COTTON RESEARCH COUNCIL

FINAL REPORT

DAQ 29L IMPROVED WATER SCHEDULING AND CROP NUTRITION IN COTTON

J.F. Bourne
Supervising Extension Agronomist
Queensland Department of Primary Industries
Toowoomba

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1.0 INTRODUCTION

Cotton growers are seeking more precise information on the yield response to different levels of inputs, so they can optimise inputs and maximise crop profitability. The consequences of inappropriate water and nutrient management were amply demonstrated in the Emerald Irrigation Area, when profitability declined, and in some cases vanished, in the early 1980s. Research at Emerald has provided basic information for developing a management decision program, as a tool for on-farm water scheduling and nutrient application decision making.

Techniques for water scheduling are regularly used in scientific experimentation. In particular the Water-Balance Method is a technique that can be easily and cheaply adapted for use by commercial growers.

This project utilises information from Emerald and other irrigation districts in the State to develop a scheduling system, WATERSCHED, as part of a Cotton Management Decision Program.

2.0 OBJECTIVES

1. To determine cotton yield response functions to differing levels of irrigation water and nutrients, to enable farmers to make better decisions on use of those input resources.

2. To develop a Cotton Management Decision Program which provides commercially relevant options of water scheduling and fertiliser application for extension officers, consultants and cotton growers, to optimise crop profitability.

3. To increase the adoption by farmers of beneficial water management and fertiliser practices.

3.0 METHODS AND RESULTS

A decision was taken early in the project period to confine work to water management only. Considerable research into yield responses to nitrogen nutrition has already been funded by the Cotton Research Council. This decision was confirmed by members of the review committee of the council, after the first twelve months of the project.

3.1 Staff

J.F. Bourne, Supervising Extension Agronomist, Toowoomba.

G. McIntyre, Senior Extension Agronomist, Dalby.

P. Vance, Senior Extension Agronomist, Kingaroy.

L. Palu, Extension Agronomist, Pittsworth.

N. Delaney, Supervising Extension Agronomist, Kingaroy.

G. Keefer, Senior Agronomist, Emerald.

J. Ladewig, District Experimentalist, Emerald.

R. Sands, Extension Agronomist, Emerald.

G. Volck, Extension Agronomist, Emerald.

J. Street, Extension Agronomist, St George.

D. Venz, Extension Agronomist, Goondiwindi.

M. Curran, University College of Southern Queensland, Toowoomba.

R. Vidler, University College of Southern Queensland, Toowoomba.

3.2 Deficit Trials

In order to obtain data for a yield response function to differing levels of water applied, commercial size, non-replicated, furrow irrigated trials were carried out for three summer seasons at sites on the Darling Downs and at Kingaroy. (Objective 1).

These trials were also used to evaluate a water-balance scheduling system, WATERSCHED, previously developed by QDPI officers at Emerald and Pittsworth. (Objective 2)

The trials were used to demonstrate WATERSCHED to local growers. (Objective 3)

Sample data sets from the Darling Downs and Kingaroy are presented in Appendix I.

Additional data was collected from commercial fields, monitored using WATERSCHED, to produce the yield response function. This was established for the Dalby area on the Darling Downs and is presented in Figure 1.

Figure 1. Yield response to total season water use
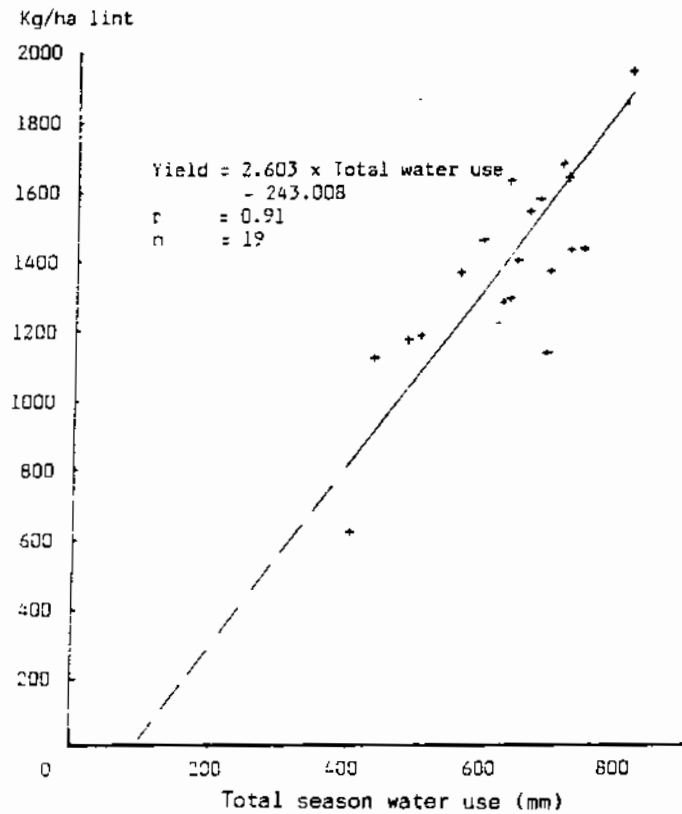
Total season water use included season effective rainfall, net stored soil moisture and irrigation applied (see Appendix I). Only data from equivalent management expertise and resource inputs was used.

3.3 Development of the WATERSHED Package

In addition to evaluating a water-balance scheduling system, a format able to be used by growers was developed. Research staff at Emerald refined and developed the basis for water-balance calculations.

A set of manual worksheets to predict irrigation dates was produced and tested by grower cooperators. A worked example is presented in Appendix II. Several computer versions of the worksheets were also developed and tested. Computer code was written by QDPI staff at Emerald and Kingaroy, and staff from the University College of Southern Queensland at Toowoomba. One grower in the Dalby district scheduled his whole property using a computer version, during the latter half of the project.

4.0 DISCUSSION

4.1 Yield Response Function

A yield response function to season crop water used enables a grower to adopt a particular irrigation strategy according to expected available water supplies.

The response in Figure 1 approximates a straight line over the range of data collected. Intuitively we could expect a gradually decreasing response to water used (or even a negative response) at very high values of total water.

It is difficult to establish an accurate response function in an area of summer rainfall as the contribution of rainfall to total water is often uncertain, unless sophisticated measuring equipment is available. An alternative is to monitor a large number of sites over which rainfall effects will even out. This was the approach used in the project.

The straight line response indicates that significant yield gains can be made up to total water use figure of 800 mm (or 8 Ml). This is in agreement with figures calculated by the CSIRO cotton research unit at Narrabri, (Hearn, 1988).

This would support the suggestion that for the best response to water applied, all cotton should be irrigated according to a 'full irrigation regime'. In the case of limited water supplies the area cropped should be reduced to maintain the correct amount of water per hectare. Hearn (op cit) suggests that while this conservative strategy may come out ahead in most seasons, there will be some when growing a larger area with less allocation per hectare will be more profitable if rainfall occurs at appropriate times.

In any case there is clearly a need for an objective scheduling approach to ensure that crops are fully watered in most cases. The approach of fully irrigating a smaller area, with limited water supplies has also been supported by a general economic analysis of cotton growing enterprises at Emerald (Turner, 1986).

4.2 Evaluation of the Water-Balance Scheduling Approach

At each of the trial sites water-balance calculations of soil moisture were compared regularly during the season with direct measurements using a neutron moisture meter. This equipment was calibrated for particular soil types involved.

It was established that predicted irrigations using the two approaches were consistently within two to three days of each other. This is an insignificant difference in a large commercial cotton enterprise as other management factors often prevent timing within two to three days of a predicted date.

Some assumptions are made in the water-balance calculations, such as the proportion of rainfall that is effectively taken up by the soil profile. An independent direct soil measurement could be useful in situations, such as after significant rainfall. It was concluded that a practical

commercial approach should be to base scheduling on water-balance calculations, but do direct field checks at specific times. This would reduce considerably the labour content of scheduling by direct measurement, used by some private consultants.

During the three seasons of trials, local measurements were made of soil parameters (field capacity, wilting point and root depth) required in water balance calculations. Measurements of crop factors were made during the growing season to confirm literature values used (Doorenbos and Pruitt, 1977).

The crop factor is an empirical value representing stage of crop growth. Tables of crop factor development with both time and accumulated day degrees were derived. The table based on day degrees produced better agreement between calculated and direct measurement of soil moisture.

The varying irrigation deficit treatments used in the trials indicated optimum deficits for irrigated cotton. On the Darling Downs, a value of 90 mm produced peak yields, while at Byee in the Kingaroy district values of up to 120 mm were appropriate. In both cases a maximum root depth of approximately one metre was achieved on a heavy grey clay soil of 200 to 250 mm/m available water. A value of 90 mm has previously been used by private consultants on the Darling Downs, scheduling with neutron moisture meter equipment alone.

Several treatments used a split deficit, in which a value of say 120 mm was used prior to flowering, followed by 90 mm for the remainder of the season. Intuitively a lower deficit during so-called 'critical growth periods' (for example, flowering) would appear to be desirable. However, no advantage of this strategy was observed.

4.3 Adoption and Benefits to Growers

In addition to the four major cooperators, commercial crops were monitored together with growers on a further 15 local properties, after specific requests. Crops were also monitored at Emerald, St George and Goondiwindi.

Benefits stated by cooperators and other growers included:

*   Better management and labour planning in relation to irrigation events. Confident predictions were made one to two weeks ahead. Ordering of water was better managed in some cases.

*   An objective prediction of the first season irrigation, and irrigation following rainfall. In the past, these have been the most difficult decisions.

The value of any decision aid, such as WATERSCHED, is greatest when it is able to be applied on a whole farm basis. While individual crop demonstrations were the initial thrust of this project, opportunities were then taken to test the system on a property basis. Growers responded very positively in this situation.

5.0 ACHIEVEMENTS RELATIVE TO OBJECTIVES

All three major project objectives were achieved, as discussed in the previous section. Some additional achievements have come out of the project.

5.1 Improved Managerial Skills in Irrigation

Adoption of WATERSCHED, together with the use of neutron moisture meter equipment by consultants has lead to improved irrigation skills generally.

Monitoring of crops on the Darling Downs for example, has shown that previous district irrigation practice was often seven to ten days later than required, and cut off too early at the end of a growing season. Previous criteria to determine irrigations, such as soil cracking and plant stress have now been replaced by measurement or estimates of soil water deficit. Even irrigators not formally using a scheduling system are now able to make rough estimates of deficit from evaporation figures regularly published in local media.

WATERSCHED is an educational package in addition to a real time decision aid. It is likely that improvements in irrigation skills due to this package may well make it 'obsolete' for experienced irrigators in future.

5.2 Availability of Weather Data

WATERSCHED requires regularly updated climatic information to make predictions. At the beginning of the project this was unavailable in most districts.

Project staff arranged for a network of automatic weather stations to be set up in major irrigation areas around the State. Funding from this project provided one station at Kingaroy.

Daily information is now accessible by computer through telephone links to each station. In addition to providing information for scheduling, this data will be of value in running a suite of crop models currently being developed by QDPI.

6.0 RECOMMENDATIONS FOR FUTURE WORK

6.1 Refinements to the WATERSCHED Decision Aid Package

Irrigation timing during the growing season is well predicted by WATERSCHED. An area of difficulty is the establishment of criteria for the final irrigation.

In a commercial situation on the Darling Downs, irrigation normally ceases at the end of February. This allows the maturing crop to deplete soil moisture, leaving dry soil conditions at picking. Alternatively, plant characteristics have been used, such as the number of open bolls/metre. At Emerald a figure of five open bolls/metre has been used, (Keefer pers. comm.). Observations in the Dalby district have indicated that irrigation beyond five open bolls/metre has boosted yield in some situations.

There is a need to develop more sophisticated, but easily measurable, criteria to determine the final irrigation. The use of a day-degree value has potential.

Prediction of irrigation requirements when the crop is very young (that is, the first four to six weeks after planting) is not handled accurately by either direct soil measurements or a water-balance calculation. This is due to the particular nature of both methods and does not require further research at this stage.

6.2 Efficient Distribution of Irrigation Water Applied to Cotton Fields

Correct timing of irrigations is of reduced value if water is distributed unevenly to the crop.

Observations from neutron moisture meter readings along the length of the furrows, at the Kingaroy site in the first year of the project, indicated a significant unevenness of soil moisture distribution. (See Figure 2.)

Figure 2. Seasonal profile soil moisture - Kingaroy 1986-87. 90 mm deficit treatment.
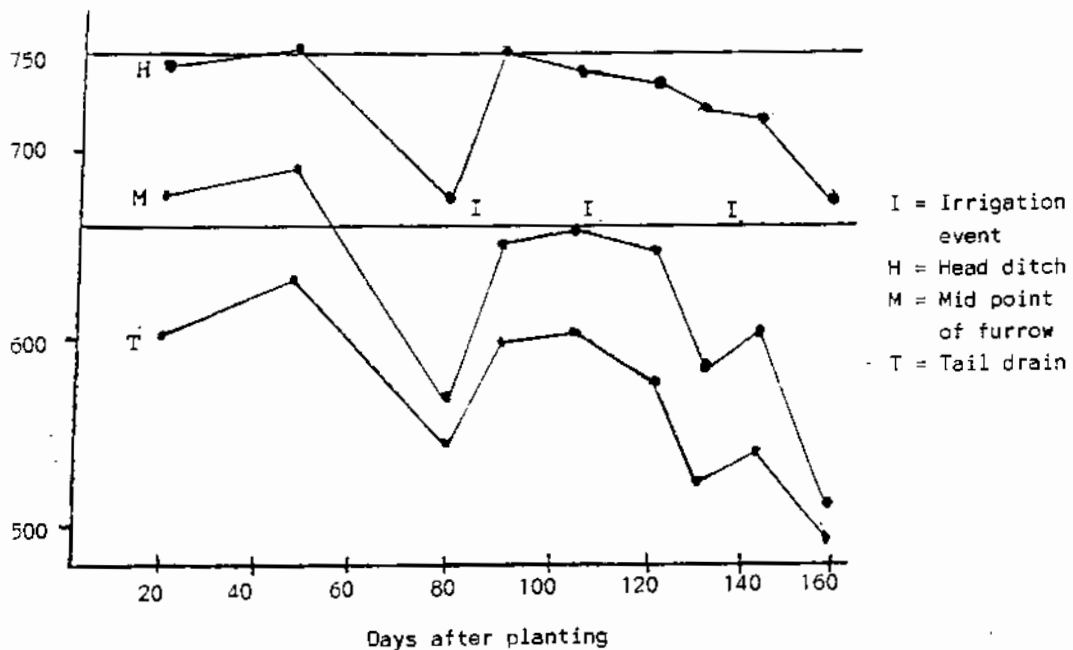
Measurement at the head ditch, mid point and tail drain were made using a neutron moisture meter. Figure 2 shows that at no time during the season was soil moisture uniformly distributed along the length of the furrow.

Previous work funded by the Cotton Research Council at Emerald has indicated that efficiencies are high in cracking clay soils (Yule and Keefer, 1984). This was not the case at Kingaroy on an alluvial, dark, hard-setting to weakly self-mulching medium clay.

There is an obvious need to measure distribution of water applied over a range of appropriate soil types in cotton growing areas and to determine strategies to improve inefficiencies where they exist.

6.3 Interactions of Water Requirement and Crop Nutrition

Work at Emerald has indicated likely response function of yield to applied nitrogen under different irrigation treatments (Keefer and Blamey, 1988). An example of the data collected is given in Figure 3. This work was carried out at Emerald Research Station on a basaltic cracking clay, 70-80 cm deep.

Figure 3. DP90 yield response to nitrogen at two water deficits, Emerald 1986-87.
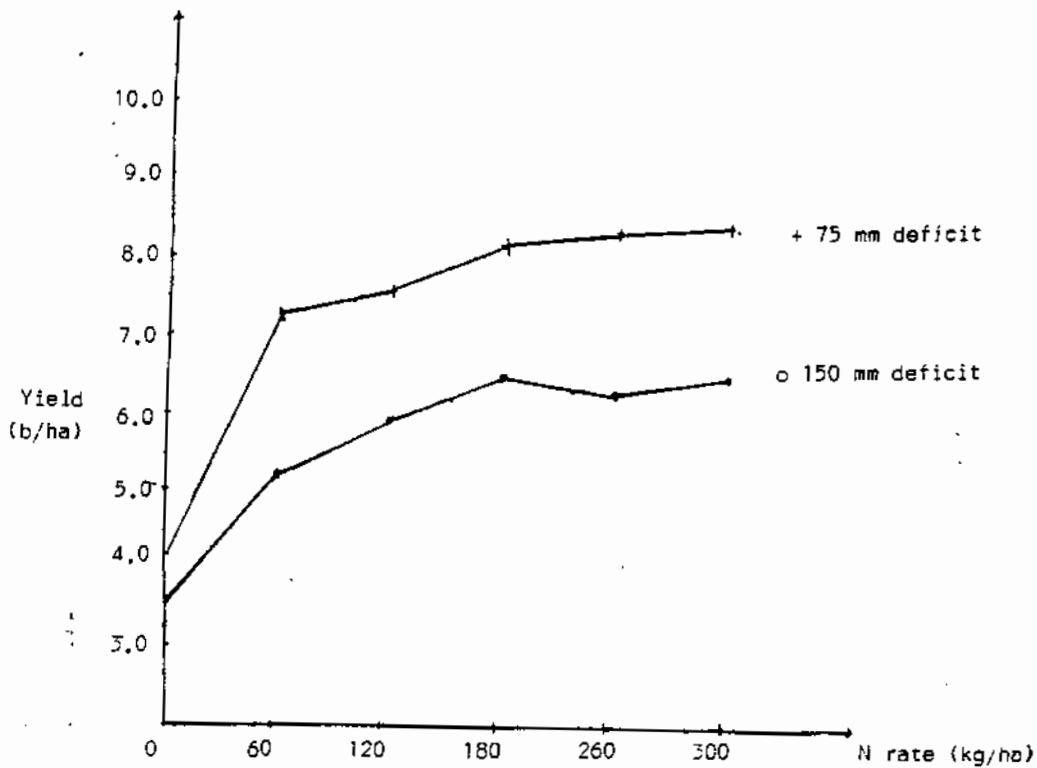
In order to evaluate interactions of water and nitrogen as they relate to a commercial farming situation, it is necessary to include an economic analysis.

A useful approach developed by a project team member, Mr Volck, is shown in Figure 4.

Figure 4. Analysis of economic returns to irrigation and nitrogen nutrition - Emerald 1986-87.
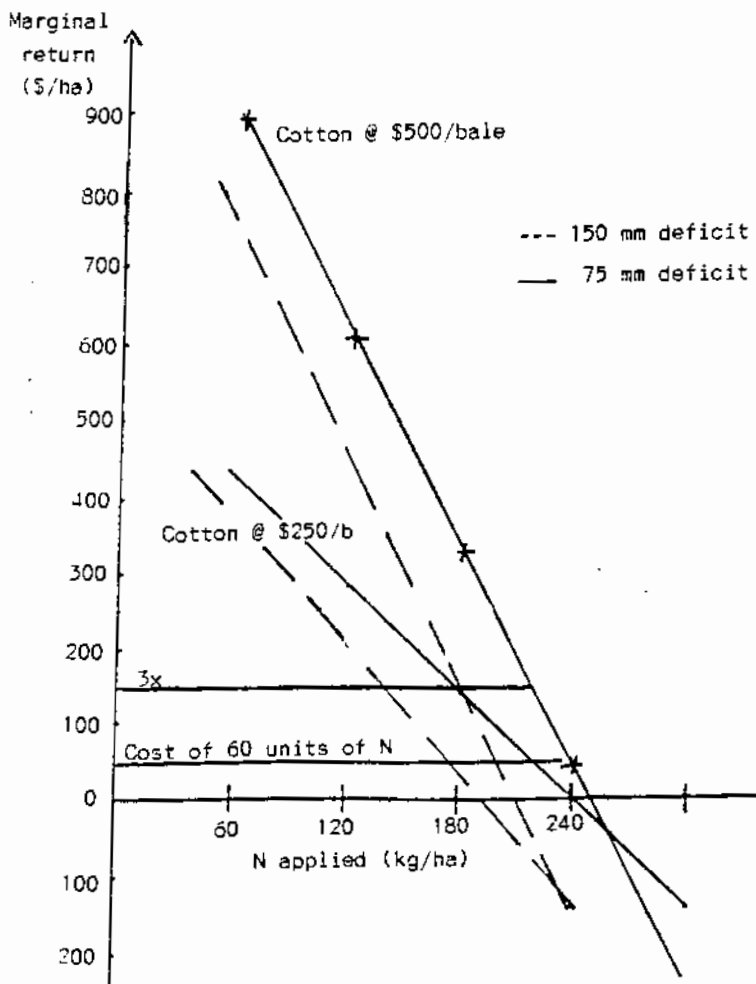
Marginal return is calculated as the difference between the gross margin at one input level and the previous level (for example, point A = GM at 120 kg/ha N less GM at 60 kg/ha).

Gross margins were calculated from a set of standard costs, with yields being taken from Figure 3.

Traditional economic theory suggests that for maximum profit a resource should be used up to the point where marginal return is equal to marginal cost. The marginal cost in this case is the cost of 60 kg/ha N, as the nitrogen treatments increment in lots of 60 kg/ha.

Most growers are conservative in this respect and so a 3:1 return to marginal cost is more realistic. The point of intersection of the horizontal and sloping lines in Figure 4 indicates the optimal N rate to apply. The analysis can be summarised in Table.

Table 1. Rate of N required (kg/ha) for a nominal 3:1 return to marginal cost

Deficit	75 mm		150 mm	
Cotton price/bale	$250	$500	$250	$500
Optimal rate of N (kg/ha)	174	216	140	180

The table indicates that even with infrequent irrigation (a high deficit) and low cotton price, a relatively high rate of N should still be applied to achieve the best economic return.

This result does not appear to support previous suggestions that low inputs of water and nitrogen (and hence yield) would be economically attractive.

There is a need to examine all data previously collected, on nitrogen and water interactions, in an economic context. The continuing interest in dryland cotton and lower inputs, requires that we have a clear picture of the likely viability of this approach.

7.0 DISSEMINATION OF PROJECT RESULTS

7.1 Local field days and media reports

Field inspections of the sites at Kingaroy and Dalby were held during each of the summer seasons. Farmer crop tours organised by the cotton-growers association and the Toowoomba Show Society also visited the sites. Additional commercial crops were monitored by both project staff and growers as a result of these events.

Results were published in local newsletters and major rural newspapers. Weather data from the automatic stations was collated and distributed weekly to local media, for growers unable to access this information directly by computer.

7.2 Technical Conferences

Summaries of project work were presented at the following conferences:

* Computers in Agricultural Extension Workshop, DPI, Toowoomba, Q, 1987.

* Computers in Agriculture Conference, Melbourne, Vic, 1988.

* Australian Cotton Conference, Surfers Paradise, Q, 1988.

* National Computers in Agriculture Conference, Maroochydore, Q, 1989.

* Irrigation Scheduling Workshop, Department of Agriculture and Fisheries, Dubbo, NSW, 1989.

The project team met annually to review and plan activities, and also regularly during each summer season.

7.3 Grower Workshops

At the completion of the project, a series of workshops was held to explain to growers the basic calculations used in WATERSCHED.

Several workshops were held at both Dalby and Kingaroy, and subsequently St George, Theodore and Emerald. Growers were first introduced to a manual approach to calculate predicted irrigation date, and then given the option to use a computer version.

Grower groups are to be convened at the conclusion of the current irrigation season to review their individual experiences with WATERSCHED. Members of the project team will provide support in the use of manual or computer versions as required.

8.0 BIBLIOGRAPHY

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Keefer, G.D. and Blamey, P. (1988), Irrigation and nitrogen management of cotton. Cotton Research Council funded project, DAQ9L (final report).

Turner, J.M. (1986), Management of Emerald and St George irrigation farms for maximum financial return. QDPI Irrigation Management Workshop Proceedings, June 1986 (Conference and Workshop Series QC89008).

Yule, D.F. and Keefer, G.D. (1984), Irrigation management of cotton for efficient water use. Australian Cotton Growers Research Conference, Toowoomba.

APPENDIX I

SAMPLE DATA FROM DALBY AND KINGAROY SITES

Site 1. 'Loch Eaton', Dalby

Planted:	1.10.88
Variety:	Siokra
Plot Size:	24 rows x 393 m
Harvest Area:	6 rows x 393 m

i. Treatment data

Irrigation Deficit mm	Date(Days) and Deficit(mm) at Irrigation					Final Deficit 22/3/89 172 days	Total Applied Water mm	Effective Rainfall mm	Total Water mm
90	8/1(99) 92.0	19/1(110) 72.8	3/2(125) 89.5	23/2(145) 111.8	10/3(160) 99.5	75.0	747.5	174.9	922.4
90/60	8/1(99) 92.0	16/1(107) 46.4	28/1(150) 63.6	15/2(137) 75.9	3/3(153) 114.3	120.8	719.9	164.7	884.6
120/90	10/1(101) 113.4	19/1(110) 72.8	3/2(125) 89.2	23/2(145) 111.8	10/3(160) 99.5	75.0	768.7	113.9	882.6
120	10/1(101) 113.8	24/1(114) 98.1	23/2(145) 159.4			181.1	759.4	167.7	927.1
150	16/1(107) 136.3	19/2(141) 179.3				211.3	754.9	171.9	926.8

Note: Early Irrigations - All Plots

23/10(24)	5/12(65)
34.1 mm	172.9 mm

ii. Yield data

Irrigation Deficit mm	Yield kg/ha	Total Water mm	Water Use Efficiency kg/mm
90	2351.2	922.4	2.55
90/60	2486.2	884.6	2.81
120/90	2013.7	882.6	2.28
120	2049.7	927.1	2.21
150	2133.0	926.8	2.30

Site 2. 'Silver Leaf', Byee (Kingaroy)

Planted:	17.11.88
Variety:	Siokra
Plot Size:	6 rows x 500 m (6 row non-irrigated buffer between plots)
Harvest Area:	4 rows x 500 m

i. Treatment data

Irrigation Deficit mm	Date(days ex planting) and Deficit(mm) at Irrigation			Net Soil Moisture Utilised mm	Effective Rainfall mm *	Total Water mm
90	31/1(75) 88.0	28/2(103) 80.0	29/3(132) 116.0	-	489.6	773.6
140	28/2(103) 1450			-	489.6	634.6
190	12/3(115) 186			-	489.6	675.6

ii. Yield data

Irrigation Deficit mm	Yield kg/ha	Total Water mm	Water Use Efficiency kg/mm
90	1260.0	773.6	1.63
90**	1530.0	773.6	2.00
140	1687.4	634.6	2.66
190	1372.5	675.6	2.03

Note: * An estimate of effective rainfall only.
      ** Watering time was reduced from 10 to 5 hours over 500 m, using several siphons/furrows.

WATERSCHED
SOIL WATER BALANCE

Field Capacity .... 400 .... mm   Paddock ... A4

Deficit .... 100 .... mm   Crop . Soybean

Refill Point .... 300 .... mm   Year ... 1989

	Date	Days from Planting	Evap- oration mm E	Crop Factor K	Crop Water Use mm C	Effective Rainfall or Irrigation mm R	Soil Water Balance mm B	Daily Crop Water Use mm D		Days to Next Irrigation I		Remarks
					ExK	Actual − 5	B − C+R	$\frac{C}{Days}$		$\frac{B - Refill}{D}$		
1	2/10			STARTING SOIL WATER BALANCE								
	9/10	7	49.9	0.1	4.9		395	$\frac{4.9}{7}$	0.7			Early season crop water use very low & not good
	16/10	14	55.8	0.1	5.5		389	$\frac{5.5}{7}$	0.8			indication of first irrigation. No real need
	23/10	21	52.4	0.1	5.2		384	$\frac{5.2}{7}$	0.7			to calculate days to irri
	30/10	28	56.0	0.2	11.2		373	$\frac{11.2}{7}$	1.6			
	6/11	35	54.3	0.3	16.3		357	$\frac{16.3}{7}$	2.3	$\frac{57}{2.3}$	25	End Nov. irr.
	13/11	42	61.1	0.3	18.3	20.0	358	$\frac{18.3}{7}$	2.6	$\frac{58}{2.6}$	22	
	20/11	49	64.0	0.5	32.0		326	$\frac{32}{7}$	4.6	$\frac{26}{4.6}$	6	Irr. 26/11
	27/11	56	61.0	0.7	42.7	I	400	$\frac{42.7}{7}$	6.1	$\frac{100}{6.1}$	16	Irrigated
	4/12	63	60.0	0.7	42.0		358	$\frac{42}{7}$	6.0	$\frac{58}{6.0}$	10	
	11/12	70	54.0	0.9	48.6	63	372	$\frac{48.6}{7}$	9.0	$\frac{72}{9.0}$	8	Irr. 19/12
2	14/12	73	10.0	0.9	9.0	110	400	$\frac{9.0}{3}$	3.0			Overcast&humid -low water use
3	18/12	77	12.3	0.9	11.1		389	$\frac{11.1}{4}$	2.8	$\frac{89}{2.8}$	32	
	25/12	84	62.2	0.9	56.0		333	$\frac{56}{7}$	8.0	$\frac{33}{8.0}$	4	Irr. 29/12
4	29/12	88	32.0	0.9	28.8	I	400	$\frac{28.8}{4}$	7.1	$\frac{100}{7.1}$	14	
	1/1	91	24.0	0.9	21.6		378	$\frac{21.6}{7}$	7.2	$\frac{78}{7.2}$	11	Irr. 12/1
	8/1	98	42.0	0.9	37.8		340	$\frac{37.8}{7}$	5.4	$\frac{40}{5.4}$	7	Irr. 15/1
	15/1	105	60.0	0.9	54.0	40	326	$\frac{54}{7}$	7.7	$\frac{26}{7.7}$	3	Irr. 18/1
	18/1	108	21.0	0.9	20.9	I	400	$\frac{20.9}{3}$	7.0	$\frac{100}{7.0}$		Final Irr.
	22/1	112	25.0	0.9	22.5		378	$\frac{22.5}{4}$	5.6	$\frac{78}{5.6}$		
	29/1	119	57.0	0.9	51.3		327					Crop yellowing
	(1)	Planting date										
	(2)	Three day run up to rain										
	(3)	4 day balance of week										
	(4)	Mid week irrigation split run into 4 days and 3 days										
	TOTALS											