Comparison of crop water use efficiency with rotation and continuous cropping in an irrigated vertisol

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Water use efficiency is a key issue for the Australian cotton industry. For the individual producer the focus is to maximise returns from a limited resource. However, the current debate on allocation of water between domestic, agricultural and environmental sectors, imposes additional significance to water use efficiency at the industry level. We are conducting a project that focuses on crop water use efficiency as a component of whole farm water use efficiency. This will be achieved by (i) identifying the current sources of variation in crop water use efficiency between production units and (ii) quantifying the contribution of rotation and tillage practices to the water use efficiency of irrigated or partially irrigated cotton crops. The aims are three folds:

1. To provide benchmarks which producers can use to identify the strengths and weaknesses in their own operation.
2. To identify crop management practices currently used in commercial operations associated with high crop water use efficiency.
3. To provide an assessment of the current performance of the industry as a whole as a measure against which progress can be identified.

Here we present some preliminary results on the effects of rotation options on the water use efficiency of subsequent cotton crops. Data from a long-term crop rotation trial conducted at the Australian Cotton Research Institute (ACRI) were analysed to find the effect of crop rotation and tillage systems on water use efficiency of the cotton crop. This experiment was established in 1985 and the details of this experiment are given elsewhere (Constable *et al.*, 1992). There were three major treatments between 1985 to 1993, which were (a) intensive tillage with cotton sown in October every year (b) minimum tillage with cotton sown in October every year and (c) a cotton/winter-wheat/summer-fallow sequence where cotton was sown with minimum tillage in October and wheat with no-tillage in May. Details of these treatments and land management practices are given in Hulugalle and Entwistle (1996). Since 1993 the rotation treatment (c) has been changed to minimum tillage continuous cotton. This provides us with an opportunity to test the persistence of rotational effects for a longer period.

Crop water use efficiency (CWUE) was calculated as the ratio of the lint yield of the crop to the amount of water used by the crop in transpiration and evaporation (evapotranspiration, ET). That is the amount of yield (lint) per unit of water actually used by the crop during the growing season;

Crop water use efficiency (kg/mm/ha) = lint yield (kg/ha) / ET (mm)

The yield/ET ratio considers only the water that was used as transpiration and evaporation and does not consider the total amount of water applied or pumped from the river, storage or bores. These measures introduce the engineering aspects of whole farm water use efficiency and are being examined in a complementary project conducted by the University of Southern Queensland.

The calculation of CWUE required the estimation of the actual amounts of crop water used during the growing season (ET). In this experiment, neutron probes were used to measure soil moisture content to 1.2 meters at intervals during the growing season in all treatments. This information was available only for the 93-94, 94-95 and 95-96 seasons. However, these readings are not sufficient to estimate the seasonal water use by the cotton crop, because they do not account for all the water used by the crop. To improve the accuracy of the estimation of water use by the crop, a spreadsheet was developed that calculates the total ET for the season using the values obtained from the neutron probes. Gaps in the records were filled using a soil water balance model, which simulates the water content of the soil profile on a daily basis based on climatic data and irrigations.

Differences in crop water use efficiency

The beneficial effects of crop rotation (cotton/winter-wheat/summer-fallow) on CWUE persisted for one year after this treatment was discontinued. In the 93/94 season, which was the first year after the rotation treatment ceased, crop water use efficiencies were significantly different ($P<0.05$) between treatments (Fig. 1). The minimum tillage rotation treatment had the highest CWUE of 1.03 bales/ML. The lowest CWUE of 0.76 bales/ML was obtained for the maximum tillage continuous cotton treatment. However, in the second and third year after the rotation treatment was stopped, the CWUE was not significantly different. This may be due to the disappearance of the rotational effect with time. It can be observed that the differences of CWUE values between treatments are declining with time.

While there were differences in CWUE between the treatments it is important to note that these did not result from differences in total water use but from the yield advantage conferred by the rotation treatment. The total water use (ET) for the three treatments did not differ significantly in any year (Table 1).

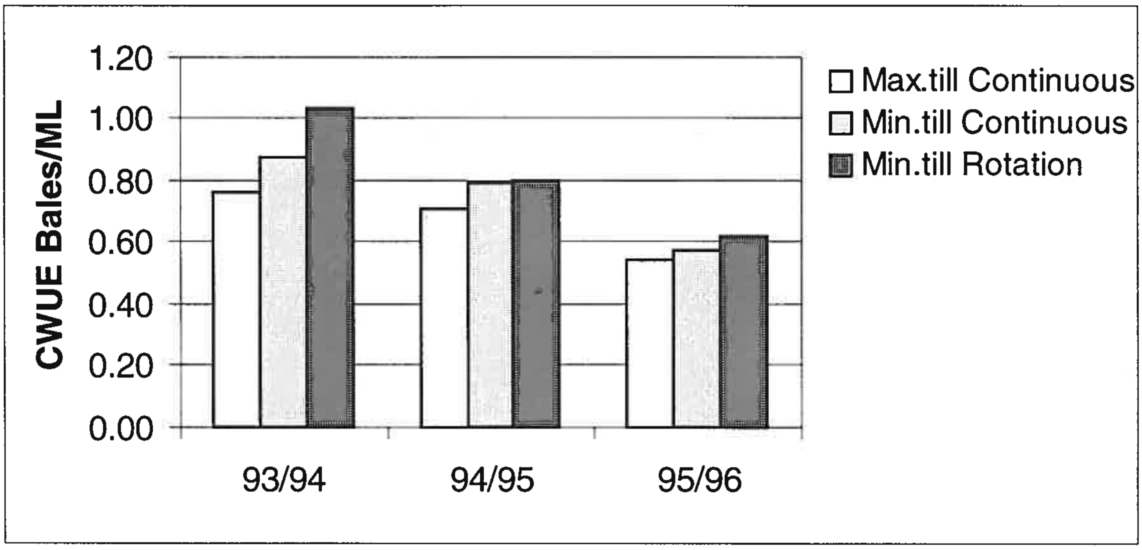

Fig 1. Crop water use efficiencies for the three seasons

Table 1 Yield, total water use and CWUE for the seasons

Treatments	93/94			94/95			95/96		
	Yield B/ha	**ET mm**	**CWUE B/ML**	**Yield B/ha**	**ET mm**	**CWUE B/ML**	**Yield B/ha**	**ET mm**	**CWUE B/ML**
Max.till. Continuous	5.7	750	.76	5.3	747	.71	4.3	782	.55
Min.till. continuous	6.6	757	.87	5.9	746	.79	4.5	797	.57
Min.till. rotation	7.6	733	1.03	6.3	786	.80	4.9	788	.62

Seasonal water use

The water used during the growing season from different sources; irrigation, rainfall and soil reserves were separately estimated (Table 2). The mean total seasonal water use for the three seasons was 746 mm, 760 mm and 789 mm for 93/94, 94/95 and 95/96 respectively. As expected, the proportion of the total water use that was contributed by irrigation varied dramatically from season to season depending on the amount of rainfall received during the season and the available soil reserves. However in any given year, the proportion of water used from irrigation did not vary between the treatments. Even though there were differences in CWUE between the treatments, this was not reflected in a difference in either total water use, or in the amount of water required from irrigation during crop growth.

Table 2. Proportion of crop water use derived from different sources for the different management treatments.

Season	Treatment	Rainfall	Irrigation	Soil reserves
93/94	max.till.cont.	0.36	0.37	0.27
	min.till.cont.	0.36	0.36	0.28
	min.till.rot.	0.37	0.35	0.28
94/95	max.till.cont.	0.37	0.48	0.15
	min.till.cont.	0.37	0.47	0.16
	min.till.rot.	0.35	0.50	0.15
95/96	max.till.cont.	0.58	0.12	0.30
	min.till.cont.	0.57	0.11	0.32
	min.till.rot.	0.58	0.11	0.31

Conclusion

These first results indicate that the rotation of cotton-wheat-fallow had beneficial effects on cotton water use efficiency when compared to continuous cropping. However it is important to note that this advantage was derived from the yield advantage conferred by the rotation and not from differences in water use.

The next stage of this project will include the analysis of the CRC farming system trials and other long-term rotation trials to continue investigating the effects of rotations on crop water use efficiency. We will also collect on-farm water management information from producers, which will be processed using approaches similar to those presented here. The aim will be to evaluate the current level of crop water use efficiency of the cotton industry.

References

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