

Assessing the impact of irrigation management on Bollgard[®] varieties through on-farm trialling (2006/2007 Season)

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Introduction

The cotton industry continues to be a leader in irrigation management. Further improvements in water use efficiency are needed in the face of diminishing water resources and declining terms of trade. In addition, the industry will face challenges regarding the Federal Government's National Plan for Water Security in progressing a sustainable cap for surface and groundwater use. The industry must maximise the return per ML whilst meeting its obligations for long-term environmental sustainability. Improved water use efficiency (WUE) provides irrigators with the capacity to maintain production with reduced water allocation.

Irrigated cotton and grain growers have achieved substantial improvements in water use efficiency by implementing best management strategies as identified in the RWUE Cotton and Grains projects and in other industry research and development projects. There is no denying that improvements in application efficiencies can be achieved with a move towards pressured systems with little run-off. Alternative row configuration may also result in water productivity improvements. However, in our drive to find the silver bullet solution to improve WUE we can sometimes overlook the economic rewards from refinement in our current farming practices. Improvements can be easy to achieve, with low capital outlay. One such improvement is the optimal choice of variety and the timing of irrigation applications.

Discussion with Darling Downs growers and consultants identified a lack of local quantitative results on the response of current Bollgard[®] varieties to different irrigation deficits. The aim of this trial was to demonstrate the value of agronomic management to improve crop water use productivity. The assessment of current furrow irrigation performance, enabled a comparison of irrigation and varietal performance, and demonstrated the relative benefits in water use productivity through improved agronomic and/or furrow irrigation management.

Methodology

A 25ha commercial field scale experiment was established to evaluate the interaction between three irrigation strategies. The experiment was conducted in the Nandi region on a transitional soil type between a Cecilvale and that of a Waco or Condamine. Total water holding capacity of the soil (0-100cm) was estimated at 470mm with a plant available water content (PAWC) for cotton of 206mm. Based on the industry recommended lower limit for re-irrigation under furrow irrigation as 50% PAWC (Milroy, *et.al.* 2002), the lower limit for this experiment's irrigation was set at 103mm.

The three irrigation treatments applied were: early (strategy A), commercial (strategy B) and late (strategy C) irrigation. These strategies were implemented as per commercial practice conducted on the Downs with the use of a Diviner at 80, 100 and 120 Diviner mm deficit respectively. A calibrated NMM was also used to enable a measure of true deficit. Varietal recommendation and provision of seed was provided by Cotton Seed Distributors. Varieties planted were Sicot 43B, Sicot 71B & Sicot 80B (all under a solid 1m row spacing). Nine (9) plots consisting of 32 rows wide (1metre row spacing) by 664m long were sown to each variety in each irrigation strategy. Plots were grouped by variety for the three irrigation strategies and an additional eight rows sown between each irrigation strategy to allow for any effects from lateral water movement to be avoided between irrigation treatments. A further 40 rows of single skip row configuration (at the growers instigation) were sown beside the trial area to compare the performance of solid with that of single skip. The single skip treatment was sown to Sicot 80B.

Irrigation

The first in-crop water was applied as per normal commercial practice with all irrigation treatments being implemented at the next irrigation. This ensured severe plant stress was not imposed in strategy C (late irrigation) during the critical square initiation and early flowering stage. Irrigation was applied to all three varieties in each irrigation strategy at the same time and occurred when Sicot 71B treatments reached the pre-required re-irrigation deficit.

Establishment

Planting occurred on the 31st October 2006. Sowing rates were 13.2 seeds/m for Sicot 71B, 12.9 seeds/m for Sicot 80B and 13 seeds/m for Sicot 43B. Starter Z fertiliser at 20kg/ha was also applied during the sowing operation.

After establishment three neutron moisture meter (NMM) access tubes (two located approximately 70metres in from the head ditch and one located 25metres up from the tail-drain) were installed on the middle row in each treatment. Two diviner tubes and one EnvironSCAN probe were also installed beside the NMM access tubes at the top end of the field. At irrigation, each variety x irrigation treatment was instrumented with Irrimate™ equipment (siphon meters and advance sensors) to assess irrigation performance.

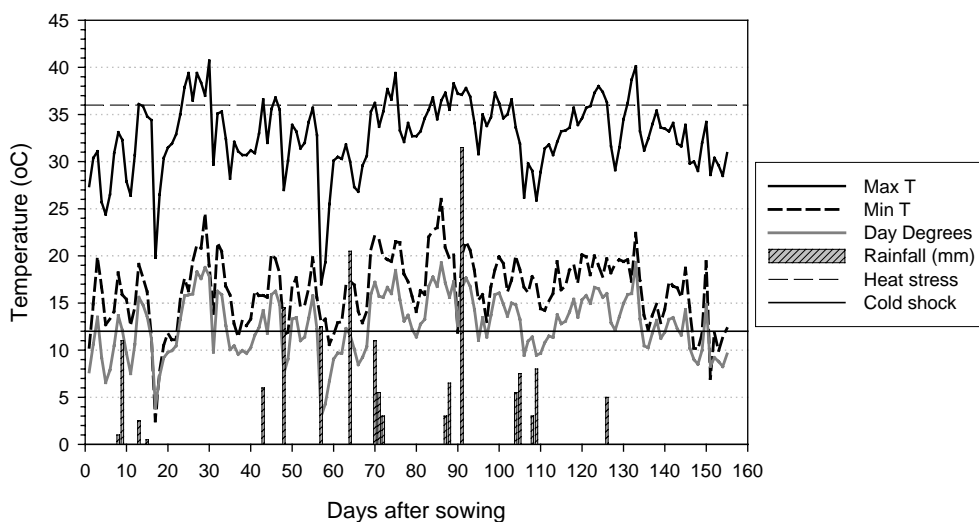
Plant emergence counts were taken to see if there were any differences between varieties in early seedling vigour and plant populations. The crop development tool (CDT) was used to monitor plant development during the season. This tool was used to assess the differences between varieties and irrigation strategies. Plants in each treatment were also measured to determine height to node ratio (HNR).

Water applied to the field, irrigation performance, crop agronomic measures, soil moisture and plant moisture status along with climatic conditions were instrumented and monitored through the growing season. Final yield at a module scale and lint quality parameters were also measured for each plot.

Results and Discussion

Early seedling development soon after planting was hindered by variable climatic conditions. This included hot windy conditions directly after planting to cool, cold conditions thereafter. Near frost conditions occurred at the site when the minimum temperature dropped to 2.5°C 17 days after sowing, followed by 5 days of minimum temperatures below 12°C (Figure 1). Directly following this cold period very warm temperatures were experienced with temperatures ranging between 35°C to 41°C for a period of 8 days. Rainfall recorded at the site for the season was 147mm. However, only 45mm was assessed as effective, with the remainder falling as numerous small shower events. Throughout the season there were 49 days of maximum temperatures 35°C and above, (2 days >40°C) and 20 cold shock days (that is <12°C) recorded at the trial site (Figure 1).

Figure 1. Seasonal temperature data at the trial site.



Cumulative day degrees reached 1966 during the growing season as calculated from the on-site automatic weather station. This figure is below the long term seasonal average. Although the crop initially experienced low day degrees with a cool, mild start, well above average maximum temperatures during the January to March period aided in the crop yield potential. Table 1 shows average maximum and minimum temperatures for the growing period.

Table 1. Monthly average minimum and maximum temperature during the season

Month	Avg. Max Temp °C	Avg. Min Temp °C
December	31.3	15.3
January	34.4	18.8
February	32.6	17.3
March	33.5	16.1
Mean	33.0	16.9

Crop Performance

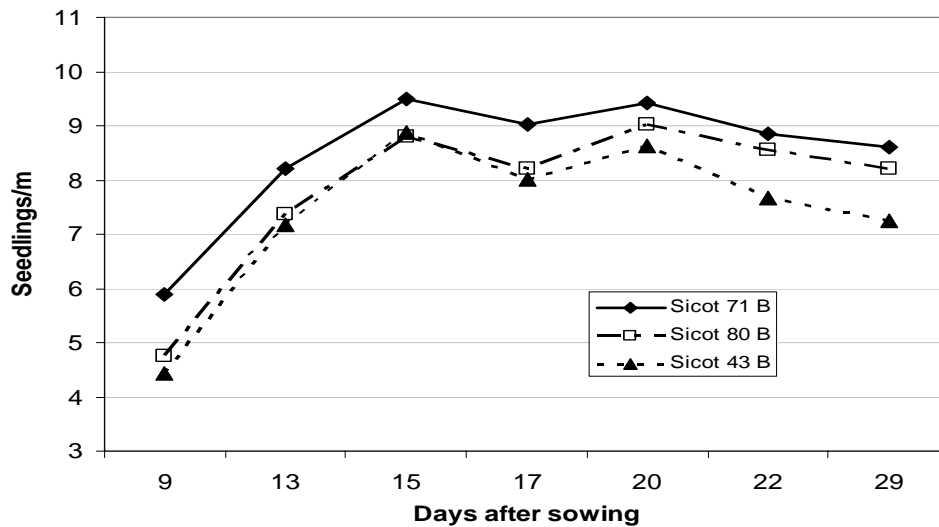
The climatic conditions after sowing and emergence resulted in a lower than expected final plant populations but was deemed acceptable (Table 2). The additional single skip configuration beside the trial site had a final plant population of 6.9 plants/m.

Table 2. Final plant populations for each varieties x irrigation strategy.

Variety	Irrigation A	Irrigation B	Irrigation C
Sicot 71 B	8.7	7.8	7.8
Sicot 80 B	7.7	8.6	8.6
Sicot 43 B	6.7	6.9	6.9

Seedling emergence counts in Figure 3 below indicate that Sicot 71B appeared to be slightly quicker out of the ground. Seedling losses, occurred in all varieties two weeks after sowing predominantly due to the variable climate conditions (as previously discussed), however this was overcome to some extent by a later, staggered emergence.

Figure 3. Seedling emergence counts



Tracking of crop development with use of the CDT found a general similarity for all varieties across the range of irrigation treatments imposed during square development with crop performance being below that of the target line associated with this tool. This is suggested to be the result of the early season climate conditions previously mentioned and demonstrates the impact which cold shock days can have on crop development. Individually, for Irrigation A strategy, all varieties consistently tracked parallel to the target line during square development with irrigation treatments B and C falling away from the target line after 700 day degrees. When comparing the varieties it was shown that Sicot 71B and Sicot 43B had the most similar squaring node development early season, with Sicot 80B being slightly higher in squaring nodes. This trend was consistent across all three irrigation treatments.

Nodes Above White Flower (NAWF) showed a very similar trend between irrigation treatments and varieties. The only distinguishing point being that the early water (Irrigation strategy A) showed a delay in all three varieties reaching cut-out compared to irrigation strategy B (commercial) and strategy C (late water).

HNR demonstrates the difference across each of the irrigation and variety treatments for both before (30th December) and after the irrigation treatments were implemented (Table 3). There was a distinct difference in the growth habit between varieties and also between the different re-irrigation deficits (irrigation strategies).

Table 3. Measures of Height:Node Ratio (HNR) used in determining Pix growth rate management for each treatment.

Date	IrrA 71B	IrrA 80B	IrrA 43B	IrrB 71B	IrrB 80B	IrrB 43B	IrrC 71B	IrrC 80B	IrrC 43B	Skip 80B
30/12	3.8	5.1	5.6	4.5	5.6	5.5	4.8	5.9	5.3	6.5
8/1	7.9	8.5	6.4	5.9	8.8	8.5	4.5	8.4	7.9	8.2
15/1	6.8	7.8	7.1	8.3	7.5	7.2	6.5	8.6	5.1	7.3

Sicot 71B (due to its more determinant growth habit) showed a more characteristic compact growth habit and demonstrated a more limited vegetative growth under an increased re-irrigation deficit in comparison to Sicot 80B. Due to Sicot 80B's more indeterminate nature, it showed a greater HNR value and therefore required an increased agronomic management. Although growth regulant was applied to all Sicot 80B treatments, the need for increased management may have been a limitation to Sicot 80B's final yield. Sicot 80B also showed little change in growth habit with an increased re-irrigation deficit (Strategy C), demonstrating its resilience to maintain its growth rate under more water limited conditions in comparison to Sicot 71B and Sicot 43B.

Irrigation Management

Pre-watering commenced on 16th October and took some 36 hours with a net volume infiltrated into the field of 2.01ML/ha. This volume applied was considered similar to what other growers had to apply due to the dry starting conditions. Total irrigation water applied throughout the season (including pre-water) is shown in Table 4. There was a similar total volume of water applied throughout the season across the three irrigation strategies. In total, Strategy A, received 5 in-crop irrigations, strategies B and C each received 4 in-crop irrigations and 3 in-crop irrigations were applied to the single skip treatment. Unfortunately, due to the inability to measure all irrigations with Irrimate™ it was not possible for us to calculate the run-off for each irrigation and therefore the total amount of water infiltrated in each irrigation strategy.

Table 4. Water applied (ML/ha) to each treatment.

	Sicot 71 B	Sicot 80 B	Sicot 43 B	Mean	Irr. Applied
A (Early)	6.98	6.96	6.94	6.96	5
B (Commercial)	6.58	6.66	6.58	6.61	4
C (Late)	6.52	6.66	6.74	6.64	4
Mean	6.69	6.76	6.75		
Single skip		5.19		5.19	3

A total of 43 irrigations were instrumented with Irrimate™ equipment during the season, however interruptions to data collection did occur due to small infrequent rain showers and fox damage to the advance sensors. From the furrow optimisation conducted during this trial it was found that generally the irrigation practices exceeded the pre-set benchmark levels of application efficiency (AE), requirement efficiency (RE) and distribution uniformity (DU) of 70%, 90% and 80% respectively. The current commercial practice was therefore considered good. One such example (third irrigation event applied in strategy A to Sicot 71B) was found to have an 87% AE, 94% RE and 86% DU. Common suggested methods of improvement in furrow irrigation were also simulated to assess their impact on AE, RE and DU and can be seen in Table 5.

Table 5. Furrow irrigation actual event and simulations to assess AE, RE and DU.

Sicot 71B_IrrigationA_No3	Actual Event -	Simulation 1	Simulation 2	Simulation 3	Simulation 4	Simulation 5	Simulation 6
No and Siphon size ID (mm)	1 x 51	1 x 51	1 x 51	1 x 55.5	1 x 55.5	2 x 51	2 x 51
Inflow rate	2.74	2.74	2.74	3.32	3.32	5.48	5.48
Time to cut-off	745	633	813	500	680	281	540
Advance to end of field	633	633	633	500	500	281	281
Deficit (ML/ha)	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Inflow (ML/ha)	0.92	0.78	1.00	0.75	1.02	0.69	1.34
Outflow (ML/ha)	0.11	0.03	0.16	0.04	0.21	0.07	0.54
Infiltration (ML/ha)	0.81	0.75	0.84	0.71	0.81	0.63	0.80
Irrigation made available to the crop (ML/ha)	0.80	0.75	0.82	0.71	0.81	0.63	0.80
AE (Application Efficiency %)	87	96	<u>82</u>	95	<u>79</u>	90.6	<u>60</u>
RE (Required Efficiency %)	94	<u>88.5</u>	96	<u>84</u>	<u>90</u>	<u>74</u>	94
DU (Distribution Uniformity %)	86	<u>81</u>	88	<u>83</u>	<u>85</u>	87.7	95
Inflow Water Saved (ML/ha)	-	0.14	-0.08	0.17	-0.10	0.23	-0.41

This range of simulations (1-6) is to increase readers understanding and does not constitute a recommendation for optimising the irrigation. Simulations shown include; changing run-time (1&2), increased siphon size (3), increased siphon size & run-time (4), double siphon size (5) and double siphon size with matched RE (6). In consideration of the first two irrigation simulations conducted (1&2) the only management input that was changed was the irrigation run-time. If the time to cut-off is stopped when the water reaches the end of the field (Simulation 1), then there is an improvement in AE over the actual event as there is proportional less water lost from the field. However, RE is reduced as there is less opportunity time for the water to infiltrate into the root-zone and a reduction in DU as the bottom end of the field is not as well irrigated as that which actually occurred. In comparison to the assigned benchmark values for AE, RE and DU this irrigation is OK but as you can appreciate increasing AE is a trade off in the value of RE and DU. Simulation 2 is an increase in run-time compared to the actual event which results in a reversal in irrigation performance indices to that stated above. The increase in run-time resulted in greater tail-water from the field (reduced AE), but results in a greater RE and DU being achieved. Obviously whether a benefit from a change in practice can result is dependent on how good your actual (current) irrigation management is to start with.

The same trend of trade off between AE, RE and DU can also be seen in the next 2 simulations where the inflow rate is increased by increasing the siphon size and the run-time changed. However, as the advance time is increased due to the higher inflow rate, the level of DU improves as the difference in opportunity time between the top and bottom of the field becomes less. This is only true however when sufficient tail-water is run. If we were to cut the water off too early the irrigation will not reach the end and would obviously cause a very severe drop in DU!

The last two simulations (5&6) are with the current siphons doubled up to achieve twice the flow rate. In the first simulation the irrigation is stopped when the water reaches the end and due to the much shorter run-time compared to the actual irrigation event there is a slight improvement in AE and DU but RE is reduced due to the reduced opportunity time for infiltration to occur from such a shorter irrigation run-time.

The last simulation (6) shows what the impact on AE is when you double the flow rate and aim to achieve the same level of RE as current practice. As there is a need for greatly increased opportunity time to enable sufficient infiltration to meet the target deficit, and RE required, DU is improved but with the increase inflow there is a resulting decrease in AE due to considerable more tail-water being run.

These simulations are only an example of what can occur when you change practice based on one measured irrigation event and will not be the same for other field or at different deficits. The interesting point to note is in this case a water saving is possible by increasing the inflow rate and pushing the water through quicker as long as the timing of stopping the irrigation is appropriate, however this will reduce RE. Further increasing the inflow rate can improve AE, however the greater risk is under irrigating the bottom end of the field or reducing AE from excessive tail-water if you do not time the stopping of the irrigation correctly. This is the main reason why if such a change in practice is being considered that an assessment be conducted to gauge:

- if an improvement can be made,

- if it is practically achievable and
- if the increased water saving is worth the possible increase risk.

The other point which needs to be noted is the more you increase the flow rate and reduce the cut-off time, the less opportunity time and infiltration that occurs and a loss in RE will result. However, there is support for the argument that as long as the irrigation has good DU the need for a high RE is redundant and may be beneficial in terms of reducing waterlogging.

The situation analysis of this field being; not excessive in run length, good inflow rates, not needing to run too much tail-water to ensure the bottom end of the field is sufficiently irrigated, being in close proximity to the sump (and therefore having a good tail-water recovery) all support the current efficient irrigation performance of this field. For this field therefore, major water savings from changing the growers current irrigation practice under furrow irrigation may still be theoretically still achievable but most likely not practical in implementation. It is prudent to note however that with out undertaking these evaluations, an assessment of their current performance for this field and an informed decision on whether or not to change practice would not have been known.

Yield and Water Productivity

The trial site was picked on the 26-27th April. The yield results for each plot are shown below in Table 6. No treatments (irrigation by variety) incurred any quality penalties with all meeting base grade or better.

Table 6. Yield results (bales/ha) for each treatment

	71 B	80 B	43 B	Mean
A (Early)	12.4	11.5	11.7	11.9
B (Commercial)	11.6	10.6	11.0	11.1
C (Late)	10.6	9.8	10.0	10.2
Mean	11.5	10.7	10.9	
Single skip		7.8		

A highlight in the trial was the performance of Sicot 71B across all irrigation strategies. It demonstrated both excellent yield and fibre quality characteristics. From general observations in-crop Sicot 43B performed better than expected in yield as this early maturing variety appeared to experience greater problems in handling the conditions imposed on the variety (both early season and within each of the irrigation strategies). Sicot 80B underperformed in all irrigation strategies having the lowest gin turnout (GTO%) and a higher micronaire in the Irrigation C (late) treatment and single-skip. Consideration however for growth habit and yield potential of a variety is needed when priority irrigating under limited water between a number of fields.

Gross Production Water Use Index (GPWUI) – the Industry standard for WUE for each variety is shown in Table 7 and was calculated as:

$$\text{GPWUI (applied)} = \frac{\text{Total Yield (b/ha)}}{\text{Total Water Applied (ML)}}$$

NB: Total water applied includes, irrigation applied + estimated effective rainfall + soil moisture reserve (starting soil moisture – final soil moisture at harvest).

Irrigation Water Use Index (IWUI) for each variety is also shown in Table 7 and was calculated as

$$\text{IWUI} = \text{Total Yield (b/ha)} / \text{Total irrigation water applied (ML)}$$

Table 7. Water use indices for each treatment

	Irr A 71 B	Irr A 80 B	Irr A 43 B	Irr B 71 B	Irr B 80 B	Irr B 43 B	Irr C 71 B	Irr C 80 B	Irr C 43 B	Skip 80 B
GPWUI Bales/ML	1.66	1.54	1.60	1.63	1.43	1.50	1.47	1.33	1.36	1.39
IWUI Bales/ML	1.78	1.65	1.74	1.76	1.59	1.67	1.63	1.47	1.48	1.5

If the trial was able to measure and assess the tail-water volume from all irrigations applied (as originally planned) it would have been possible for us to assess each irrigation strategy based on irrigation infiltration instead of irrigation applied and therefore account for any differences in tail-water volume run. It is suggested that this would have further highlighted a greater benefit in terms of GPWUI from the early (strategy A) irrigation treatment.

For each irrigation treatments (varieties combined) in terms of GPWUI there was a trend of reduced GPWUI with an increase in soil moisture deficit before irrigation. For each variety within each irrigation treatment there was the same trend with Sicot 71B having the highest value followed by Sicot 43B and then Sicot 80B. Overall, the highest GPWUI was for Sicot 71B in the early watered strategy followed by Sicot 71B in the commercial strategy, then Sicot 43B and Sicot 80B both in the early water irrigation strategy. Results demonstrate that an increase in GPWUI can be achieved over commercial practice by reducing the re-irrigation deficit (or better matching re-irrigation deficit to PAWC). The increase achieved over commercial practice in terms of GPWUI from irrigating at a small deficit has been calculated as comparable to an improvement in GPWUI from a modest savings (0.2ML) in water use through furrow optimisation for the season.

GPWUI in the single skip treatment was slightly higher than Sicot 80B and Sicot 43B in the late irrigation treatment due to less irrigation water being applied and more soil water being available at the end of the season. The performance of the single skip treatment in comparison to the solid plant was below expectation. As the whole trial was managed as a solid crop it is acknowledged that a different agronomic management concept is required in comparison to the solid for the single skip treatment to reach the maximum yield potential.

The IWUI results for each variety are higher, as this index involves applied irrigation water only. It followed the same trend as GPWUI across varieties and irrigation treatments.

The good performance of the current irrigation practices undertaken in the trial site and increased yield and GPWUI over commercial practice is support for the argument that improved irrigation water efficiency can be found through improved agronomic management (re-irrigation timing).

Conclusion

Improved farm water use efficiency is a farm by farm and field by field case where the methods of improvement are a compromise between management constraints and farmer resilience to risk, and an assessment of where the best return for their change in management may occur.

Whatever management decisions or change in management practices are undertaken, individual irrigators must consider their desired levels for the three irrigation performance indicators (AE, RE and DU) and a situational analysis of the field in question (based on performance measures made on that field and not generalised assumptions based on assumed similar fields).

Assessment of all management inputs under the growers control is required to decide which is the most rewarding change in practice in terms of water use productivity. An Irrimate™ assessment is one such tool available to growers to enable an empirical assessment of irrigation performance. Assessment of field water holding capacity, the most appropriate irrigation deficit to use and the changes in agronomic crop management as a result of a redefined irrigation strategy should also be undertaken and discussed with growers agronomists for possible water use productivity improvements. Authors of this article encourage that an assessment of irrigation performance be undertaken and it is hoped this article highlights that all management inputs be considered for improvement and not any one input in isolation.

Finally, an empirical assessment should always occur to enable a quantitative assessment of current irrigation performance. This assessment may simply be measuring water applied throughout the season and the resulting yield or may be a more thorough investigation such as an Irrimate™ assessment. Regardless, of the extent to which an assessment is carried out, without undertaking an irrigation performance assessment of current practice, the ability to make an informed decision to change your irrigation management or irrigation system for improved water productivity can not be subjectively made.

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