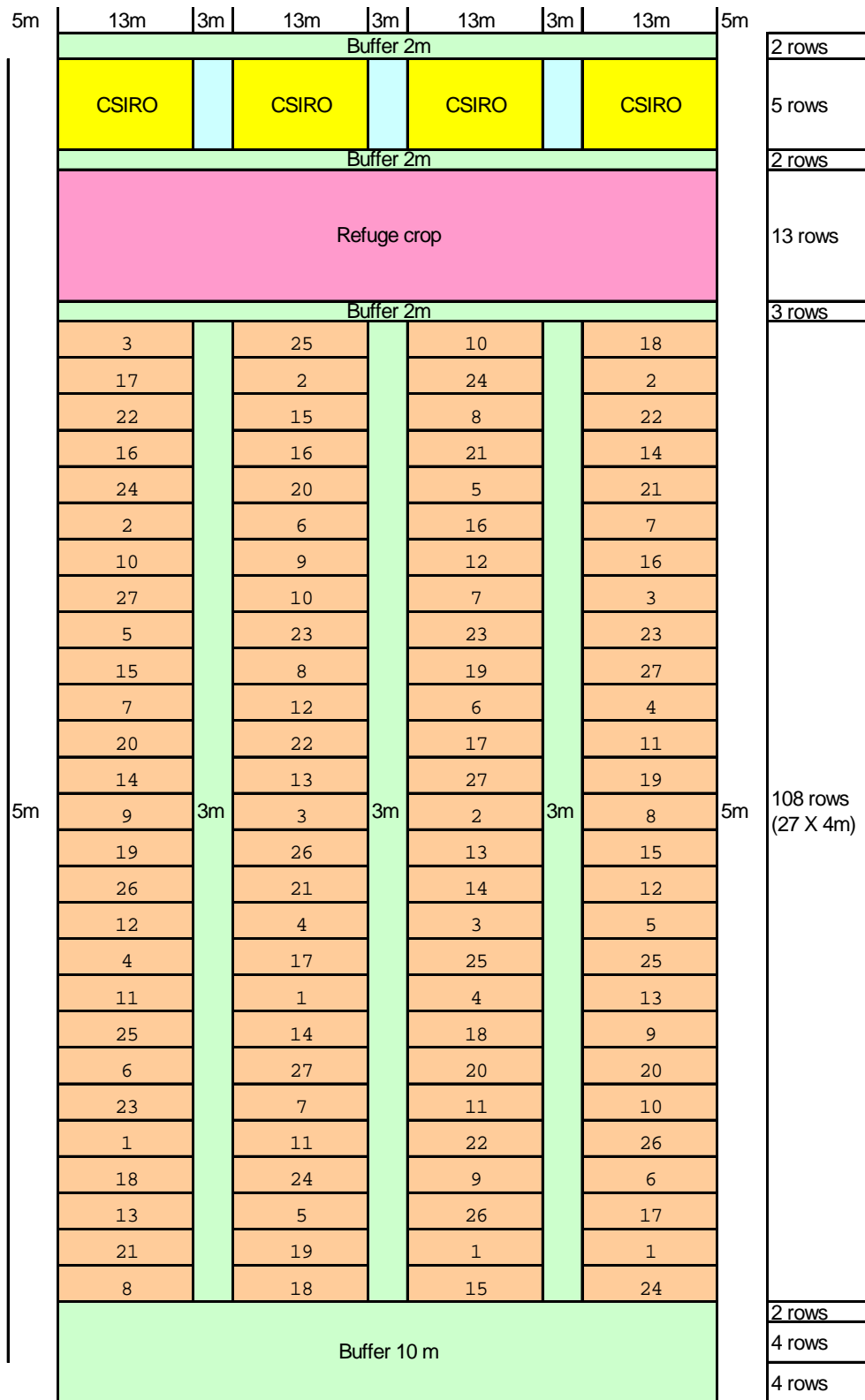
Treatment numbers for each replication			
R1	R2	R3	R4
3	25	10	18
17	2	24	2
22	15	8	22
16	16	21	14
24	20	5	21
2	6	16	7
10	9	12	16
27	10	7	3
5	23	23	23
15	8	19	27
7	12	6	4
20	22	17	11
14	13	27	19
9	3	2	8
19	26	13	15
26	21	14	12
12	4	3	5
4	17	25	25
11	1	4	13
25	14	18	9
6	27	20	20
23	7	11	10
1	11	22	26
18	24	9	6
13	5	26	17
21	19	1	1
8	18	15	24

Stage1	Stage2	Stage3	Treat No.
1	1	1	1
2	1	1	2
3	1	1	3
1	2	1	4
2	2	1	5
3	2	1	6
1	3	1	7
2	3	1	8
3	3	1	9
1	1	2	10
2	1	2	11
3	1	2	12
1	2	2	13
2	2	2	14
3	2	2	15
1	3	2	16
2	3	2	17
3	3	2	18
1	1	3	19
2	1	3	20
3	1	3	21
1	2	3	22
2	2	3	23
3	2	3	24
1	3	3	25
2	3	3	26
3	3	3	27

Treatment 3 = 30% less irrigation than standard

Treatment 2 = Standard irrigation (see previous page for definition)

Treatment 1 = 30% higher irrigation than standard irrigation



**Figure 1.** Layout of cotton research block at Broome, 2005. Irrigation treatment numbers are shown, as described in Table 1.

**Irrigation system:**

T-Systems Australia supplied the drip tape (TSX 510-20-380), layflat hose (50 mm) and miscellaneous fittings. Because the irrigation rate changed for most plots as plant growth stages changed, three layflat supply lines were required for each replication so that the drip tape could be reconnected as required. The layflat supply lines were colour coded to avoid confusion and the trial was hand planted (Figure 2).



**Figure 2.** Planting (Sicot 71BR) the irrigation trial at Broome, 2005.

Irrigation water was sourced from a bore on the property, approximately 20 m from the trial site. An Aquamaster™ flowmeter, which uses electromagnetic technology for highly accurate flow measurement, was installed and connected to a Toro™ irrigation controller so that each of the irrigation zones could be irrigated independently and automatically, after the daily schedule was inputted in the controller.

**Daily irrigation scheduling:**

The trial needed daily irrigation due to the very low water holding capacity of the sandy soil in the region. This in turn necessitated the daily calculation of the irrigation requirement for each treatment and was facilitated by a spreadsheet (see Table 2). An automatic weather station (Vaisala WXT510) was located at the trial site so that the collaborator had ready access to the daily weather data. Weather data could be either read directly from the station, accessed by a dialup modem or viewed on a website managed by Hydrodata. Each day the collaborator typed in the temperatures and Et from the previous day and the spreadsheet calculated the irrigation requirement for the high, normal and low treatments. Crop factor was also automatically calculated by a formula based on accumulated day degrees.

The collaborator programmed the irrigation controller and the daily irrigation then ran automatically until the appropriate volumes of water had been applied to each treatment.

**Table 2.** An extract from the spreadsheet used to calculate the daily irrigation requirement for each treatment.

Date	Temperature		Day-Degs	Sum Day-degs.	Et (mm)	Crop factor	Et X CF (mm)	Litres needed	Litres needed	Litres needed
	Max.	Min.								
10-May	34.3	19.1	14.70	14.70	6.7	0.35	2.35	4,280	3,292	2,305
11-May	34.7	20.7	15.65	30.35	6.5	0.35	2.28	4,152	3,194	2,236
12-May	32.2	21.3	14.73	45.08	6.3	0.35	2.21	4,025	3,096	2,167
13-May	32.4	20.3	14.30	59.38	5.7	0.35	2.00	3,641	2,801	1,961
14-May	32.1	17.5	12.75	72.13	6.8	0.35	2.38	4,344	3,342	2,339

**Crop management:**

In addition to daily irrigation, the fertigation schedule detailed in Table 3 was utilised. The schedule was based on previous research at Katherine (NT) and Shamrock Station, south of Broome.

**Table 3.** Schedule of fertiliser use at Broome.

DAS	Date	Urea	Ammonium sulphate	Potassium chloride	Phosphoric acid	Zinc sulphate	Pollyfeed	Calcium nitrate
-3	7 May						50	50
0	10 May					12.5	50	50
7	17 May		20		20		50	50
14	24 May	30		25		12.5		
18	28 May		40		20			
21	31 May		40			12.5		
28	7 Jun	20		50	25		50	
32	25 Jun		40			12.5		
35	28 Jun	20		50	30			
39	2 Jul		40					
42	5 Jul	40		50	30			
46	9 Jul	40		50				
49	12 Jul	40		50	30			
56	19 Jul	40		50				
63	26 Jul	40		75	30			
70	2 Aug	40		75				
78	10 Aug	40		50	30		25	
85	17 Aug	40		50	30	4 L	25	
96	28 Aug			50				
103	4 Sep			50				
TOT.		390	180	675	245	50	250	150

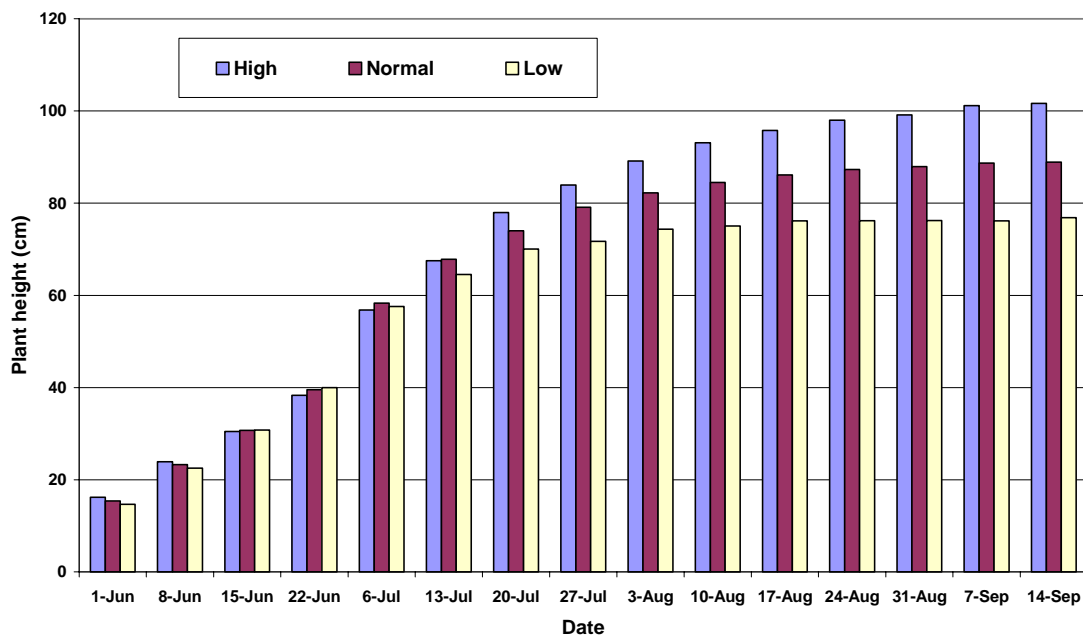
NB: Fertiliser in red is to compensate for possible losses following 150 mm of rain on 19 June.

The variety Sicot 71BR was used and weed management consisted of one Roundup™ application post emergence and no insecticide applications or growth regulants were required. The trial was hand picked in November.

## Results

Results from the trial require careful interpretation due to irrigation supply malfunctions that started at the critical full boll load stage of the season. Very serious problems with the T-Systems irrigation pipe and fittings plagued the trial and have compromised the results. In particular, the black layflat supply lines split randomly during the second half of the season. The complex trial design meant that almost 2 km of layflat was used and leak detection and repair was challenging. T-Systems eventually replaced all the layflat with pipe from a different manufacturer but serious under-watering had already damaged the plants. The second fitting failure was the “drain valves”. Monitoring of water applied to the treatments revealed that >30% of the irrigation water applied was “leaking” from the drain valves. The valves were removed and discarded but plant damage had already occurred. Remedial actions were taken when malfunctioning equipment was discovered but down-time whilst obtaining new supplies and undertaking repairs compromised plant growth and, ultimately, the trial results.

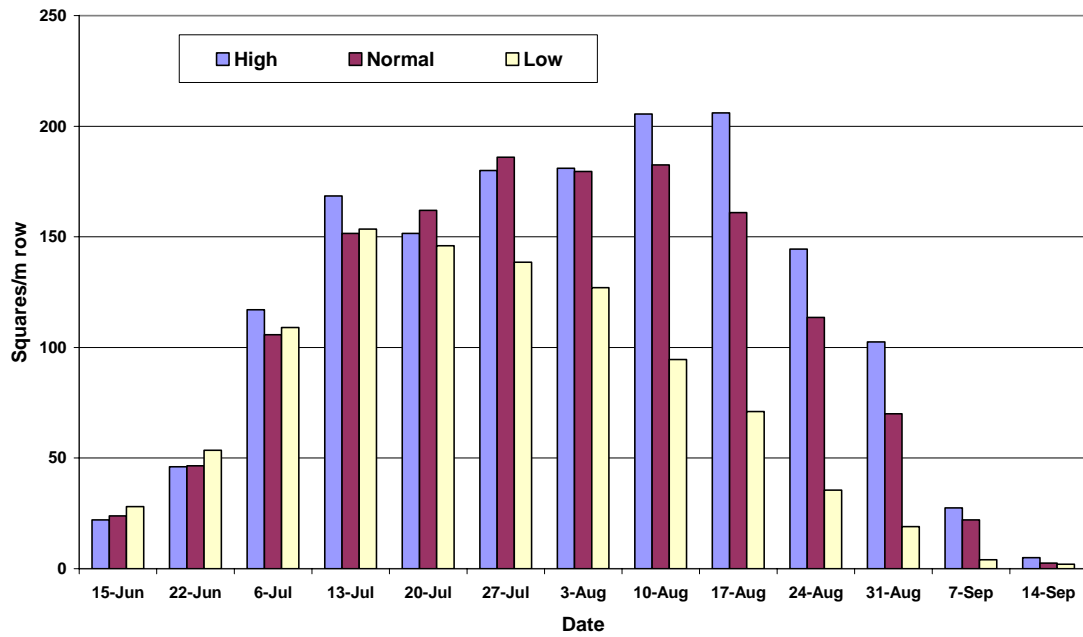
Plant growth parameters including plant height, node, square, flower and boll development were monitored for each of the irrigation treatments throughout the season. To measure the main effects of irrigation level, Figures 3-7 show the results from the continuously “high”, “normal” and “low” treatments, rather than combinations of irrigation rates and plant growth phases. These more complex interactions are shown later in relation to yield.



**Figure 3.** The effect of three irrigation treatments on plant height.

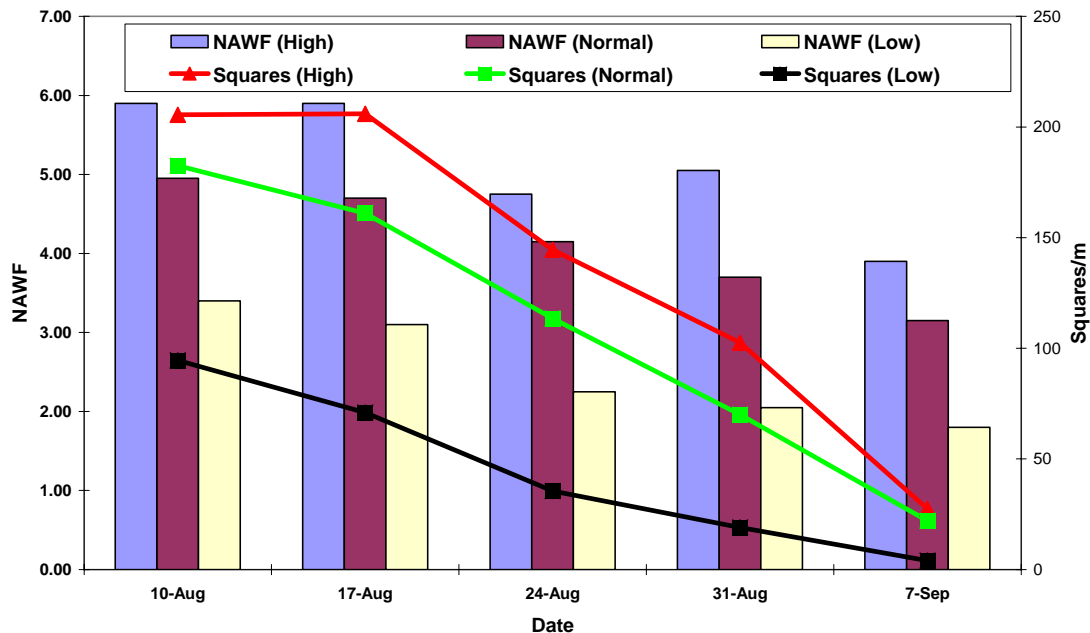
Plant height followed expected trends with the wettest treatment attaining a height of 101 cm, followed by 88.9 cm and 76.8 cm respectively for the drier treatments. Early stages of growth appeared to be little influenced by the volume of irrigation water applied but differences appeared later, probably as stored moisture was depleted and the plants became increasingly dependent on irrigation. The treatment receiving least water effectively stopped growing higher about 3 August, whilst the same effect occurred on 17 August and 14 September for the wetter treatments respectively (Figure 3).

Figure 4 shows that square production was also strongly influenced by irrigation both temporally and numerically. In the low irrigation treatment, square production peaked at about 150 squares/m on 13 July, normal irrigation two weeks later with 186 squares/m and the high treatment maintained a long peak of over 200 squares/m from 10 August.

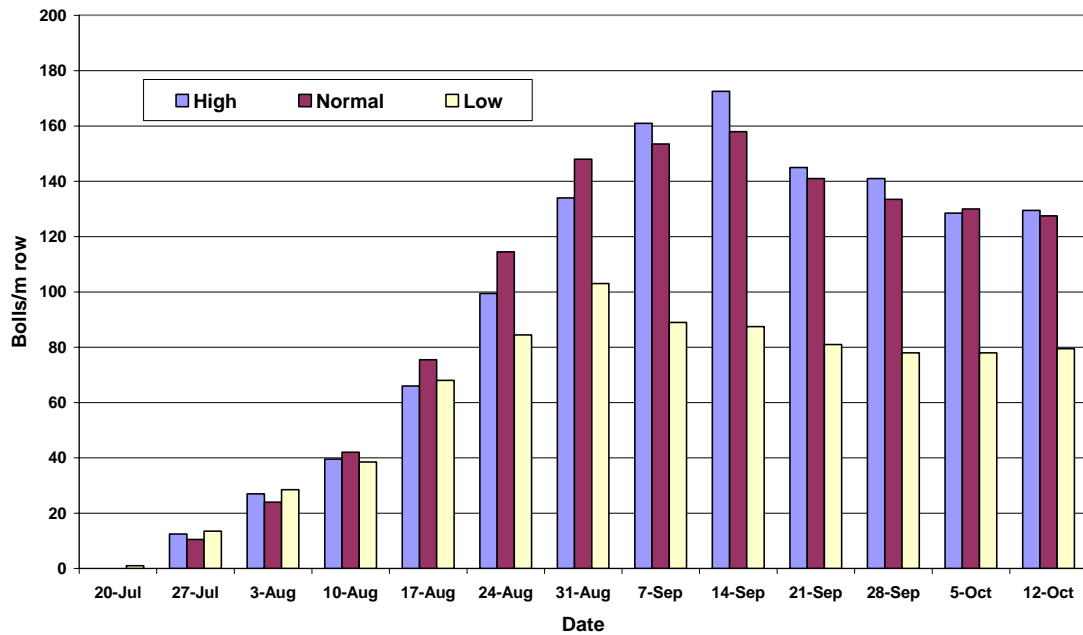


**Figure 4.** The effect of three irrigation treatments on square production.

Not surprisingly, NAWF followed a similar pattern as square development with the wettest treatment maintaining a higher NAWF value and for longer than the drier treatments shown in Figure 5.

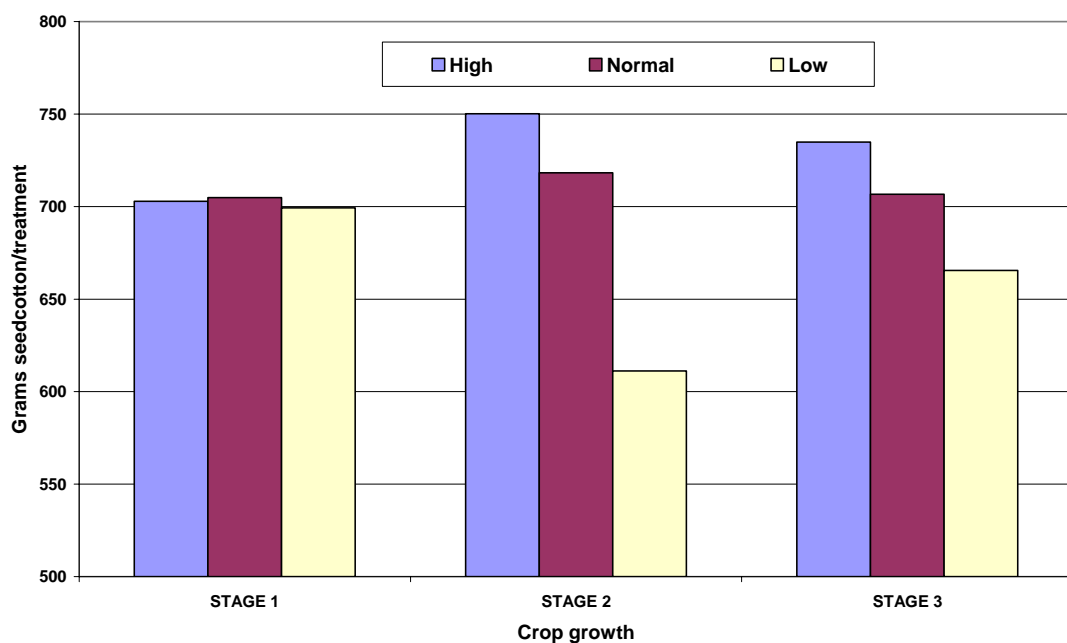


**Figure 5.** The effect of three irrigation treatments on square production decline and changes to nodes above white flower (NAWF).



**Figure 6.** The effect of three irrigation treatments on boll production.

The boll accumulation for each of the main irrigation treatments is shown in Figure 6. Boll accumulation was interrupted by the irrigation equipment failures mentioned earlier. The low water treatment was the most severely impacted and peaked at slightly more than 100 bolls/m before declining to a final 80 bolls/m. However, even the wettest treatment also suffered major boll losses. Boll load peaked at 172 bolls/m, which was about 50 bolls/m less than expected from previous seasons. Boll load declined further to 129 bolls/m which is also an excessive level of shedding relative to previous seasons.



**Figure 7.** The effect of three irrigation treatments on boll production in relation to crop growth stage.

The interaction between crop growth stage and the level of irrigation on final crop yield is shown in Figure 7. The figure shows that Stage 1 ( emergence to first flower) was insensitive to the volume of irrigation water applied. However, 150 mm of rain fell in a single event during this growth phase and therefore stored soil moisture resulting from the unexpected rainfall may have masked the impact of the irrigation treatments during that growth phase.

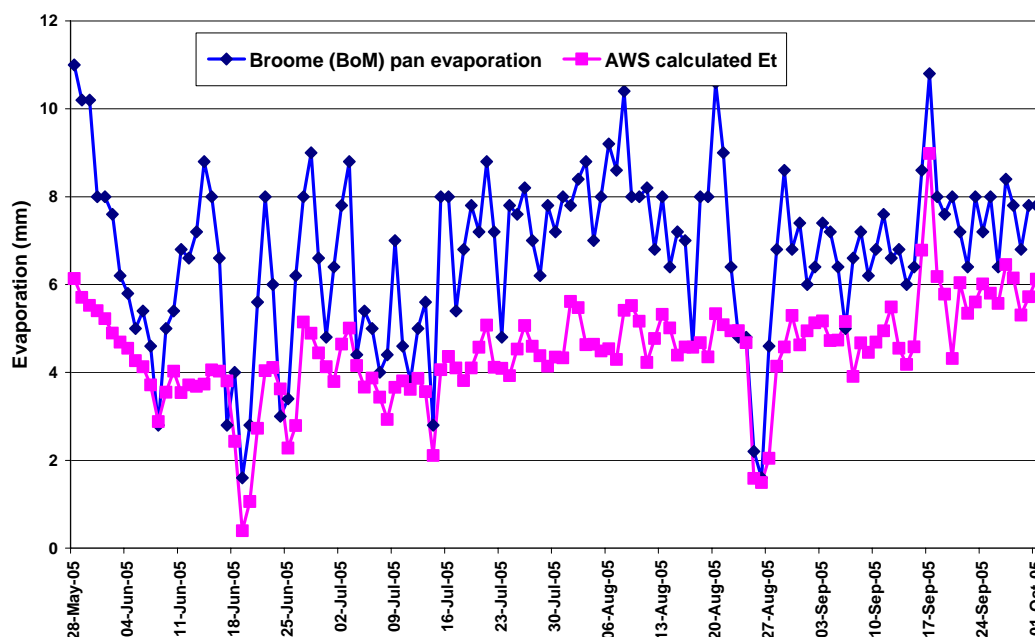
Growth stages 2 & 3 responded similarly with a positive relationship between irrigation water applied and yield.

The trials were hand picked over several days and completed in early November. Table 4 summarises the yield data for the 27 treatment combinations assessed in the trial. The growth Stage 1 data are consistent with the results in Figure 7, and indicate that the level of early irrigation had little influence on final yield. However, low irrigation in later stages of crop growth was highly deleterious to yield. The wettest irrigation treatment in Stage 2 (first flower to 4 NAWF) was important in achieving high yield. In fact the top 16 yields had either high or normal irrigation levels in Stage 2. Conversely, nine of the lowest eleven yields coincided with low irrigation in Stage 2. Stage 3 (4 NAWF to picking) was less strongly influenced by irrigation level. However, general irrigation supply failures may have masked the importance of this growth phase.

**Table 4.** Yield and irrigation level in each growth stage.

<b>Yield (grams/plot)</b>	<b>Rank</b>	<b>Stage 1</b>	<b>Stage 2</b>	<b>Stage 3</b>
937.61	1	LOW	NORMAL	HIGH
861.63	2	LOW	NORMAL	NORMAL
842.15	3	HIGH	HIGH	HIGH
803.75	4	NORMAL	NORMAL	HIGH
789.37	5	NORMAL	HIGH	LOW
767.21	6	NORMAL	HIGH	NORMAL
753.83	7	HIGH	HIGH	NORMAL
749.89	8	LOW	HIGH	HIGH
748.55	9	HIGH	HIGH	LOW
733.07	10	NORMAL	HIGH	HIGH
725.64	11	HIGH	HIGH	NORMAL
716.34	12	NORMAL	NORMAL	LOW
701.12	13	LOW	HIGH	NORMAL
699.34	14	HIGH	NORMAL	HIGH
698.45	15	LOW	NORMAL	LOW
691.22	16	LOW	HIGH	LOW
687.00	17	HIGH	LOW	HIGH
663.63	18	HIGH	LOW	NORMAL
662.44	19	NORMAL	NORMAL	NORMAL
661.58	20	HIGH	NORMAL	LOW
637.22	21	NORMAL	LOW	LOW
636.61	22	NORMAL	LOW	HIGH
626.79	23	LOW	LOW	NORMAL
597.98	24	NORMAL	LOW	NORMAL
543.48	25	HIGH	LOW	LOW
524.23	26	LOW	LOW	HIGH
503.29	27	LOW	LOW	LOW

In previous seasons, irrigation scheduling was based on Class A pan evaporation data from the Bureau of Meteorology Broome facility, which is approximately 30 km from the trial site. However, the purchase and location of an automatic weather station (AWS) at the trial site enabled local evapotranspiration (Et) data to form the basis of irrigation scheduling, as described in the methods section of this report. Et and pan evaporation are generally considered to approximate each other but the data shown in Figure 8 illustrates a wide discrepancy between the two measurements. Although the same trends are displayed, the pan evaporation data is consistently much higher than calculated Et.



**Figure 8.** The relationship between Class A pan evaporation data from the Bureau of Meteorology (Broome) and locally calculated evapotranspiration (Et).

The ramification of using calculated Et instead of pan evaporation, in terms of total irrigation water applied, is summarised in Table 5. Interestingly, the Et used this season resulted in only 67% of the water that would have been used if pan evaporation was the basis for scheduling. The table also summarises the targeted irrigation volumes and estimates of actual water applied for the three major treatments, “high,” “normal” and “low”. As discussed, equipment failures led to the droughting of all treatments and this is reflected in the very poor yields attained. However, even if equipment failure had not interfered, the “normal” irrigation treatment using calculated Et would still have been low and probably compromised yield. Differences in plant growth between the irrigation treatments can be seen clearly in Figure 9.

**Table 5.** Total irrigation water planned and actual applied compared to irrigation required if pan evaporation was used to schedule irrigations.

TREATMENT	HIGH Et + 30%	NORMAL Et	LOW Et – 30%	PAN EVAPORATION
Target	7.53 ML/ha	5.79 ML/ha	4.05 ML/ha	8.59 ML/ha
Actual (est.)	5.65 ML/ha	4.34 ML/ha	3.04 ML/ha	Not used
Yield (bales/ha)	4.95	3.89	2.96	Not used

NB: Et was calculated by a Vaisala Weather Transmitter WXT510.



A) High irrigation plot



B) Normal irrigation plot

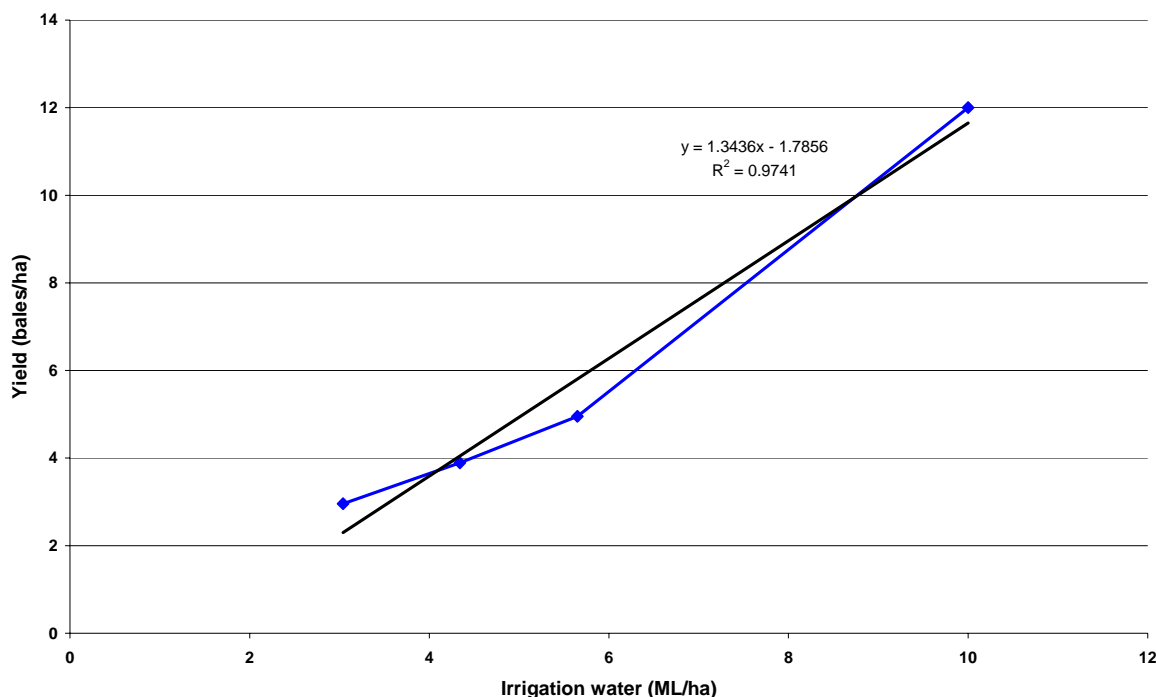


C) Low irrigation plot

**Figure 9.** The impact of the main irrigation treatments is shown in A) “high” irrigation; B) “normal” irrigation; and C) “low” irrigation, all from replication four.

## Outcomes

In previous years in the Broome area, irrigation was scheduled according to pan evaporation data obtained from the Bureau of Meteorology (Broome) and yields of around 12 bales/ha were achieved. However, to obtain these excellent yields, 9-10 ML/ha of irrigation water was applied and this was considered to be high water use compared to Katherine where similar drip irrigated yields were achieved with about 6 ML/ha. For these reasons the trial aimed to investigate the use of locally calculated Et and standard crop factors for irrigation scheduling.



**Figure 10.** The relationship between applied irrigation water and lint yield at Broome.

The planned outcome from irrigation research at Broome was the development of an irrigation schedule to maximise yield. Unfortunately research has been terminated before this goal could be achieved but a strong relationship between applied irrigation and yield has been developed as shown in Figure 10. Clearly, yield maximisation and a definitive irrigation schedule have not been achieved, but these data provide an excellent basis for further research in the happy event that the cotton growing prospects of the region was revisited.

## Conclusion

This project aimed to assess the value of using Et, calculated on-site by an automatic weather station, in combination with standard crop factors to schedule drip irrigation of cotton at Broome. Flawed irrigation pipe that split repeatedly in the second half of the season compromised the trials and serious yield penalties occurred before the pipe could be replaced. However, even without product failures, it appears that using Et values calculated by the weather station would not have achieved adequate yields compared to using Class A pan evaporation data in the irrigation formula. The relationship between yield and applied irrigation water, developed by this project, shows that by using calculated Et a volume of 5.79 ML/ha would have been applied and achieved an unacceptable yield of 5.99 bales/ha. In contrast, previous trials using about 9 ML/ha determined by pan evaporation data achieved about 12 bales/ha. This result throws into doubt the value of scheduling irrigation by Et in the west Kimberley environment. The reliability of the weather station is also being investigated.

As an interim recommendation, pan evaporation and crop factors are suggested as a reliable basis for irrigation scheduling for cotton in the west Kimberley. Our data shows that substituting calculated Et values for pan evaporation will lead to under watering and poor yields. However, pan evaporation based scheduling also has its drawbacks, including the fact that it aims to replace the water used in the previous day, rather than the water needed on a given day. An irrigation schedule based on the soil available water would provide the ultimate tool for optimising irrigation because it would meet the daily requirements of the plant. However significant work to characterise the sands in the Broome area would be a prerequisite to determine plant available moisture, water holding capacity, bulk density and other soil parameters. Calibration of soil moisture measuring devices would be an important requirement to the development of a practical scheduling system for growers.

### ***Extension Opportunities***

The project has been terminated with no apparent prospects of resurrection. There are no immediate extension opportunities although it is hoped that a compendium of research conducted at Broome can be compiled and published as a bulletin. Unfortunately research conducted by Western Agricultural Industries Pty Ltd remains confidential and any future publications will be devalued by the omission of the company's data.

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

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The Canning Basin, and associated aquifers, lie to the southeast of Broome in a sparsely inhabited and undeveloped region of WA. The sustainable yield of the aquifer has not been accurately quantified but could probably support 100,000 ha of irrigated agriculture. The water quality is excellent and can be accessed at depths of 15-35 m. The soil overlaying the Canning Basin is a deep, red sand with poor nutrient and water holding status. Native vegetation is predominantly spinifex and acacia scrub.

Prospects for cotton growing in the west Kimberley have been investigated by Western Agricultural Industries Pty Ltd (WAI) and the Cotton CRC. The broad conclusions from WAI research were that outstanding yields and fibre quality could be obtained from drip irrigation and that industry development was justified. Regrettably, the WAI data remains confidential but the CRC has generated preliminary data from its trials.

The poor water holding capacity of the west Kimberley soils dictates that irrigation is applied daily to avoid plant stress. Drip irrigation is ideal for this purpose and also facilitates fertigation as required. Previous research has scheduled irrigation according to a formula based on pan evaporation and a standard crop factor calculation. This method has generated excellent yields of about 12 bales/ha but required 9-10 ML/ha of applied irrigation water.

The aim of this project was to investigate the suitability of using calculated evapotranspiration (Et), rather than pan evaporation, to schedule irrigation. Three levels of irrigation were used; “normal”; “normal” + 30%; and “normal” – 30%. Each of the three irrigation treatments was applied to a factorial experiment with three plant growth stages so that the interaction between irrigation rate and plant growth could be measured.

The trial was negatively impacted by faulty irrigation supply lines which started to split without warning from late mid-season. Although T-Systems replaced all 2 km of faulty pipe at their cost, water stress to all treatments had caused premature cutout and boll shedding. Consequently both the irrigation water actually applied and the resultant yields were low.

Despite the logistical problems that plagued this trial, some useful conclusions can be drawn from the data, including:

- The volume of irrigation water applied in the sowing to 1<sup>st</sup> flower growth stage had no effect on final crop yield
- Growth stage 2 (1<sup>st</sup> flower to 4 NAWF) was highly sensitive to irrigation and the higher rates of irrigation were linked to higher yields
- Using evapotranspiration (Et) to schedule irrigation resulted in only 5.8 ML/ha being applied compared to 8.6 ML/ha if pan evaporation was used, but yield was seriously reduced by the lower irrigation rate
- Data from this trial show that Et was not a useful parameter for irrigation scheduling in the west Kimberley

Further research is needed to optimise water use in drip irrigated cotton in the west Kimberley. Ideally, an irrigation system based on plant available soil moisture should optimise yield, but the basic soil data and soil moisture measuring technology is not developed for the region.