

SALT, NUTRIENT AND PESTICIDE LEACHING UNDER A SODIC VERTISOL IRRIGATED WITH GROUND WATER IN NORTH-WEST NEW SOUTH WALES

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Abstract

Deep drainage out of the crop root zone can lead to salt, nutrient and pesticides moving into ground water, possibly contaminating drinking water and river systems. The objective of this study was to estimate deep drainage under three cropping systems and quantify salt, nutrients and pesticides leached out of the root zone. The residual effects of three cropping systems, continuous cotton, cotton-dolichos and cotton-wheat, on deep drainage, nutrient, salt and pesticide leaching were evaluated from 2000 to 2002 using ceramic cup samplers and chloride mass balance models on a sodic Vertisol. Soil water samples were analysed for Cl, Na, NO₃-N, K, Ca and Mg. Soil was sampled in transects to a depth of 1.2 m and analysed for chloride and pesticide concentrations. Drainage estimates were used to quantify salt and nutrient movement beyond the root zone. Residual effects of the rotations were reflected in deep drainage with the ex-continuous cotton and ex-cotton-wheat the highest and the ex-cotton-dolichos the lowest. Wheat resulted in the highest drainage during the cotton-wheat-sorghum rotation sown from 2000 to 2002. Organochloride pesticides were absent in soil sampled from 1.2 m after the 2000/2001 cotton. Deep drainage reflected residual effects of rotation systems, but was improved by sowing wheat in 2001. The absence of pesticides in the deep subsoil suggests that there would be no impact on groundwater in this site.

Additional Keywords: chloride mass balance, sodicity, drainage, nutrients, salinity, pesticides

Introduction

The estimation of deep drainage and the evidence for salts, nutrients and organochloride pesticides leaching in Australian Vertisols has been reported by several researchers (Keating *et al.* 1996; Moss *et al.* 1999; Hulugalle and Weaver 2000; Gordon 2000; Zischke and Gordon 2000; Ghadiri and Rose 2001; Tolmie *et al.* 2002; Hulugalle *et al.* 2004). Deep drainage in Vertisols beyond the root zone of crops suggests that salts, nutrients and pesticides may be accumulating at depth or even moving into groundwater. The leaching of salts from the root zone is essential for sustainability, although nutrients become inaccessible and a cost to the farmer (Hulugalle *et al.* 2004). The objective of this study, therefore, was to estimate drainage and quantify salt, nutrient and pesticide leaching in a cotton-wheat-sorghum rotation from 2000-2002 in the northwest of NSW, Australia.

Materials and Methods

Experimental Site

The experiment was located at 'Beechworth', Merah North in north-western New South Wales (149°18'E, 30°11'S), Australia, which has a semi-arid climate. The experimental site experiences four distinct climatic seasons with a mild winter and a hot summer. The hottest month is January (mean daily maxima and minima of 34°C and 19°C, respectively), and the coldest is July (mean daily maxima and minima 18°C and 3°C, respectively). In north-western NSW, cotton is usually sown in late October and harvested in late April of the following year. Mean annual rainfall is 616 mm. The soil is a deep uniform grey clay classified as a fine, thermic, montmorillonitic, Typic Haplustert (Soil Survey Staff 1996). The mean particle size distribution in the 0-1.2 m depth was 67% clay, 10% silt and 23% sand; pH (in 0.01M CaCl₂) was 7.4 and soil organic C 0.49%. The exchangeable sodium percentage for depth increments 0-0.3 m, 0.3-0.6 m, 0.6-0.9 m and 0.9-1.2 m were 8, 13, 16 and 17, respectively. The K, Ca, Mg, Na and Cl contents in the 0-1.2 m depth prior to sowing cotton in 2000 was 6, 138, 66, 23 and 14 t/ha, respectively. The experimental site is irrigated with poor quality bore water.

There were three cropping sequences: continuous cotton, cotton-wheat, and cotton-dolichos sown since 1993. After 2000 the three treatments were sown with cotton during 2000/2001, wheat during 2001 and sorghum during 2001/2002 with stubble being incorporated. Each 400-m long plot consisted of 24 rows spaced 1 metre apart. There were nine irrigations during the 2000/2001 cotton season and three during the following wheat crop. The cotton received 130 kg N ha⁻¹ and the wheat received 66 kg N ha⁻¹. The 2001/2002 sorghum crop received five irrigations and 43 kg N ha⁻¹ after sowing.

Soil cores (50-mm i.d.) were extracted pre and post crop from a diagonal transect in each treatment. Six cores were extracted from each treatment, and divided into 4 depths increments: 0-0.3 m, 0.3-0.6 m, 0.6-0.9 m and 0.9-1.2 m. The soil was air-dried, ground by hand and passed through a <2mm sieve. A blotting paper tension table (Beatty and Loveday 1974) was used to form a saturated paste. An extract from the saturated paste was obtained and titrated through a Buchler chloridimeter to determine the concentration of chloride in the saturated extract, which was used to determine the chloride in the drainage water and soluble chloride content. Water samples were taken from the head-ditch during each irrigation and analysed for chloride by titration (Beatty and Loveday 1974). At each sampling site in the diagonal transect in each treatment a neutron probe access tube and ceramic cup sampler were installed to a depth of 1.2m. The soil water content in the 0.2-1.2 m depth was determined using a neutron moisture meter which had been calibrated *in situ* (Greacen 1981). Soil was sampled from the surface 0-0.05 m at the same time for gravimetric determination of soil water content. Soil water samples were removed as well and analysed for Cl by titration, nitrate-N with a nitrate probe calibrated with the Kjeldahl method and K, Ca, Mg and Na using atomic absorption spectrophotometer. The profile water content was used to estimate infiltration of irrigation and rainfall when both events occurred together. The data collected was used in chloride mass balance models, a steady state model for the cotton during 2000/2001 and sorghum during 2001/2002 (Willis 1995) and a transient state model for wheat during 2001 (Slavich *et al.* 1995). This was because Weaver *et al.* (2004) had shown that chloride flux was in steady state for the cotton and sorghum and in transient state for the wheat. The deep drainage estimates and seasonal nutrient and salt concentrations, which were determined in the soil water extracted at 1.2 m, were used to calculate the seasonal nutrient and salt leaching out of the cotton root zone.

Pesticide Analysis

100ml of Hexane-Acetone AR mixture (50/50) was added to 2 grams of air dry soil, which was sampled from 0.9-1.2 metres post cotton season during 2000/2001, and was passed through a 2 mm sieve, and sonified for 30 min. The mixture was left to settle for 1 minute and the supernatant liquid was poured into a 250 ml separating funnel, the sediment was rinsed with Hexane. The separation process involved washing with 100ml of deionised water in 20 ml aliquots until emulsion layer disappeared. The aqueous phase was discarded and the hexane mixture was passed through a glass funnel containing a glass fibre filter paper and 20 grams of anhydrous sodium sulphate. The mixture was evaporated down to about 1 ml on a steam bath. A chromatographic column was made by adding 5 grams of deactivated Florisil and approximately a 2 cm layer of anhydrous sodium sulphate. The column was wash with 40 ml of hexane, completely soaking up the Florisil. The extract was transferred to the top of the column and with it completely inside the anhydrous sodium sulphate layer, was washed with 130 ml of hexane/diethyl ether AR (85/15) in two or three aliquots. The eluent was collected and evaporated down to about 1 ml on the steam bath and transferred to a reaction vial and evaporated down to about 3 ml. The sample was then analysed by gas chromatography. The standard was an environmental protection authority (EPA) method 608 for pesticides (2000 µg/L), 2 ml of which was added to a previously analysed soil sample (2 grams). The spiked sample followed the same procedure as the other soil samples.

Results and Discussion

Deep drainage estimates

Deep drainage out of the 1.2 m depth showed that the ex-continuous cotton > ex-cotton-wheat > ex-cotton-dolichos during the cotton-wheat-sorghum rotations from 2000-2002 (Table 1). Drainage was greatest for all three ex-treatments during the wheat in 2001, followed by the cotton during 2000/2001 and then the sorghum during 2001/2002. Salt and nutrient leaching followed the same trend (Table 2). The pattern of drainage between the ex-treatments may be due to several reasons. The concentration of chloride in the soil pre and post cotton during 2000/2001 changed from 7 to 7 t/ha, 10 to 12 t/ha and 25 to 29 t/ha for the ex-continuous cotton, ex-cotton-wheat and ex-cotton-dolichos, respectively. The ex-continuous cotton received frequent irrigations every year from 1993 to 2000, leaching more salts and nutrients through the profile (Table 2). There was little change in the chloride concentration pre and post cotton during 2000/2001, suggesting that the chloride mass balance was in steady state conditions and good drainage present. The ex-cotton-wheat was fallowed every second summer and did not receive high water inputs when compared to the ex-continuous cotton. Rotation with wheat has been shown to significantly improve sub-soil structure of Vertisols through a combination of frequent and intensive wetting and drying cycles and establishment of stable biopores (Hulugalle *et al.* 2002). This is probably the reason for higher drainage during the wheat in 2001 when all three treatments were sown with a cotton-wheat-sorghum rotation. Poor soil structure in the ex-cotton-dolichos rotation probably led to impeded drainage (Hulugalle *et al.* 2002).

The advantage of deep drainage is the removal of salts out of the root zone, although the disadvantage is the loss of nutrients. This is a financial cost to the farmer that cannot be avoided.

Table 1. Seasonal water inputs (irrigation + rainfall (mm)) and resulting deep drainage out of the 1.2 m depth (mean ± sd) at ‘Beechworth’, Merah North.

Season	2000/2001	2001	2001/2002
Irrigation+Rain input	1000 mm	630 mm	397 mm
ex-treatment/Crop	Cotton	Wheat	Sorghum
ex-continuous cotton	64 ± 31	99 ± 82	47 ± 42
ex-cotton-wheat	55 ± 36	83 ± 71	40 ± 25
ex-cotton-dolichos	14 ± 11	23 ± 8	12 ± 3

Leaching Fractions

The leaching fractions (LF) for the ex-continuous cotton, ex-cotton-wheat and ex-cotton-dolichos was 6.4, 5.5 and 1.4 % during the cotton in 2000/2001, 15.7, 13.2 and 3.7 % during the wheat in 2001 and 11.9, 10.1 and 3.0 % during the sorghum in 2001/2002, respectively. The rotation with wheat during 2001 for all ex-treatments improved the leaching fraction, although residual treatment effects remained even during the sorghum in 2001/2002.

Nutrient Leaching

The ex-continuous cotton leached the highest amount of salts and nutrients (Table 2). The ex-cotton-wheat leached the least amount of salts but more nutrients when compared with the ex-cotton-dolichos for NO₃-N, K and Mg (Table 2). The ex-cotton-dolichos leached the least NO₃-N.

Table 2. Seasonal salt and nutrients (kg/ha) (mean ± sd) leached out of the 1.2 depth at ‘Beechworth’, Merah North during cotton in 2000/2001.

	Cl	NO ₃ -N	K	Ca	Mg	Na
ex-continuous cotton	8629 ± 6887	106 ± 40	3 ± 1	57 ± 44	53 ± 14	620 ± 292
ex-cotton-wheat	657 ± 453	20 ± 9	0.5 ± 0.1	4 ± 3	12 ± 3	87 ± 37
ex-cotton-dolichos	1180 ± 197	8 ± 3	0.4 ± 0.2	12 ± 8	11 ± 5	98 ± 22

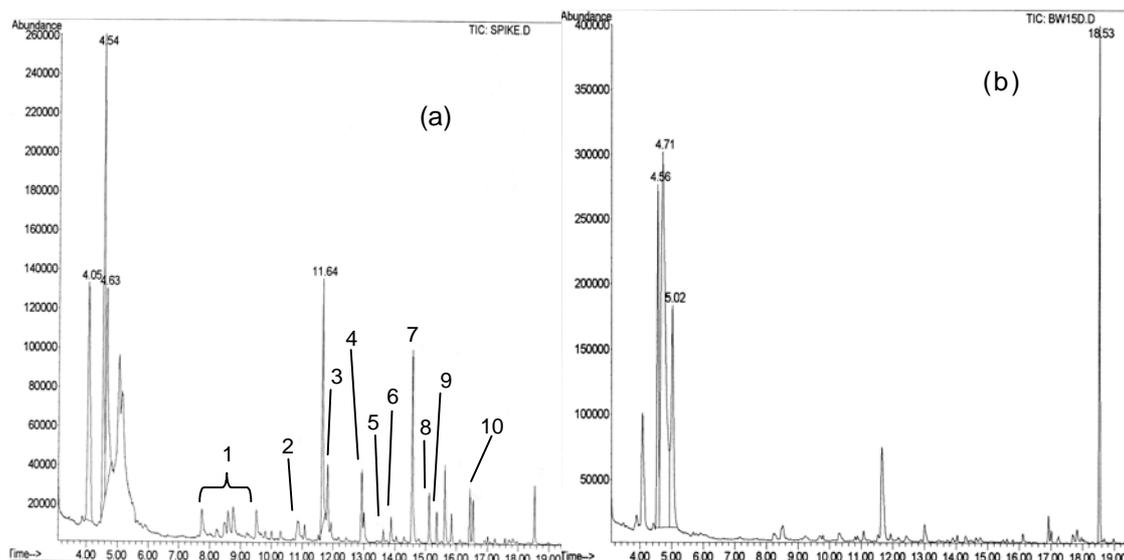


Fig. 1 Gas Chromatography / Mass Spectrometry (GC/MS) output for a spiked sample (2000 µg/L) with organochloride pesticides (a) (1 α -Lindane, 2 Heptachlor, 3 Aldrin-R, 4 Heptachlor Epoxide, 5 DDMU, 6 Endosulfan I, 7 PP'-DDE, 8 Endrin, 9 Endosulfan II, 10 Endosulfan sulphate) and (b) a GC/MS from a soil sample taken post cotton during 2000/2001 at 1.2 metres.

Pesticides

The peaks that were present in the spike matched those in the EPA 608 standard and are shown in figure 1 (a). In Figure 1 (b) there was no evidence of any of these peaks (pesticides) which indicated the absence of organochloride

pesticides at 1.2 metres. It appears, therefore, that they are not leaching into groundwater systems in grey Vertisols. Keating *et al.* (1996) did not find any evidence of organochloride pesticides in Queensland groundwater. Further chromatographic analysis of soil and water samples and identification of the peaks seen in Figure 1(b) are underway. Non-organochlorine pesticides currently in use by farmers may have been leached into the soil profile.

Conclusions

Residual effects of rotation systems were reflected in deep drainage during the cotton-wheat-sorghum rotation from 2000 to 2002. High concentrations of salts and nutrients were leached out of the root zone from the better-structured treatments. Rotation with wheat in 2001 improved drainage in all three ex-rotation systems. The absence of organochloride pesticides in the deep subsoil suggests that there would be no impact of this group of pesticides on groundwater systems in this site.

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