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

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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 perchor-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 Analyser (Blakemore, 1987). For the 2012 samples, SO$_4^{2-}$ and Cl$^-$ were analysed using a Dionex$^\text{™}$ Aquion$^\text{™}$ Ion Chromotograph. Filtered samples were also analysed for K$^+$, Ca$^{2+}$ and Mg$^{2+}$ using atomic absorption spectroscopy on a GBC Avanta $\Sigma$ 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 \(\text{NO}_3^-\) and \(\text{K}^+\) 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 \(\text{SO}_4^{2-}\), \(\text{Ca}^{2+}\) or \(\text{Mg}^{2+}\) losses (Figure 1). In 2012, DC grazing significantly \((P<0.10)\) reduced \(\text{Cl}^-\) and \(\text{Na}^+\) leaching by 51% and 35%, respectively. The decreases in \(\text{NO}_3^-\), \(\text{K}^+\) and \(\text{Cl}^-\) 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 \(\text{NO}_3^-\), \(\text{K}^+\) and \(\text{Cl}^-\), but not for \(\text{SO}_4^{2-}\), \(\text{Ca}^{2+}\) or \(\text{Mg}^{2+}\). The \(\text{Na}^+\) 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 \(\text{SO}_4^{2-}\), \(\text{Ca}^{2+}\) \(\text{Mg}^{2+}\) and \(\text{K}^+\) that were similar to those from the SG treatment in this study. However, losses of \(\text{NO}_3^-\) and \(\text{Na}^+\) 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).](image)

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 ($\text{NO}_3^-$, $\text{Cl}^-$, $\text{SO}_4^{2-}$) and cation ($\text{K}^+$, $\text{Ca}^{2+}$, $\text{Mg}^{2+}$, $\text{Na}^+$) 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 $\text{NO}_3^-$, $\text{K}^+$, $\text{Cl}^-$ and $\text{Na}^+$ 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 $\text{NO}_3^-$, $\text{K}^+$ and $\text{Cl}^-$. The $\text{Na}^+$ 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 $\text{SO}_4^{2-}$, $\text{Ca}^{2+}$ or $\text{Mg}^{2+}$.

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References


