Hanly, J.A., Kamikazi, S., Christensen, C.L., Hedley, M.J., Horne, D.J., 2017. Effects of grazing management on nutrient anion and cation losses in drainage waters from dairy pastures. In: *Science and policy: nutrient management challenges for the next generation*. (Eds L. D. Currie and M. J. Hedley). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 5 pages.

EFFECTS OF GRAZING MANAGEMENT ON NUTRIENT ANION AND CATION LOSSES IN DRAINAGE WATERS FROM DAIRY PASTURES

James Hanly, Sandrine Kamikazi, Christine Christensen, Mike Hedley & Dave Horne

Fertilizer and Lime Research Centre, Institute of Agriculture and Environment, Massey University, Private Bag 11 222, Palmerston North 4442, New Zealand
Email: J.A.Hanly@massey.ac.nz

Abstract

Reducing the duration that cows spend grazing paddocks, by increasing the time they spend on standoff facilities, has been shown to reduce nutrient losses to water. One such grazing management strategy is the use of year-round, duration-controlled (DC) grazing, where stock only graze for 4 hours at most grazings. The 3-year (2009-2011) study of Christensen (2013) showed that DC grazing reduced leaching losses of nitrate (NO_3^-) and potassium (K^+), compared to standard grazing (SG) practices. However, losses of other nutrient anions and cations were not fully evaluated. This current study extends the evaluation of the above study to include drainage water losses of sulphate (SO_4^{2-}), calcium (Ca^{2+}) and magnesium (Mg^{2+}) over a 5-year period (2009-2013), as well as the losses of chloride (Cl^-) and sodium (Na^+) in a single year (2012).

The DC treatment reduced NO_3^-, K^+ and Cl^- drainage water losses in proportion to decreases in grazing time (approximately a 50% reduction) and Na^+ losses by 35%. In contrast, the DC treatment did not significantly reduce SO_4^{2-}, Ca^{2+} or Mg^{2+} losses. The size of the reductions supports the view that the urine spot is likely to be the predominant source of leaching losses for NO_3^-, K^+ and Cl^-, but not for SO_4^{2-}, Ca^{2+} or Mg^{2+}. Although the Na^+ leaching reduction was not in direct proportion to the decrease in grazing time, the size of the reduction suggests that the urine spot was the major source of loss for this nutrient also.

Introduction

In pastoral grazing systems, livestock return nutrients back to pastures unevenly through urine and dung. Nutrients that accumulate in urine patches during the summer-early winter period are prone to leaching during the subsequent winter-spring drainage season (Shepherd *et al*., 2011). While much research has focused on mitigating the losses of nitrogen (N) and phosphorus (P) to water from agricultural soils, there have been fewer studies quantifying losses of other nutrients, namely sulphur (S) and the nutrient cations. While these latter nutrients are not considered to be of concern for water quality, their loss does represent a removal from potential productive use. Studies that have evaluated the losses of sulphate (SO_4^{2-}), chloride (Cl-) and nutrient cations have mainly focused on quantifying the influence of fertiliser (Steele *et al*., 1984; Heng *et al*., 1991; Monaghan *et al*., 2000; Morton *et al*., 2004) or dicyandiamide, a nitrification inhibitor (Di & Cameron, 2004; Blard *et al*., 2006). The influence of grazing management practices on these nutrient anion and cation leaching losses has not been previously evaluated.

Year-round duration-controlled (DC) grazing is a management practice that has been shown to reduce nutrient losses to water. This strategy involves reducing the duration cows spend grazing paddocks to 4 hours at most grazings, by increasing the time they spend on standoff facilities. The 3-year (2009-2011) study of Christensen (2013) showed that DC grazing reduced leaching losses of NO_3^- and K^+, compared to standard grazing (SG) practices. This current study extended the evaluation of the above study to include drainage water losses of SO_4^{2-}, calcium (Ca^{2+}) and magnesium (Mg^{2+}) over a 5-year period (2009-2013). Losses of Cl^- and sodium (Na^+) were also quantified in drainage samples from 2012.

Materials and methods

This research involved analysing drainage water samples collected during a three-year long research study (2008-2011) conducted by Christensen (2013) and also collected from the 2012 and 2013 drainage seasons. The trial site, the experimental design and the drainage water analysis methods are described below.

Site description and experimental design

The trial site was established in 2008 at Massey University's No. 4 dairy farm, Palmerston North, New Zealand, which has an average annual rainfall of approximately 1000 mm. The site has a slope of <3% and the soil type is Tokomaru silt loam, which is classified as argillic-fragic perch-gley pallic soil. This soil has natural poor drainage and so the installation of artificial drainage is common practise. The trial site consisted of 14 grazed pasture plots (average area of 850 m^2/plot) that were individually fenced and drained with an isolated mole and pipe drainage system. Mole channels were ploughed at 2 m intervals at a depth of approximately 0.45 m. These channels intercepted a gravel trench above a perforated pipe drain of 0.11 m diameter at 0.60 m depth (Christensen, 2013). The pasture species on the plots were predominately a mix of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*).

The trial had two grazing treatments using dairy cows: standard grazing (SG) and DC grazing, which were replicated on seven drainage plots each. At the majority of grazings, over the 5-year period, the SG treatment was grazed for approximately 7 hours each day-grazing and 12 hours for night-grazing, while the DC treatment had 4 hours for both day and night grazings. Grazings were alternated between day and night grazings. Both treatments were managed so as to minimise treading damage using good practise, which included scheduling grazings only when the soil moisture deficit was greater than 5 mm. The stocking intensity was the same for both treatments at each grazing, and was set according to pasture covers as measured using a rising-plate meter.

Drainage water collection and analysis

The installed mole and pipe drainage system for each plot channelled drainage into individual tipping bucket (approximately 5 L per tip) flow meters that were installed in sampling pits nearby. All tipping buckets had data loggers to provide continuous measurements of flow rate. During each drainage event, approximately 0.1% of the water from every second tip of the tipping bucket flow meter was automatically collected, which provided a volume proportioned mixed sample from each drainage event for analysis. Drainage water samples were filtered through a 0.45 µm filter within 12 hours of collection and stored frozen until analysis. Filtered samples were analysed for NO_3^- and SO_4^{2-} using colorimetric methods on Technicon Auto Analysers (Blakemore, 1987). For the 2012 samples, SO_4^{2-} and Cl^- were analysed using a Dionex™ Aquion™ Ion Chomotograph. Filtered samples were also analysed for K^+, Ca^{2+} and Mg^{2+} using atomic absorption spectroscopy on a GBC Avanta Σ spectrometer. This same method was also used to analyse Na^+ in water samples from the 2012 drainage season.

Results

The DC treatment significantly ($P<0.05$) reduced the amounts of NO_3^- and K^+ leached by 55% and 49%, respectively, on average over the 5-year period of the trial. In contrast, the DC treatment did not significantly reduce SO_4^{2-}, Ca^{2+} or Mg^{2+} losses (Figure 1). In 2012, DC grazing significantly ($P<0.10$) reduced Cl^- and Na^+ leaching by 51% and 35%, respectively. The decreases in NO_3^-, K^+ and Cl^- drainage losses from DC grazing were in proportion to the decrease in grazing time (approximately a 50% reduction annually). The size of the loss reductions for these nutrients supports the view that the urine spot is likely to be the predominant source of leaching losses for NO_3^-, K^+ and Cl^-, but not for SO_4^{2-}, Ca^{2+} or Mg^{2+}. The Na^+ leaching reduction was not in direct proportion to the decrease in grazing time, but the size of the reduction suggests that the urine spot was still the major source of loss for this nutrient. On a similar soil type, Monaghan *et al.* (2000) measured leaching losses of SO_4^{2-}, Ca^{2+} Mg^{2+} and K^+ that were similar to those from the SG treatment in this study. However, losses of NO_3^- and Na^+ were substantially higher in their study, being 30 kg N/ha and 28 kg Na/ha for the nil N fertiliser treatment.

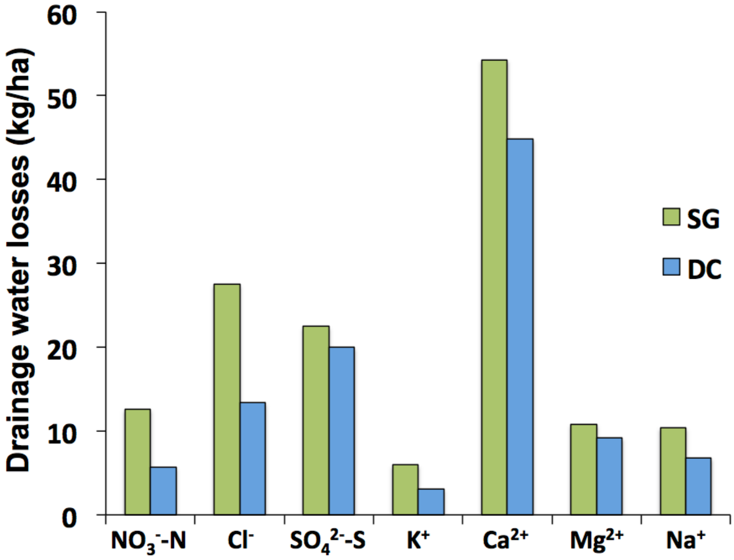

Figure 1. Average annual drainage water losses of nutrients in drainage water over 5 years (Cl^- and Na^+ data for 2012 only).

Leaching loss of anions is expected to be balanced by an equivalent loss of cations, if the soil solution is to remain neutral. The 2012-year results showed that for drainage events with higher nutrient concentrations, the total positive charge from cations closely matched the total negative charge from the three major anions (Table 2). However, there was a surplus of cations relative to anions at lower concentrations. Heng *et al.* (1991) also measured a slight surplus of cation over anion moles of charge, particularly for later season samples with lower concentrations of anions and cations. A possible reason they gave for the discrepancy in the charge balance was the contribution of bicarbonate, which was not measured. Steele *et al.* (1984) also found a close correlation between the total amounts (on a chemical equivalency basis) of anions and cations leached from soil.

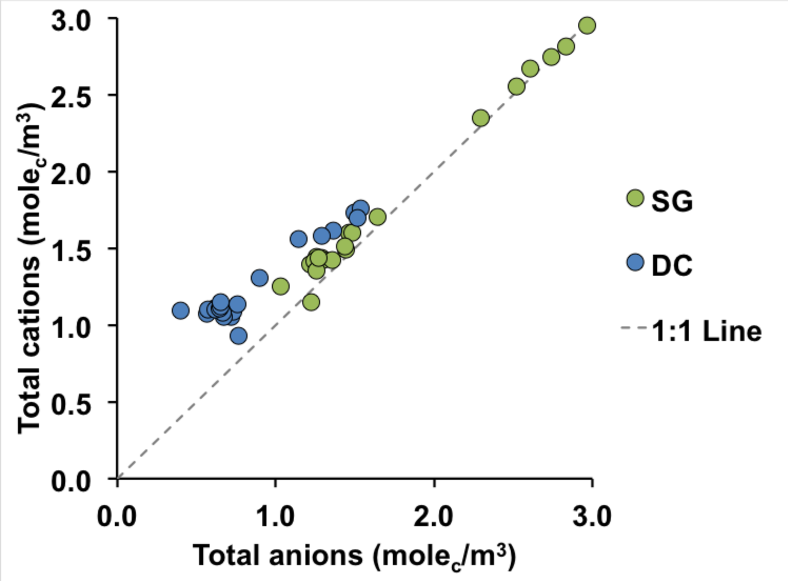

Figure 2. Drainage water average total anion (NO_3^-, Cl^-, SO_4^-) and cation (K^+, Ca^{2+}, Mg^{2+}, Na^+) charge concentrations at each drainage event for both grazing treatments in 2012**.**

Conclusions

Reducing grazing duration year-round was an effective strategy for reducing the losses of NO_3^-, K^+, Cl^- and Na^+ to water. The size of the reductions measured for the DC treatment supports the view that urine spots are the predominant source of losses for NO_3^-, K^+ and Cl^-. The Na^+ reduction was not in direct proportion to the decrease in grazing time, but the size of the reduction suggests that urine spots are still the major source of loss for this nutrient. Duration-controlled grazing did not significantly affect leaching losses of SO_4^{2-}, Ca^{2+} or Mg^{2+}.

Acknowledgements

This research was funded by the Pastoral 21 Research Programme. The authors also thank the staff of Massey University's No.4 Dairy Farm and the Fertilizer & Lime Research Centre (Ian Furkert, Jeya Jeyakumar, Bob Toes, Glenys Wallace & Ross Wallace) for their assistance with this research.

References

Blakemore, L.C., 1987. Methods for chemical analysis of soils. *NZ Soil Bureau scientific report*, 80:71-76.

Blard, A., Bolan, N.S., Vogeler, I., Saggar, S., Singh, J., 2006. The role of nitrification inhibitors in mitigating nitrate-Induced cation leaching in grazed pastures. In: *Implementing sustainable nutrient management strategies in agriculture*. (Eds L.D. Currie and J.A. Hanly). Occasional Report No. 19. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 7 pages.

Christensen, C.L. (2013). *Duration-controlled grazing of dairy cows: impacts on pasture production and losses of nutrients and faecal microbes to water*. A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Soil Science, Massey University, Palmerston North, New Zealand.

Di, H., & Cameron, K., 2004. Effects of the nitrification inhibitor dicyandiamide on potassium, magnesium and calcium leaching in grazed grassland. *Soil use and management,* 20(1), 2-7.

Heng, L., White, R., Bolan, N., Scotter, D., 1991. Leaching losses of major nutrients from a mole-drained soil under pasture. *New Zealand Journal of Agricultural Research,* 34(3), 325-334.

Monaghan, R., Paton, R., Smith, L., Binet, C., 2000. Nutrient losses in drainage and surface runoff from a cattle-grazed pasture in Southland. *Proceedings of the New Zealand Grassland Association,* 62: 99–104.

Morton, J., Roach, C., Tong, M., & Roberts, A., 2004. Potassium in soil and pasture and leaching of cations on an allophanic soil in New Zealand. *New Zealand Journal of Agricultural Research,* 47(2), 147-154.

Shepherd, M., Phillips, P., Snow, V., 2010. The challenge of late summer urine patches in the Waikato region. In*: Adding to the knowledge base for the nutrient manager*. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 8 pages.

Steele, K., Judd, M., & Shannon, P. (1984). Leaching of nitrate and other nutrients from a grazed pasture. *New Zealand journal of agricultural research,* 27(1), 5-11.