

The effect of drip emitter rate on bromide movement in a drip irrigated vineyard

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Abstract

A field-scale solute transport experiment was undertaken using a bromide tracer to understand leaching in soils of drip irrigated vineyards. The effect of applied irrigation volume was investigated with 3 distinct emitter rates (treatments) of 1 L/h (T1), 1.6 L/h (T2) and 2.3 L/h (T3). Depth concentration profiles of bromide and the recovered mass of applied bromide showed just one significant difference (times 2) between the irrigation volume treatments. Soil water content remained very high throughout the experiment, which indicates that antecedent soil moisture is a major factor that strongly influences soil leaching rates and patterns. These results on bromide movement are indicative of nitrate and salt movement and suggest that close attention needs to be placed on irrigation timing and soil water content to avoid excessive leaching, especially when fertiliser is applied so that nutrients are kept within the root zone.

Key Words

Drip emitter rate, irrigation volume, bromide tracer, field solute transport, nutrient movement, soil water.

Introduction

Scarcity of water in many parts of the world has led to increased interest and indeed greater need for improvements in the management and distribution of water resources for irrigation. In some countries the water situation is critical and it is necessary to increase global food production to reduce the widespread hunger. Increasing water use efficiency can be achieved by several means, including system design, soil moisture monitoring, irrigation scheduling and reducing loss pathways such as drainage beyond the root zone. In an irrigated production system nutrient use efficiency is strongly related to water use efficiency. Indeed fertilizer is often applied at the same time or close to when a field is irrigated. While soil water and nutrient supply are often separated into two distinct problems, they are actually closely associated. We believe that for many irrigated agricultural production systems there is a great need to focus on soil nutrient status and soil water together.

To further understand the relationship between soil water dynamics and nutrient movement a study was undertaken on a drip irrigated vineyard in the Riverina wine region of NSW Australia. Recently, this region has experienced constraints on water allocations for irrigation and irrigation water costs have risen. In addition, over the last 10 years there has been a large increase in the area of drip irrigation systems (while the area of furrow irrigated vines has declined). Hutton *et al.* (2007) report that there are large differences in the application rates of fertilizer and evidence of inefficient fertilizer application practices. Therefore, there is a major need for improved understanding on fertilizer application for drip irrigation systems. This paper seeks to increase understanding on the movement of nutrients and solutes from drip irrigated vineyards. In that context, this work aims to investigate the effect of irrigation volume on the leaching characteristics of a tracer during the growing season. A tracer approach was chosen as it relates to the movement of nutrients (such as nitrate) and salts. The objectives of this experiment were to: 1) observe the spatial and temporal leaching characteristics from a surface applied drip source; 2) calculate the water and nutrient use efficiency of different irrigation volumes; and 3) estimate the risk of nutrient and solute leaching.

Methods

Site description and instrumentation

The experimental site is located within a 2.7 ha commercially managed vineyard near Griffith, NSW, Australia (34° S, 146° E). The vineyard is drip irrigated and was planted with Chardonnay grapes in 2002 at a row spacing of 3.6 m and vine spacing of 2.5 m using a single cordon, spur pruned growing system. This site has low relief which is typical for the extensive Riverine plains that are distributed across the south and west of NSW. The landscape contains deep alluvial sediments with some sandy prior streams which were deposited by the action of ancient streams. At the surface (0 – 15 cm) the soil is a clay loam texture and

below this the profile becomes a sandy clay loam. The soil at the experimental site is classified as a Brown Dermosol (Isbell 2002). This soil drains well and is commonly found across this region. The soil bulk density was measured using the core method (McKenzie *et al.* 2002) and the soil particle size analysis was determined using the hydrometer method. Soil chemical and physical properties at 6 depths are given to characterise the experimental site (Table 1).

Table 1. Soil chemical and physical properties by depth for the field experimental site

Depth (cm)	EC (dS/m)	pH (1:5 water)	Bulk density (g/ cm ³)	Sand (per cent)	Silt (per cent)	Clay (per cent)
0-10	0.13	7.09	1.40	48.5	8.9	42.6
10-20	0.21	7.19	1.40	40.3	7.9	51.9
20-45	0.48	7.24	1.46	28.9	7.7	63.3
45-60	0.64	8.21	1.27	27.9	11.3	60.9
60-75	0.46	8.91	1.30	31.6	10.5	57.9
75-100	0.36	9.44	1.37	40.1	11.8	48.2

Irrigation was controlled by the vineyard property owner and was scheduled and managed on a commercial basis. The decision to irrigate was determined according to weather conditions and crop condition, although at certain times the irrigation schedule was fixed. There were three irrigation treatments (T1, T2 and T3) that were established and varied according to different drip emitter rates (1.0, 1.6 and 2.3 L/h). Each treatment received irrigation for the same period of time. Irrigation commenced on 26 September 2008 and finished on 30 April 2009. A randomised complete block design was chosen and each irrigation treatment was replicated four times. Each plot was 25 m long and three vine rows wide. To maintain regular observations on the dynamics of the soil moisture granular matrix resistance sensors (Watermark Irrrometer Co. USA) were installed on 26 September 2008 at three depths (0.25, 0.5 and 0.75 m) in the middle row of each plot. These sensors recorded soil matric potential (kPa) every 2 h which was stored on a field-based data logger.

Tracer application

Bromide (Br⁻) was applied as an aqueous solution at 32 mg Br⁻/cm² (as KBr) on 7 November 2008 (close to flowering when fertilizer is typically applied). This is a comparable level to that used in other tracer studies (Tilahun *et al.* 2005). An animal health vaccinator (NJ Phillips Pty Ltd) was used to inject 5 ml doses 5 cm apart in a square grid layout (625 cm²) at a depth of 20 mm below the soil surface. The centre of the injection grid was placed directly underneath a drip emitter. There were 15 injection sites in each plot to allow for a total of 5 separate sampling times. Due to the destructive nature of the soil core sampling there was no repeated sampling.

Soil sampling and laboratory analysis

Soil core samples were taken at predetermined locations along each plot on five occasions (7, 26, 46, 83 and 131 days after the Br⁻ was injected) during the 2008/09 growing season. Each coring point was directly under the centre of the Br⁻ injection grid and was taken using a tractor-mounted hydraulic ram to a 1 m depth. The core samples (50 mm diameter) were segmented into 8 depth increments: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm and stored in zip-lock plastic bags. Bentonite powder was poured into the cored hole to prevent a preferential pathway developing at each sample point. Soil core samples were oven dried (48 h at 105°C) and the gravimetric water content was determined. Samples were crushed and passed through a 2 mm sieve. An aqueous soil extract solution (1:1 ratio) was prepared using 20 g of dried soil and 20 ml of deionised water. Each solution was shaken with a rotating laboratory shaker, then centrifuged and filtered (0.48 µm) into vials and analysed for Br⁻ using ion chromatography (Dionex ICS-2500 system).

Transfer function modelling, statistical analysis and mass balance

A least squares optimisation technique was used to calculate the best fit of observed values of field-averaged normalised Br⁻ concentrations from 8 depths with a probability density function (pdf) at 5 different sampling times. Two pdf's were investigated, the convective dispersion equation (CDE) and the convective lognormal transfer function (CLT) (Butters and Jury 1989):

$$f_l(z) = [1/(2\pi)^{1/2}\sigma z] \exp \left[- \left(\ln \left(\frac{ll}{z} \right) - \mu \right)^2 / 2\sigma^2 \right] \quad [1]$$

where μ = mean, σ^2 = variance. The CLT provided a much better fit to the data than the CDE. Analysis of variance (ANOVA) was used to check for differences between the treatments at each sampling time. Then a

Bonferroni multiple comparison was used to determine whether there was a significant difference of the mean travel depth of Br⁻ between treatment pairs (i.e. T1 vs. T2 etc.). The mass of Br⁻ recovered from the soil core samples was compared with the applied mass of Br⁻ less the small background concentration of Br⁻. The percentage recovery of the applied Br⁻ solute is an important calculation to check that the solute is adequately accounted for.

Results

Bromide concentration profiles

The depth concentration profiles of Br⁻ clearly showed that there was a great amount of solute movement during the first 3 weeks after the start of the experiment. Figure 1 shows a depth concentration profile for T1 for the 5 sampling times during the course of the experiment. After sample time 2 (26 days) there was much less Br⁻ measured and it is thought that it was mostly leached from the soil profile.

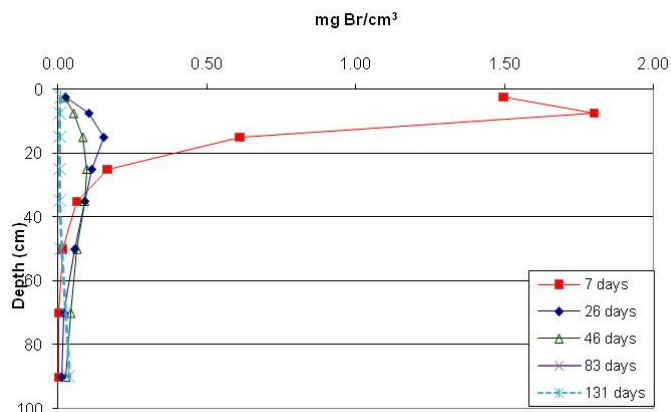


Figure 1. Bromide concentration (mg Br⁻/ cm³) by depth for treatment 1 at 5 sampling times during 2008/09

Using a convective lognormal (CLT) model for solute transport it was found that the level of applied irrigation volume produced a significant difference ($P = 0.04$) in the average depth reached by the solute at time 2 only, while at times 1 and 3 there was no significant difference. At times 4 and 5 there were significant differences in the variability of the depth reached by the solute, however these data are not conclusive since by time 4 a large proportion of the solute mass had leached beyond the measurement region. The difference in the depth concentration profile of Br⁻ for all treatments at sample time 2 is given in Figure 2.

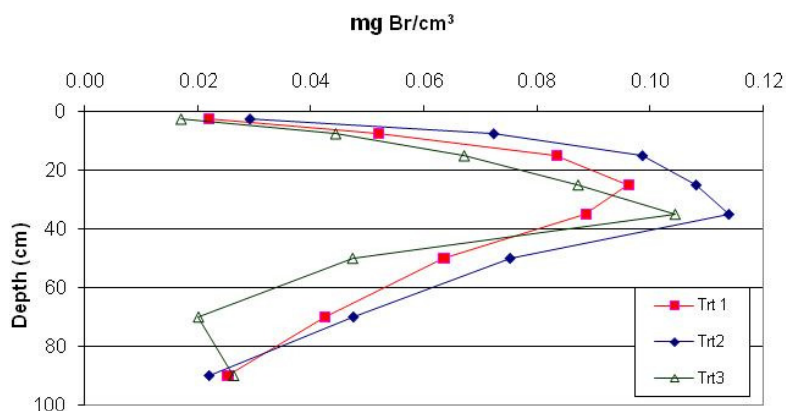


Figure 2. Bromide concentration (mg Br⁻/ cm³) by depth for all treatments (T1, T2, T3) at the sample time 2

Mass balance

The mass balance is the amount of Br⁻ that was recovered as a percentage of the amount applied (Figure 3). These results support and further emphasise that there was no significant difference between the treatments. Most Br⁻ was recovered after 7 days (time 1), but by sample time 2 >70 % of the applied Br⁻ had been leached. By the end of the experiment the Br⁻ concentrations were close to the background levels.

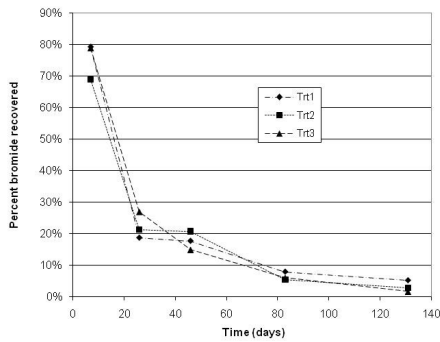


Figure 3. The percentage bromide recovered as a percentage of the amount applied at 5 sampling times for 3 different irrigation volume treatments (T1 = 1 L /h, T2 = 1.6 L /hand T3 = 2.3 L /h)

Soil moisture

The soil moisture status was very wet from the start of the experiment and remained wet for all the treatments (T1, T2 and T3) for the period until the end of 2008. In fact, for much of this period there was little difference between the treatments, for example the soil water potential is shown at 50 cm depth (Figure 4). These data agree with other measurements of soil water content (data not shown) taken at time 1-5.

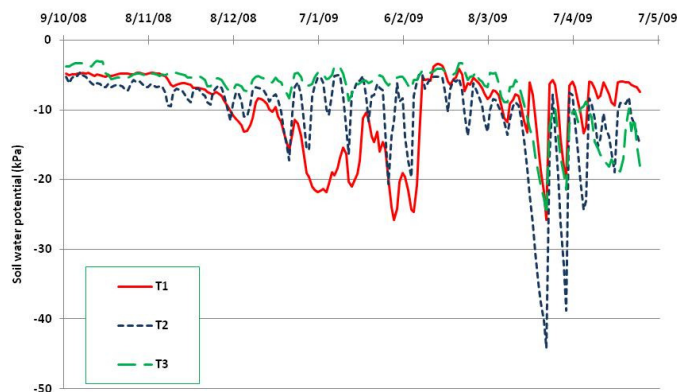


Figure 4. Soil water potential (kPa) at 50 cm depth for the 3 applied irrigation volume treatments during 2008/09

Conclusion

The applied irrigation volume was only once found (time 2) to have a significant effect on the average depth concentration of Br. At other times there was either no significant difference (time 1 and 3) or a difference could not be observed due to leaching beyond the depth of measurement. This suggests that the drip emitter rate and ultimately the irrigation volume is not a dominating factor on the leaching of Br. The soil water content plays an important role on leaching and appears to be more important than irrigation volume. Analysis of solute transport parameters using a transfer function modelling approach confirms this interpretation. Therefore, we believe that greater attention needs to be placed upon the soil moisture than drip emitter rate or irrigation volume to avoid excessive nutrient leaching.

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