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FINAL REPORT - COTTON RESEARCH COUNCIL

DAQ7 IRRIGATION MANAGEMENT OF COTTON FOR EFFICIENT WATER USE

Queensland Department of Primary Industries

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COMMENCED: 1982/83

AIMS:

The aims of the project are to provide a basis for sound irrigation management of cotton through studies of:

(i) Crop response to a range of irrigation management options in terms of crop irrigation efficiency (yield per unit water applied) and plant fruiting development.

(ii) Soil water balance in relation to irrigation application efficiency (infiltration per unit water applied), crop water use, ground-water accessions and model predictions of all these factors.

Methods:

Experiments have been conducted over three seasons (82/83 - 84/85) on the BUg cracking clay on the Emerald Research Station and over one season (84/85) on the AUg cracking clay on the east bank of the Emerald Irrigation Area. The experiments have measured crop response, soil water balance, irrigation application efficiency and crop water use under a range of irrigation management options. Other aspects considered are soil loss, soil aeration and cultivar response.

The irrigation schedules were based on potential crop water use estimated by a crop factor - Class A pan evaporation model.

RESULTS

Crop Yields

Table 1. The number of irrigations and lint yields for three irrigation deficits tested over three seasons on the Emerald Research Station.

Irrigation Treatment (deficit)		Number of Irrigations			Lint Yields Bales/ha		
		82/83	83/84	84/85	82/83	83/84	84/85
Very Frequent	(45 mm)	11	7	8	8.4	8.3	7.8
Frequent	(75 mm)	7	5	6	8.9	9.1	8.3
Infrequent	(120 mm)		2			8.9	
Very Infrequent	(150 mm)	3	2	2	7.0	8.8	5.6

An obvious feature of the results in Table 1 is the consistently high yields of the frequent (75 mm deficit) treatment over three seasons of differing rainfall patterns requiring different numbers of irrigations. The lower yields in 84/85 were partly associated with a 14 day wet period in December when 144 mm of rain fell on eight days. At this site the very frequent (45 mm deficit) treatment had consistently lower yields than the frequent (75 mm deficit) treatment. At some sites in some seasons the reverse applied depending on rainfall incidence in relation to irrigation. Yields from the very infrequent (150 mm deficit) treatment were also closely related to rainfall and irrigation timing.

Leaf Area Index

Typical leaf area index at peak flowering data are presented in Table 2. Table 2 shows that leaf area development was related inversely to irrigation deficit and that vegetative growth was restricted in the IF and VIF treatments in particular. Plant growth in the well watered treatments (VF and F) was similar in both seasons. The better growth in the VIF treatment in the 1983/84 compared to 1982/83 was due to well distributed rainfall. A comparison of Table 1 with Table 2 indicates that the critical leaf area index for cotton is about three.

Table 2. Leaf area index (L.A.I.) at peak flower for treatments in 1982/83 and 1983/84 seasons.

Treatment	Irrigation Deficit mm	L.A.I. at peak flower 1982/83	L.A.I. at peak flower 1983/84
VF	45	4.5	4.7
F	75	4.0	4.3
IF	120		3.1
VIF	150	2.3	2.8

Irrigation Application, Runoff, Infiltration, and Efficiency

Typical water application and runoff data are shown in Figure 1 for three treatments in 1983/84. The increase in application rate during each irrigation was due to adding syphons to prevent possible uneven wetting. The water application rates were similar at all irrigations and differences between treatments were in period of irrigation which varied from seven hours for the VF treatment to 22 hours for the VIF treatment. Total water application increased with increasing deficit prior to irrigation. Irrigation was stopped when the runoff rate was relatively stable and all treatments produced runoff curves of similar shape. The total runoff depended mainly on the period of runoff and did not vary greatly across treatments. The total infiltration (water application minus runoff) was approximately equal to the deficit prior to irrigation. Irrigation application efficiency (total infiltration/total water application) was lowest in the VF treatment due to the difficulty of limiting runoff in proportion to the amount of infiltration. The final infiltration rate was calculated as the difference between the application and runoff rates at the end of each irrigation. Since runoff rate is increasing this calculated infiltration rate will depend on the period of runoff. The

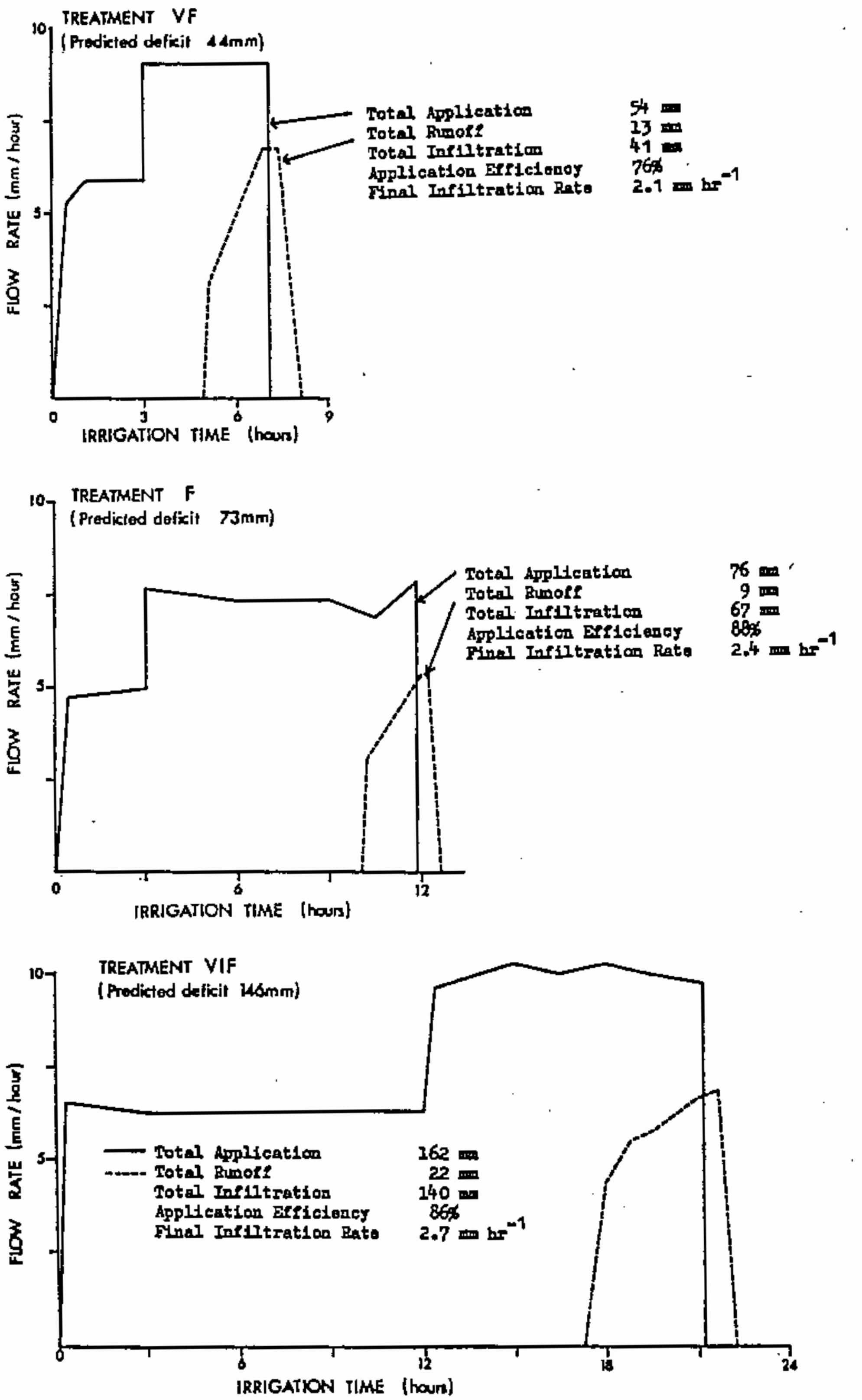

Figure 1. Typical water application and runoff curves for three treatments in 1983/84. The values listed are calculated from the curves.

final infiltration rate in all treatments was similar, and was therefore independent of irrigation deficit.

The parameters from all irrigations in 1983/84 are summarised in Table 3. The results in 1982/83 were similar but some irrigations were not measured and the data are therefore not presented.

Table 3. Mean irrigation parameters for each treatment in 1983/84.

Treatment	Mean Irrig. Deficit mm	Mean Total Infilt. mm	Mean Final Infilt. Rate mm hr^{-1}	Mean Applic. Effic. %
VF	51	49	2.3	74
F	75	70	2.6	88
IF	107	92	2.8	87
VIF	140	126	2.3	89

In 1983/84, total infiltration approximated the predicted deficit in the VF and F treatments. This was expected since total infiltration equals crop evapotranspiration if drainage is zero, and the predicted deficit also equals crop water use, if evapotranspiration rates are near potential. In the IF and VIF treatments mean total infiltration was less than the mean predicted deficit, possibly because our predictive model makes no adjustment for plant water stress or smaller plant effects in these treatments, and the model did not accurately predict the recharge after rainfall. Our model is intended to provide a reasonably reproducible basis for irrigation management across seasons in commercial applications and these weaknesses are unlikely to be significant in those applications.

The final infiltration rates are low and vary little across treatments, (Table 3). Since these rates are averaged over the length of the irrigation furrows, they are not simplistically related to soil hydraulic properties. However they are applicable to irrigation management and continued irrigation at rates of 2 to 3 mm hr^{-1} would contribute little to tbe total infiltration. Table 3 shows that the application efficiency can be high except in the VF treatment where the short period of each irrigation made limiting runoff difficult. High efficiency can be achieved by minimising runoff and as discussed previously, this management will have little effect on total infiltration.

These results support the hypothesis that cracks dominated the water entry process into these soils under flood irrigation, and that total infiltration was related to the volume of crack present at irrigation or to soil water deficit. The infiltration process once the cracks are filled with water was similar in all treatments.

Crop Water Use Efficiency

Data summarising crop water use efficiency, in terms of both total water use and irrigation water use, are presented in Table 4 for 1982/83 and 1983/84 seasons.

Table 4. Seasonal irrigation infiltration, yield per unit total water use and yield per unit irrigation applied at Emerald Research Station in 1982/83 and 1983/84.

Treatment (Irrigation Deficit) mm	Seasonal Irrigation Infiltration mm		Yield / Total Water Use kg/ha/mm		Yield / Irrig. Water Use kg/ha/mm	
	82/83	83/84	82/83	83/84	82/83	83/84
45	540	340	2.6	3.6	3.5	5.6
75	480	350	2.9	3.8	4.2	5.9
120		185		3.9		10.8
150	340	250	2.5	3.8	4.6	7.8

In both years the 45 mm treatment yielded less (by 7 to 9%) than the 75 mm treatment (Table 1). This yield loss could be attributed to waterlogging effects and resulted in lower water use efficiencies. The 150 mm treatment also yielded less than the 75 mm treatment in both seasons, by 22% in the low rainfall 1982/83 season and by 4% in 1983/84 (Table 1). Since the 150 mm treatment was irrigated only three times in 1982/83 and twice in 1983/84 waterlogging effects should be small and the yield decrease would be due mainly to water stress. While total water use efficiency varies little across treatments in each season, the efficiency of use of irrigation water increases as irrigation frequency decreases. The 120 mm treatment produced the highest efficiencies in 1983/84. Since previous discussion has indicated the benefits possible from decreasing irrigation frequency, this limited data set suggests an irrigation deficit of about 100 mm could produce high yields while decreasing risks from waterlogging. Additional benefits may also be obtained by changing the irrigation deficit with stage of growth.

Soil Aeration

Soil aeration was measured near the head-ditch and the tail drain in 1983/84 to study effects associated with period of inundation. Figure 1 shows that in the VF treatment water was in the furrows near the head ditch for about 7 hours compared to about 3 hours near the tail drain.

The soil air content data are summarised in Tables 5 and 6.

Table 5. Soil air content profiles one day after irrigation. Values are in $m^3\ m^{-3}$.

Soil Depth (m)	VF Treatment Head Ditch	VF Treatment Tail Drain	IF Treatment Head Ditch	IF Treatment Tail Drain
0 - 0.1	0.26	0.30	0.35	0.35
0.1 - 0.2	0.06	0.08	0.11	0.10
0.2 - 0.3	0.02	0.02	0.03	0.03

Table 6. Soil air contents ($m^3\ m^{-3}$) at a depth of 0.2 to 0.3 m during irrigation cycles.

Days After Irrigation	VF Treatment Head Ditch	VF Treatment Tail Drain	IF Treatment Head Ditch	IF Treatment Tail Drain
1	0.02	0.02	0.03	0.03
4	0.04	0.04	0.05	0.07
7	0.08	0.11		
11			0.09	0.10
1	0.03	0.06		

The soil air content profiles (Table 5) are similar to those reported for Narrabri cotton soils. Table 5 shows that the surface 0.1 to 0.2 m of the hill was well aerated but very low air contents occurred at 0.2 to 0.3 m depth. There was some indication of higher air contents near the tail drain but the effects of period of inundation appear to be small. The IF treatment had slightly higher air contents than the VF treatment and this was associated with slightly lower water contents.

Table 6 shows that soil air contents do increase with time but there were extended periods in both treatments when the air content was less than 0.1 $m^3\ m^{-3}$. Since the sampling of VF treatment included a complete irrigation cycle, Table 6 shows that at this soil depth the air content would be low throughout the season. It is also likely that a similar situation existed at other sil depths below 0.3 m. While the IF treatment had similar soil air contents, recovery to an adequate aeration status would occur later in the irrigation cycle. The implications of these low air contents are unclear since the treatments all produced high yields. The land slope of 1% provided excellent surface drainage and prevented prolonged surface pondage and associated waterlogging effects.

Soil Loss

Samples of runoff were collected at the Emerald Research Station site during the 1984/85 season and analysed for sediment concentration. Some preliminary data are available.

Typical sediment concentrations for pre-plant irrigation were 2 to 3 g/L and total soil loss during the pre-irrigation was calculated at about 0.8 t/ha. Pre-irrigation was followed by a rainfall of 21 mm. This event produced sediment concentrations of 3 to 8 g/L and a total soil loss of about 3 t/ha.

These results indicated the potential for a serious soil erosion problem in the Emerald Irrigation Area. Consequently a research project is being conducted during 1986/87 to quantify the extent of the soil erosion problem.

Cultivar Response

A progress report on this section of the project has been forwarded by Mr Keefer.

CONCLUSIONS

Some of the detailed data collected needs to be further developed and evaluated but the experiments have:-

* quantified the plant and soil responses to irrigation management.
* quantified cotton cultivar response to irrigation management.
* highlighted both the benefits of appropriate irrigation schedules and the costs of poor irrigation timing.
* shown the industry that reliable irrigation scheduling techniques are available.
* provided data which enable decisions to be made on the irrigation management best suited to a particular farm situation.
* shown that furrow irrigation management can be highly efficient and productive on these soils.

As a consequence irrigation management in the Emerald Irrigation Area is now generally soundly based and farm production is showing the benefits. The Emerald model has performed so well that its widespread testing in the industry is warranted.

PUBLICATIONS

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