

Deep Drainage and Irrigation Management

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Introduction

Deep drainage (DD), defined as water that passes beyond the root zone, can be an important contributor in terms of recharging ground water and also in transporting certain amounts of soluble salts away from the principal root zone. As such, DD is not necessarily an adverse component in the soil or landscape water balance. However, excessive DD is not only economically poor practice but may also lead to rising ground water tables and increased solute concentrations elsewhere in the landscape. The Australian cotton industry has become increasingly aware of the large amount of deep drainage (DD) in many of the heavy textured soils (Vertosols) that are flood irrigated (Silburn et al., 2004). This information contradicted earlier beliefs in the cotton industry that “clay soils don’t drain” (Hearn, 1998). A review by Silburn and Montgomery (2003) was instrumental in helping the industry change their view of “leak proof” Vertosols, though work by Dalton (2003) stated that “deep drainage in surface irrigated cotton systems has remained a contentious issue and one that has not been well understood or grasped by the Industry”. Seasonal deep drainage values under irrigated cotton of 100 mm and 200 mm have been calculated using volume balance measurements (Dalton, 2003), and Gordon (2000) measured seasonal deep drainage (using a large lysimeter) of 95 to 305 mm/year under drip irrigation and 165 to 180 mm/year under furrow irrigation on the Darling Downs, Queensland.

Methods

In the current study, a total of 28 drainage lysimeters (35 cm length of undisturbed soil core (30 cm diam.) installed at 150 cm depth) have been installed over 9 sites (Pampas, Macalister, Dalby, St George (North and South), Goondiwindi, Bogabilla (two adjoining fields) and Dirranbandi,

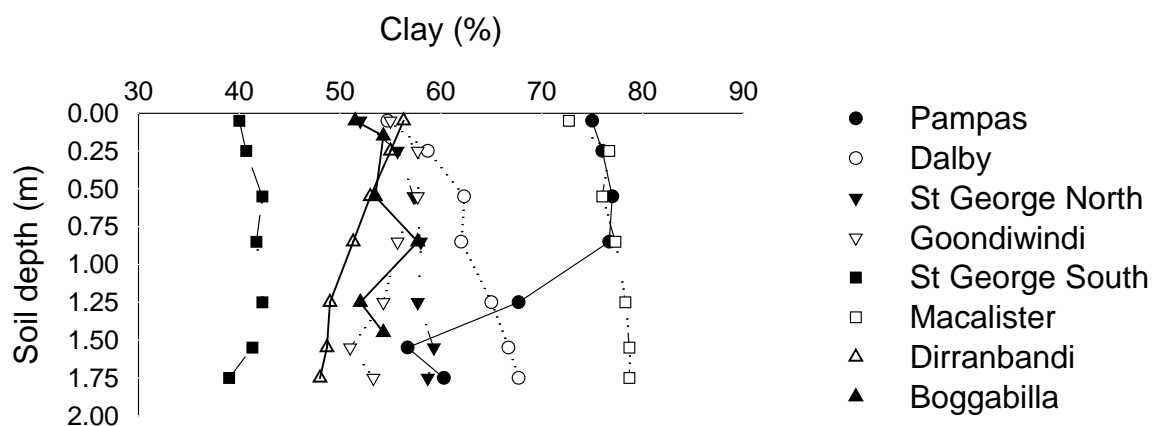


Figure 1. Clay content (%) to 1.8 m depth at each of the 8 drainage lysimeter sites. Data are the means of a soil core taken at the head, mid and tail locations in each monitored paddock, and a mean of all six locations at Bogabilla.

representing soils of the cotton area that have differences in terms of clay content (Fig. 1) and field lengths 500 to 1200 m. In each field a lysimeter has been installed in each of three locations - near the head ditch, middle of field and near the tail drain. A constant low suction applied to the base of

the lysimeter extracts the DD passing through the lysimeter, the DD water travels through a tipping bucket, the volume of water and event time are logged, before the water passes into a collection vessel. Up to four cotton irrigation seasons have been monitored at the sites (2002-03, 2003-04, 2004-05 and 2005-06). The Bogabilla site presents an opportunity to compare DD under a traditional furrow irrigated cotton field and an immediately adjoining cotton field irrigated with a lateral move irrigation machine. Each field at Bogabilla has three lysimeters, installed immediately opposite each other (just before the 2005-06 cotton season) at the head, mid and tail ditch locations of the furrow irrigated field. In addition to monitoring DD at all sites, the water quality (in terms of electrical conductivity) of both the irrigation waters applied and the water collected in the collection vessels has been collected at all sites, over several seasons.

Results

Table 1 presents DD (as the actual water volumes collected in the collection vessel at each of the in-field locations) measured to date. Three “trends” in the data can be identified. The interpretation of these trends is critical in terms of understanding and rationalising the “drivers” of DD (or the lack of DD); information that can then be passed on to the Australian Cotton industry in the form of packages of Best Management Practices. Opportunity will be taken at the Conference to present these results to the delegates, seeking their input into rationalising the various drivers of DD under cotton.

(i) The first trend can be described as a sequential reduction in DD from the head ditch to the mid-field location to the tail drain. This is evident on six occasions: at Macalister in the 2002-03 and 2005-06 seasons, Goondiwindi in the 2003-04 and 2004-05 seasons, St George (south) in the 2003-04 season and St George (north) in the 2005-06 season (Table 1). The trend may well be related to and reflect efficient irrigation practice where irrigation siphons are stopped as soon as the irrigation water reaches the tail ditch end. However, yield data from six of the DD sites across 3 seasons (collected by yield monitor or hand-picking in the absence of a yield monitor) shows up to a 25% reduction in yield from head to tail ditch in all fields sampled (Fig. 2). Hence, the low values of DD at the tail ditch end of cotton fields may well be reflecting serious under-watering of the crop in that part of the field.

(ii) The second trend is for large values of DD, in different field locations in the 2002-03 and 2003-04 seasons. The five largest values recorded were 316, 235, 196, 176 and 175 mm, where 100 mm equals 1 megalitre (ML); the first three at Goondiwindi (tail and mid in 2002-03 and head in 2003-04), the fourth largest at the Dirranbandi tail ditch location in 2003-04, and the fifth largest at the Macalister head ditch in the 2002-03 season. Using the growers’ estimates of water applied in two of these seasons show that the measured DD represents 51% and 37% of the applied water at the Goondiwindi head in 2002-03 and the Dirranbandi tail in the 2003-04 season, respectively. The trend seems well related to either large siphon size as well as to known, lengthy periods of inundation on specific occasions. The Goondiwindi site uses 75 mm siphons, and the combination of those with the very strong cracking (observed) for that soil may well account for that site having 5 of the 10 >100mm readings of DD. However, it should also be noted that values of DD >100mm (1 ML) are small, accounting for only 10 of 58 measured values (17%). On two occasions, large values of DD, 176 mm at Dirranbandi (tail) and 175 mm Macalister (head) can be attributed to long periods of surface water inundation. The Dirranbandi figure is linked to a continually blocked field

exit drain at that site (in that season, subsequently repaired) and the “flooding” of the field at Macalister prior to the commencement of drip irrigation for the remainder of the season.

(iii) The third trend, in contrast to the second trend, is for very small values of DD recorded across all sites, apart for St George (north and south). Small values include a total of 17 values of DD <10 mm that include 14 values of DD = 0. Interesting is the Macalister site, that recorded 175 mm of DD at the head location in the 2003-04 season and then only 5 mm DD at the same location in the 2004-05 season. The most obvious explanation is that water was in most short supply in the second season and very little water was applied to the crop, Most evident are the very low values of DD recorded across many sites in the 2005-06 season, reflecting a combination of limited water and above average normal in-season day and night air temperatures¹.

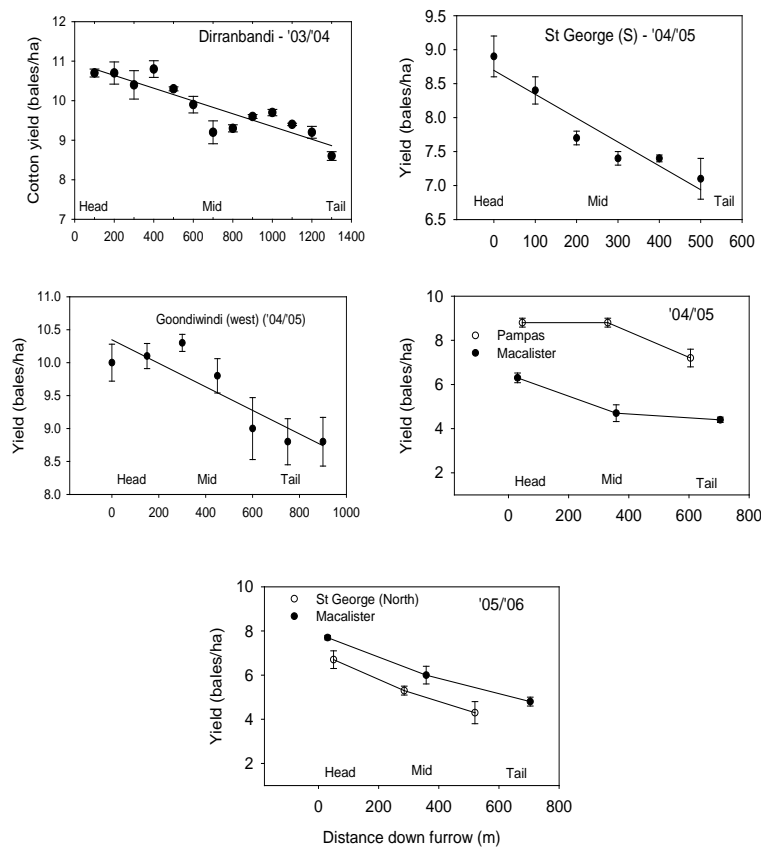


Figure 2. Cotton yield (bales per ha) from six lysimeter sites over three seasons. Data were collected using yield monitors on cotton pickers at each of the Dirranbandi, St George and Goondiwindi sites. Yield data are the average of four passes over the lysimeter locations for the duration of 1 minute travel as the picker advanced down the field between head and tail ditches. In the absence of yield monitors, yield estimates from Pampas, Macalister and St George (north) sites were derived from hand-picking 3 rows of 1 metre length, directly over the head, mid and tail lysimeters at each site. (The vertical bar at each data point indicates the standard deviations of the average yield).

Table 2 shows the potential for dramatically reduced DD from the use of a lateral move in comparison to traditional furrow irrigation. Apart from one occasion, at the head ditch end of the

¹ Wiggington and Foley (2006) present statistics to demonstrate the intensity of the 2005-06 cotton season: “...accumulated day degrees for Narrabri West PO from 10/05 to 2/06 were 1852; the greatest number (by 42) than ever recorded...the number of hot days...also high at 58...5 more than the 1957 high of 53 (greatest ever recorded).

field at the first irrigation (when there was 31 mm DD) there was no DD under the lateral move, as compared to seasonal totals of 105, 87 and 93 mm at the head, mid and tail locations in the adjoining furrow irrigated field. The DD data collected correspond well with the total amounts of water applied (in season) to each field (about 400 and 230 ML for the furrow and lateral move, respectively) that equates to 7 and 2.6 ML/ha. Crop yield was similar between the two fields.

Table 1. Deep-drainage as volumes collected (mm) and DD fraction (DDL) (DD as a percentage of water applied) at head mid and tail locations under irrigated cotton from seven monitoring sites.

Site	Season	Head		Mid		Tail	
		Vol.	DDL	Vol.	DDL	Vol.	DDL
Macalister	02/03 ¹	175		na*		51	
	03/04 ²	5		na*		33	
	04/05	41	12	101	30	0	0
	05/06	12	**	10	**	0	**
Goondiwindi	02/03 ¹	24		196		316	
	03/04 ²	235	51	101	22	21	5
	04/05	104	18	23	4	19	3
	05/06 ³	0	**	1	**	11	**
St George (S)	02/03	14		68		37	
	03/04	104	13	91	12	18	2
	04/05	40	4	92	9	50	5
	05/06 ⁷	5	**	37	**	33	**
St George (N)	2004 ⁴	24		55		1.6	
	05/06	27		22		0	
Pampas	04/05	71	7	106	11	62	6
	05/06 ⁵	0		0		0	
Dalby	04/05	39	8	95	20	34	7
	05/06 ⁶	0		0		0	
Dirranbandi	03/04	0	0	21	4	176	37
	05/06	0	**	0	**	0	**

* na = non-operational lysimeter; replaced before 2004-05 season

** Total irrigation water applied, not yet known.

Crops other than cotton: maize¹, sorghum², sunflower³ & wheat⁴, sorghum⁵ soybean⁶ and field pea⁷ (all irrigated apart from ⁵ that was rainfed) **Note:** lysimeters were installed at different sites in different years.

Table 2. Deep-drainage as volumes collected (mm) at head, mid and tail locations under two adjoining cotton fields at the Boggabilla site in 2005-06; F = furrow irrigated, and L = irrigated by lateral move machine.

	1 st Irrigation		2 nd Irrigation		3 rd Irrigation		4 th Irrigation		Total	
	F	L	F	L	F	L	F	L	F	L
Head	57	31	31	0	16	0	1	0	105	31
Mid	29	0	15	0	36	0	7	0	87	0
Tail	57	0	10	0	18	0	7	0	92	0

Figure 3 shows the dramatic increase in electrical conductivity (EC) between the irrigation waters applied to each field, and the water collected as DD leachate. The St George (north) site recorded a 97% increase in EC levels between water applied and the collected leachate. The smallest increase was 50% at Macalister, where the applied irrigation water (principally bore water) is inherently high in EC (3.4 ds/m). In terms of EC values, deemed critical to crop growth, values >4 ds/m are

regarded as deleterious to cotton growth and values >5 ds/m are deemed deleterious to aquatic ecosystem health (I. Gordon, pers. comm.).

Discussion

Considering that when irrigation water is not in short supply, cotton farms apply, on average, 5-6 ML/ha/season, deep drainage values of approximately 100mm (i.e. 1 ML/ha/season) suggest a potential gain in water use efficiency of about 20% is possible. This water could be used to expand the area planted to cotton, or better irrigate the current cotton area, or be returned as environmental flows, depending on the circumstances. At the other end of the spectrum, 1 ML/ha of DD can cause substantial groundwater rises in cotton areas serviced from surface water supplies. Examples of rising and/or spreading groundwater have been observed in monitoring bores in proximity to the Goondiwindi and St George irrigation areas. The quality of these groundwaters is another issue. The leachate data collected in the current project apparently demonstrates large salt loads being mobilised under all the sites being monitored for DD. The fate of these waters, once they by-pass the cotton root zone, is currently under investigation as a development of the current project. A combination of investigations of historic borehole logs and real-time logging of groundwater levels around selected irrigation areas will be employed to develop better understanding of the rate and trajectory of change, and the drivers of these changes. The outcome will be plausible estimates of the likely steady state water level rises - the bane of many irrigation areas in Australia. It is highly likely that by reducing DD with more efficient irrigation management, a win-win outcome will be achieved for both the grower and for natural resource management, hence fulfilling the overall project goal of “less water used more efficiently with reduced leakage to groundwater aquifers”.

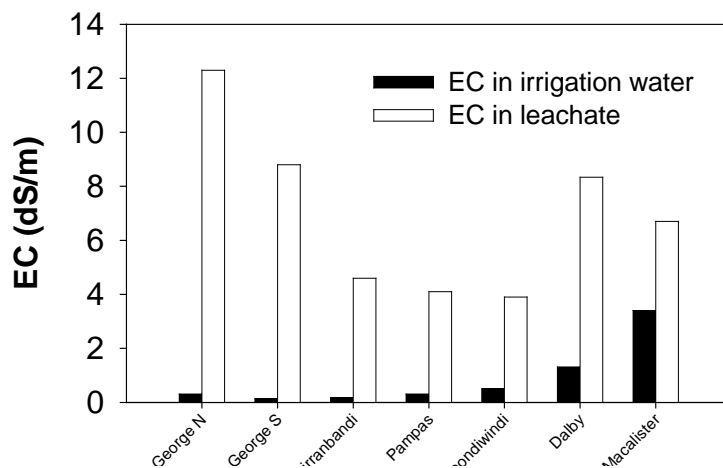


Figure 3. Water quality for the 2003-04 cotton season, in terms of electrical conductivity (ds/m), of both the irrigation waters applied at each lysimeter site and the water collected as deep drainage (leachate) in the lysimeter collection vessels. Data are the means of several irrigations and collection times for each water source.

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