Drainage under permanent beds in a furrow-irrigated Vertisol

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Abstract

Comparative studies of drainage and leaching under tillage systems in irrigated tropical and sub-tropical Vertisols are sparse. The objective of this study was to quantify drainage under cotton-based cropping systems sown on permanent beds in an irrigated Vertisol. Drainage and soil water storage were measured with the chloride mass balance method and neutron moisture meter, respectively, during the 2002-03, 2004-05, 2006-07 and 2008-09 cotton seasons in an on-going experiment in a Vertisol in NW NSW. The experimental treatments were: cotton monoculture sown either after conventional tillage or on permanent beds, and a cotton-wheat rotation on permanent beds where the wheat stubble was retained as *in-situ* mulch into which the following cotton crop was sown. In 2005, a split-plot design was superimposed on the existing experiment such that the main plot treatments were irrigation frequency (“frequent”, 7-14 day irrigation interval; “infrequent”, 14-21 day irrigation interval), and sub-plot treatments were the historical tillage system/crop rotation combinations. In comparison with cotton monoculture sown either after conventional tillage or on permanent beds, soil water storage, particularly during the early part of growing season when rainfall provided the major proportion of crop water requirements, and drainage were greatest when a cotton-wheat rotation was sown on permanent beds. Drainage was higher when irrigation frequency was higher. Drainage water losses in a furrow-irrigated Vertisol may be reduced and rainfall conservation improved by sowing a cotton-wheat rotation with *in situ* stubble retention under less frequent irrigation.

Key Words

Cotton, minimum tillage, farming systems, rotation, Vertosol

Introduction

Land preparation methods used in irrigated cotton (*Gossypium hirsutum* L.) production in Vertisols range from intensive to minimum tillage or permanent beds (McKenzie *et al*., 2003). By definition, a permanent bed implies that the bed stays in place for several seasons in comparison with being ploughed down and reconstructed every year as with more intensive tillage systems (McKenzie *et al.,* 2003; (Hulugalle and Daniells, 2005). Long-term use of permanent beds can lead to significant improvement in soil physical, chemical and biological properties (Hulugalle and Daniells, 2005).

Comparative studies of drainage and leaching under tillage systems in irrigated tropical and sub-tropical Vertisols are sparse. Research has, however, been conducted in rainfed Vertisols. In tropical central Queensland, Tolmie and Radford (2004) observed that, compared with conventional tillage, deep drainage estimated using the chloride mass balance approach was greater with zero tillage and suggested that this was due to a higher numbers of drainage pores (McGarry *et al*., 2000). Dalal (1989) inferred from soil chloride profiles that that drainage and leaching were greater under zero-tillage in southern Queensland. Drainage and leaching in fine-textured, swelling soils from temperate regions have also been reported to be greater under zero- or minimum-tillage than under intensive tillage (Addiscott and Thomas, 2000; Catt *et al*., 2000; Shipitalo *et al*., 2000). These authors suggested that the major pathways of nutrient and water movement under dry conditions were soil cracks and fractures, whereas under wet conditions, particularly in zero- and minimum-tilled soil, macropores created by earthworms and plant roots dominated. In summary, although direct measurements of drainage and leaching in Vertisols under varying tillage systems are sparse, inferences made from salt distribution in the soil profile suggests that drainage and leaching are likely to decrease with increasing tillage intensity. Drainage pathways in Vertisols may also differ with varying tillage intensity. The objective of this study was to quantify drainage under cotton monoculture sown after conventional tillage or on permanent beds, and under cotton in a cotton-wheat rotation sown on permanent beds.

Materials and methods

The experimental site was located at the Australian Cotton Research Institute, near Narrabri (149°47'E, 30°13'S) in New South Wales, Australia. Narrabri has a sub-tropical, semi-arid climate and experiences four distinct seasons with a mild winter and a hot summer. The hottest month is January and July the coldest. Mean annual rainfall is 593 mm. The soil at the experimental site is an alkaline, self-mulching, grey clay, classified as a fine, thermic, smectitic, Typic Haplustert (Soil Survey Staff, 2006). Mean particle size distribution in the 0-1 m depth was: 64 g/100g clay, 11 g/100g silt and 25 g/100g sand. ESP values were of the order of 10 in the 0.6-1.2 m depth but were < 6 in the shallower depths.

Drainage was measured during the 2002-03, 2004-05, 2006-07 and 2008-09 cotton seasons in a long-term experiment, est. 1985 (Constable *et al*., 1992) The experimental treatments were: cotton monoculture sown either after conventional tillage (slashing of cotton plants after harvest, followed by disc-ploughing and incorporation of cotton stalks to 0.2 m, chisel ploughing to 0.3 m followed by bed construction) or on permanent beds (slashing of cotton plants after harvest, followed by root cutting, incorporation of cotton stalks into beds, and bed renovation with a disc-hiller), and a cotton-wheat rotation on permanent beds where the wheat stubble was retained as *in-situ* mulch into which the following cotton crop was sown laid out in a randomized complete block design with four replications. The rows (beds) were spaced at 1-m intervals with vehicular traffic being restricted to the furrows. Cotton was sown during October and picked during May, and wheat was sown during May or June. Wheat was sown on beds and in furrows. Cotton and wheat rotation crops were furrow irrigated at an average rate of 1 ML/ha (100 mm) subject to water availability, rainfall and soil water content at intervals of approximately 7-14 days. In 2005, a split-plot design with two replications was superimposed on the existing experiment such that the main plot treatments were irrigation frequency (“frequent”, 7-14 day irrigation interval; “infrequent”, 14-21 day irrigation interval), and sub-plot treatments were the historical tillage system/crop rotation combinations. Quality of irrigation water is given in Table 1. Individual plots were 190 m long and 36-44 rows wide.

Table 1. Seasonal average of irrigation water quality during 2002-03, 2004-05, 2006-07 and 2008-09 cotton seasons. EC_w, electrical conductivity; SAR, sodium adsorption ratio.

Season	pH	EC_w	Cl	Ca	Mg	K	Na	NO_3-N	SAR
		(dS/m)	(mg/L)						
2002-03	8.3	0.26	12.0	14.0	13.4	2.7	19.4	21.8	0.9
2004-05	8.1	0.30	18.2	23.0	14.9	3.8	38.0	5.2	1.5
2006-07	7.8	0.39	24.1	23.6	16.1	3.6	111.4	14.4	4.3
2008-09	8.1	0.38	24.3	31.8	15.3	6.0	47.4	24.4	1.7

Soil chloride concentration was evaluated in samples taken after cotton sowing and after cotton picking. Six 50-mm diameter soil cores were extracted from each plot with a tractor-mounted soil corer from the 0-0.30 m, 0.30-0.60 m, 0.60-0.90 m and 0.90-1.20 m depths during the 2002 and 2003, and 0-0.15 m, 0.15-0.30 m, 0.30-0.45 m, 0.45-0.60 m and 0.60-1.20 m depths subsequently. Air-dried soil was passed through a 2 mm-sieve and chloride concentration determined by $AgNO_3$ titration (Loveday, 1974). Soil water content in the 0.20-1.20 m depth interval was measured at 7-10 day intervals during the cotton season with a neutron moisture meter which had been calibrated *in-situ*. Soil water content in the soil surface was measured gravimetrically. Drainage was estimated with the chloride mass balance method assuming either steady state or transient state conditions (Weaver *et al*., 2005). Results were analysed using analysis of variance, and means and standard errors of the means calculated.

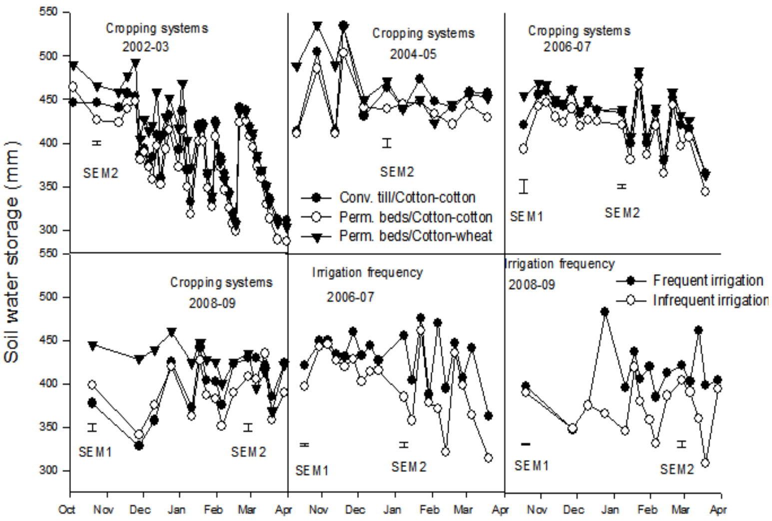

Figure 1. Effects of cropping system and irrigation frequency on soil water storage in the 0-1.2 m depth. SEM1, for first data point; SEM2, all other data points.

Results and discussion

Soil water storage

Among cropping systems, soil water storage was generally highest under the cotton-wheat rotation sown on permanent beds (Figure 1). During growing seasons when rainfall was the major source of early season water for the cotton crop (2004-05, 2008-09) soil water storage was greatest under the cotton-wheat rotation sown on permanent beds (Figure 1). When a major proportion of early season water requirements were supplied by irrigation (2002-03, 2006-07), however, differences in soil water storage among cropping systems were smaller. The higher early season soil water storage under the cotton-wheat rotation when rainfall was adequate reflects the greater rainfall infiltration (Silburn and Glanville, 2002) and lower evaporation resulting from the *in situ* wheat stubble, and better soil water storage capacity due to its greater subsoil porosity (Hulugalle and Daniells, 2005; Hulugalle *et al*., 2005). As the season progressed, and water used by the cotton increased (Tennakoon and Hulugalle, 2006), with much of it coming from irrigation, the magnitude of the differences among treatments decreased or disappeared.

In summary, the rainfall harvesting and storage capability of a cotton-wheat rotation where cotton is sown into *in situ* wheat stubble is superior to cotton monoculture sown either on permanent beds or after conventional tillage. Reduction in water availability due to a combination of drought and legislation has become a major constraint in irrigated farming systems in many Australian states during the past decade (DECC, 2009; eWater CRC, 2009). Consequently, management systems which conserve all rainfall received *in situ*, thus reducing the requirements for irrigation water, can contribute greatly to the sustainability of irrigated farming systems.

Drainage

Drainage, particularly in the deeper depths, was highest ($P < 0.01$) during the cotton seasons of 2004-05, 2006-07 and 2008-09 under the cotton-wheat rotation on permanent beds (Figure 2). This reflects the distribution of drainage pores in these treatments (Hulugalle *et al*., 2005). During the 2002-03 cotton season, however, subsoil drainage did not differ significantly among treatments, although there was a trend towards higher values under permanent beds. Drainage also varied significantly ($P < 0.001$) with depth, with that out of the 1.2 m being lowest. Drainage was least during the 2002-03 season, presumably because water inputs were relatively low.

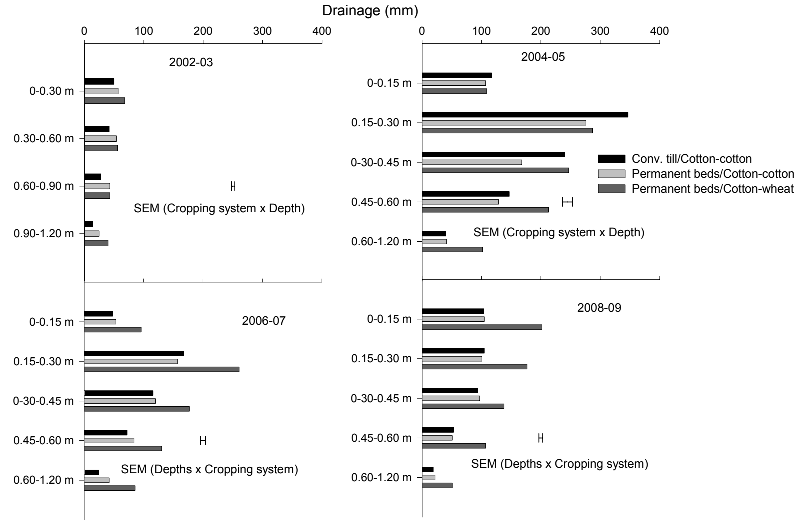

Figure 2. Effect of cropping system on drainage. Horizontal bar is SEM.

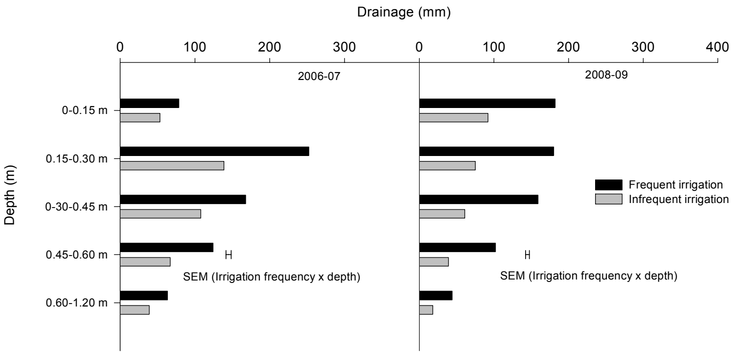

Figure 3. Effect of irrigation frequency on drainage, 2006-07 and 2008-09 seasons. Horizontal bar is SEM.

Drainage in all depths was greater ($P < 0.05$) with a higher irrigation frequency than with an "infrequent" irrigation frequency (Figure 3) during the 2006-07 and 2008-09 cotton seasons. This is not unexpected, as the proportions of water (as a fraction of seasonal rainfall + irrigation) which drained out of the root zone were similar with both irrigation frequencies. However, the pathways of drainage may have differed between the two treatments. The drier soil profile in the infrequently irrigated treatments would have resulted in more cracking, and consequently drainage via the soil cracks would have been the dominant pathway (Favre *et al*., 1997; Novak *et al*., 2000) whereas with frequent irrigation and wetter soil, more water would have drained by matric flow.

Conclusions

In comparison with cotton monoculture, soil water storage, particularly during the early part of growing season when rainfall provided the major proportion of crop water requirements, and drainage were greatest when a cotton-wheat rotation was sown on permanent beds. Drainage was higher when irrigation frequency was higher, *viz*. 7-14 day irrigation interval. Drainage water losses in a furrow-irrigated Vertisol may be reduced and rainfall conservation improved by sowing a cotton-wheat rotation with *in situ* stubble retention under less frequent irrigation.

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