



The effect of irrigation and urine application on phosphorus losses to subsurface flow from a stony soil



C.W. Gray^{a,*}, R.W. McDowell^{b,c}, S. Carrick^d, S. Thomas^e

^a AgResearch, Lincoln Research Centre, Private Bag 4749, Christchurch, New Zealand

^b AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand

^c Soil and Physical Sciences, Faculty of Agriculture and Life Sciences, PO Box 84, Lincoln University, Lincoln 7647, Christchurch, New Zealand

^d Landcare Research, PO Box 69040, Lincoln, New Zealand

^e Soil Water & Environment Group, Plant and Food Research, Private Bag 4704, Lincoln, New Zealand

ARTICLE INFO

Article history:

Received 12 May 2016

Received in revised form 28 September 2016

Accepted 30 September 2016

Available online xxx

Keywords:

Irrigation
Leaching
Lysimeter
Water quality
Phosphorus
Pasture

ABSTRACT

Diffuse losses of phosphorus (P) from agricultural land via subsurface flow (*viz* leaching) can result in degradation of surface water quality. Factors such as irrigation and soil pH can increase the solubility of P and its subsequent loss to water. Urine patches are known to alter pH by up to 3 units, but it is unknown if this increases P loss. This study investigated subsurface P loss from a stony soil subjected to different rates of irrigation (12, 25, 50 mm h⁻¹) with or without the application of urine (600 kg N ha⁻¹), a typical N loading rate under a cattle urine patch, using intact lysimeters. Results showed that despite receiving urine, average total P (TP), filtered reactive P (FRP) and filtered unreactive P (FURP) concentrations were significantly ($P < 0.05$) lower (27, 3, 7 $\mu\text{g L}^{-1}$) than non-urine treatments (40, 8, 11 $\mu\text{g L}^{-1}$). Increasing the rate (not amount) of irrigation did not affect the load of P lost. Total P loads were generally low (0.070–0.167 kg ha⁻¹) compared to other studies where P loss has been measured in drainage from pasture soils after P fertiliser application. The lack of differences observed with increasing irrigation rates was thought to be due to attenuation as P moved from preferential flow pathways in the topsoil to matrix flow in the subsoil gravels. The lower P losses following urine application were due to: 1) the buffering effect of the soil negating any significant pH-induced solubilisation of P; and 2) enhanced P uptake and decreased drainage (due to greater evapotranspiration) as dry matter production increased in response to the nitrogen applied in urine. However, despite this soil having only a moderate Olsen P concentration, typical of productive landuses in the region, FRP and TP concentrations still exceeded guidelines for good surface water quality. Strategies should be considered to decrease these losses, especially where drainage occurs via preferential flow pathways that negate attenuation of P losses, or are well connected to surface waters such as using precision irrigation.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Diffuse losses of phosphorus (P) from agricultural land are recognised internationally as a major cause of surface water degradation (Carpenter *et al.*, 1998). In response, there has been considerable research invested in quantifying the main sources of P (McDowell *et al.*, 2007) and transport pathways by which P enters surface water bodies from land (Heathwaite and Dils, 2000). This information is central to any attempt to identify how best to mitigate P losses and minimise or prevent surface water eutrophication.

Historically, the vast majority of studies have focused on P loss by surface and near surface pathways (Heathwaite and Dils, 2000; McDowell and Sharpley, 2001). In comparison, much less research has been undertaken investigating subsurface (*viz* leaching) losses of P through soils, because of the assumption that most subsoils have a moderate to high capacity to sorb/precipitate and retain P (Correll, 1998). However, over the last two decades perceptions have gradually changed, with the increased recognition that P leaching and subsurface runoff may also be an important loss pathway under some combinations of agricultural management practices, soil properties, and climatic conditions (Kleinman *et al.*, 2009; Sims *et al.*, 1998). For instance, in circumstances where soils have a high P status, a low P sorption capacity or when soils have been saturated with P, and hydrological conditions are conducive to drainage from soils, subsurface P loss has been shown to be

* Corresponding author.

E-mail address: colin.gray@agresearch.co.nz (C.W. Gray).

important (Breeuwsma et al., 1995; Sims et al., 1998; Dils and Heathwaite, 1999; McDowell and Monaghan, 2015).

In New Zealand, over the last two decades there has been large-scale expansion and intensification of dairying. The national dairy herd has increased from 3.3 million cows in 1999/2000 to 4.78 million cows in 2012/13 (LIC, 2013). Much of this expansion, particularly in the South Island lowlands, has occurred on stony alluvial soils that are extensively irrigated (Carrick et al., 2013). For example in the Canterbury region, satellite imagery indicates that of the 302,000 ha of irrigated land identified from 2008 to early 2011 (Pairman et al., 2011), 196,000 ha occurred on stony soils. Furthermore, there are also large areas of stony soils in other parts of the North and South Islands of New Zealand, for which there is potential for intensive irrigated land use (Carrick et al., 2013). It is recognised that many of these irrigated, stony soils have a high vulnerability to P leaching i.e. low anion storage capacity (ASC), rapid permeability and low water holding capacity (McDowell et al., 2013). Recent research also suggests that if this P undergoes deep drainage into groundwater in aquifers with gravel or sand lithology, there is a possibility that this groundwater could contribute P to surface water, if there is good connectivity between both water bodies (McDowell et al., 2015). There is however a lack of information on the concentrations and loads of P leaching from irrigated stony soils. Furthermore, it is not clear what effect different rates of irrigation may have on P losses, which can vary between 5 and 80 mm h⁻¹ for a centre pivot irrigator (INZ, 2014). For example, could high irrigation rates enhance the movement of P through the activation of preferential flow pathways compared to low rates where P movement may be dominated by matrix pathways?

Recent studies have also investigated the potential for P loss from soils that have had urine applied. For example, Carrick et al. (2014) found the application of urine to irrigated lysimeters resulted in rapid leaching of total P following urine application to a stony sandy soil. This was attributed to solubilisation of organic matter by urine and consequent increase in soluble P—possibly as a result of an increase in soil pH. For example, Monaghan and Barraclough (1993) showed solubilisation of carbon in urine amended soil, which they attributed to the increase in pH following urea hydrolysis. In contrast, Scott et al. (2015) found that the application of urine (400 kg N ha⁻¹) had no effect on the amount of dissolved (*viz.* filtered) reactive P (DRP) lost via leaching above those measured in control soils. Given the large number of urine events which occur on grazed dairy pasture soils, which have been estimated to cover 20–30% of the grazed paddock area per year (Moir et al., 2011), its potential to exacerbate P loss is something which warrants further investigation. Therefore, the objective of this study was to measure P losses from a stony soil subject to different rates of irrigation with or without the application of urine. It was hypothesised that the application of urine and increasing the rate of irrigation would result in an increase in the concentration and load of P losses from soils due to an increase in soil pH and flow via preferential flow pathways, respectively.

2. Materials and methods

2.1. Soil description and lysimeter collection

Twenty-four undisturbed monolith lysimeters (50 cm diameter and 70 cm deep) were collected from the AgResearch Farm in Lincoln, Canterbury. The soil at the site is an Eyre shallow silt loam (Orthic Recent soil [Hewitt, 2010]; Orchrupt (Soil Survey Staff, 1998)). It is a well-drained soil with a silt loam topsoil overlying a sandy, very stony subsoil (>400 mm depth). The site was in permanent ryegrass/clover (*Lolium perenne* L)/(*Trifolium repens*) pasture. Bulk soil samples were also collected at four depths to 400 mm from three pits at the site. Some basic soil properties are given in Table 1.

Lysimeter collection followed the method of Cameron et al. (1992). Briefly, undisturbed soil monoliths were hand carved in situ from the ground surface, and a lysimeter casing progressively pressed down over the cores to collect a soil monolith. A cutting ring at the base of the cylinder created a 0.5-cm annular gap between the soil monolith and the casing, which was filled with liquefied petroleum jelly. Once the jelly solidified, it formed an effective seal to prevent edge flow. A bottom plate with a sampling port which contained tubing was installed at the base of the lysimeter to allow collection of drainage. No suction was applied to the bottom of the lysimeters. Completed lysimeters were installed in a purpose-built trench facility at ground level, and rainfall excluded using a mobile rain shelter.

2.2. Experimental design and management

Lysimeters were first irrigated with tap water to flush the cores and then allowed to drain before treatments were applied. The trial was arranged in a full factorial design with six treatments (three irrigation rates with or without urine), replicated four times. Thereafter each lysimeter received the same amount of irrigation but at three different rates (12, 25 or 50 mm h⁻¹), considered representative of the rates applied under centre pivot irrigators (INZ, 2014). Irrigation was applied via sprinklers mounted directly over the top of each lysimeter, and applied when the soil water deficit was 10–15 mm. The sprinklers were calibrated and controlled individually to deliver an even volume of water throughout the experiment. Irrigation began in February and continued until November. Synthetic urine (10 L m⁻²) was applied at a rate of 600 kg N ha⁻¹ to half the lysimeters to simulate a typical N loading rate under a cattle urine patch (Haynes and Williams, 1993). To maintain an equivalent soil water content, the same volume of water was applied to the remaining lysimeters. The composition of synthetic urine was based on that of Kool et al. (2006) and contained 6 g N L⁻¹ and a range of salts to mimic 'real' urine properties like pH. Phosphorus was applied to the surface of all lysimeters as single superphosphate (SSP) (sieved to <2 mm) at a maintenance rate of 30 kg P ha⁻¹ at the start of the trial. A bromide tracer was also applied to all lysimeters in 10 mm of

Table 1
Selected properties of the Eyre soil sampled at the lysimeter site.

| Sample depth (mm) | pH | Olsen P (mg L ⁻¹) | Total carbon (%) | CaCl ₂ -extractable P (mg L ⁻¹) | ASC (%) | Fe (mmol kg ⁻¹) | Al (mmol kg ⁻¹) | Volumetric stone content ^a (%) |
|-------------------|-----|-------------------------------|------------------|--|---------|-----------------------------|-----------------------------|---|
| 0–75 | 5.8 | 33 | 3.8 | 0.172 | 15 | 57 | 96 | 0 |
| 75–150 | 5.9 | 20 | 2.7 | 0.027 | 17 | 59 | 96 | 0 |
| 150–300 | 5.9 | 16 | 1.7 | 0.010 | 22 | 59 | 96 | 0 |
| 300–400 | 5.7 | 13 | 1.4 | 0.006 | 22 | 56 | 82 | 2 |

^a Stone content at 400–500 mm depth 60% and 500–700 mm depth 71%.

Download English Version:

<https://daneshyari.com/en/article/8487296>

Download Persian Version:

<https://daneshyari.com/article/8487296>

[Daneshyari.com](https://daneshyari.com)