Reducing nitrate leaching losses by using duration-controlled grazing of dairy cows

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Abstract
Duration-controlled grazing practices, in conjunction with the use of cow housing and/or feed-pad facilities, reduce both the time that cows spend in paddocks and the quantity of excreta deposited in paddocks. Therefore, duration-controlled grazing has the potential to reduce nitrate-N leaching into New Zealand waterways. Excreta is collected from the stand-off facilities and spread evenly back on to paddocks.
A large scale, long term field trial is currently being carried out at Massey University's No. 4 Dairy Farm to investigate the effect of duration-controlled grazing of cows on the concentrations of nitrate-N in drainage water. Other parameters being measured are phosphorus and faecal indicator organism concentrations in surface runoff water, pasture accumulation and estimated cow intakes. After one full year of grazing treatments, a large reduction in nitrate-N concentrations in drainage has been achieved through using duration-controlled grazing practices. Halving the average amount of time that cows spent on pasture, over the 2008/09 lactation season, reduced nitrate leaching by 41% (by 5.2 kg NO_3^- -N /ha) compared with the standard grazing treatment (where losses were 12.6 kg NO_3^- -N /ha). Duration-controlled grazing during summer and autumn is likely to have the larger influence on reductions in nitrate leaching compared with duration-controlled grazing during winter and spring. This study confirms that duration-controlled grazing is an effective strategy for reducing the transfer of N from dairy farms to surface waters.

Key Word
Nitrate leaching, duration-controlled grazing practices.

Introduction

Dairy farming in New Zealand is based predominantly on grazed pastures, resulting in low cost milk production compared with other more intensive feed supply systems (Holmes *et al.* 2007). However, these pastoral based dairy farms are a major contributor to the contamination of surface waters through nitrogen (N) and phosphorus losses (P) from leaching and surface runoff, respectively (Sharpley and Syers, 1979). The greatest N losses arise from the urine patches that cows deposit when grazing (Ledgard and Menneer, 2005; Silva *et al.* 1999). The concentrations of N in urine patches are too high (approximately 600-1000 kg N/ha; (Di and Cameron 2002; Haynes and Williams 1993), for plants to utilise the N fully, and the excess is prone to leaching as nitrate when drainage occurs (de Klein, 2001; Di and Cameron, 2002; Ledgard and Menneer, 2005; Silva *et al.* 1999).

One way of reducing the N leaching losses from grazing is by adopting duration-controlled grazing practices, which involve limiting the time cows spend in paddocks between milkings by removing them to housing or a feed-pad to receive supplementary feed (de Klein *et al.* 2000). This practice decreases the number of dung and urine patches distributed to the paddock, and hence, reduces the potential for N leaching and P runoff. The added effluent collected from the animal shelter can then be stored and returned to paddocks when conditions are favourable (de Klein, 2001). This excreta is spread evenly and at nutrient rates and timings that match plant uptake (Chadwick *et al.* 2002).

Several duration-controlled grazing studies have been conducted in overseas countries, however there have been no long-term experiments performed in New Zealand to confirm the long term impacts of this duration-controlled grazing. Short-term studies and modelling work have been completed in New Zealand surrounding the practice. These studies indicate that N leaching decreases under duration-controlled grazing (de Klein and Ledgard, 2001; de Klein *et al.* 2006). Therefore, a large-scale, long-term field experiment has been established at Massey University's No. 4 Dairy Farm, in the Manawatu region of New Zealand, to quantify a range of impacts under duration-controlled grazing practices. These impacts include; N concentrations in drainage, P concentrations and faecal indicator organisms in surface runoff water, and pasture accumulation and subsequent cow intakes. This paper presents the nitrate-N losses in drainage water from the 2009 drainage season (up to early October 2009), after one full year of grazing treatments.

Methods

Trial site

A three year field trial has been established on Massey University's No. 4 Dairy Farm near Palmerston North, Manawatu, New Zealand (NZMS 260, T24, 312867). The trial site is located in a flat landscape (c. <3% slope) which receives an average annual rainfall of approximately 1000 mm. The site supports a mixed pasture sward of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) on a mole-pipe drained Tokomaru silt loam soil, an Argillic-fragic Perch-gley Pallic Soil (Hewitt, 1998).

The research area consists of fourteen plots (average area 850 m^2/plot), each with an isolated mole and pipe drain system. Mole channels were installed at 2 m intervals at a depth of 0.45 m. Drainage from the mole channels is intercepted by a pipe drain (0.11 m diameter), which was installed perpendicular to the moles at a depth of 0.60 m. Further description of the topography and soil properties of the site are provided by Houlbrooke *et al.* (2004).

Experimental design

The trial consists of two treatments; one being a Standard Grazing (*SG*) treatment which involves a grazing duration of ~6 hours for day grazings and ~12 hours for night grazings. The other treatment is a Duration-controlled Grazing (*DCG*) treatment which involves a grazing duration of ~ 4 hours for both day and night grazings. Plots for both treatments are grazed on the same day with the same average stocking rate, which is determined by pasture cover estimated using a rising-plate pasture height meter. Grazings are alternated between day and night to create the average grazing duration difference between the two treatments that would occur over a year (~11 grazings/year).

The trial was established during the summer of 2008 and the drainage season that year began on 25 June. Grazing treatments commenced on 3 September during the first grazing rotation of the 2008/09 lactation season. The final grazing for that lactation season was on 29 May 2009. In 2009, three drainage events occurred between 13 February 2009 and 2 March 2009, which is not typical for this time of the year in the Manawatu, and the winter drainage began on 15 May 2009. Grazing of the trial area for the 2009/10 lactation season commenced on 8 September 2009.

At each grazing, cows are provided a target of 5-6 kg DM/cow as grazed pasture from the treatment plots and another 2-3 kg DM/cow from another source. Prior to each grazing the *SG* cows are fed 2-3 kg DM/cow as supplementary feed on a feed pad and then grazed on the *SG* plots to obtain a further 5-6 kg DM/cow. The *DCG* cows first receive 5-6 kg DM/cow from grazing *DCG* plots and then after 4 hours are removed to receive the remainder of their feed requirements elsewhere, to simulate their return from grazing to a standoff facility.

In 2008, all plots received N fertiliser (urea) at a rate of 30 kg N/ha in mid-September and again in mid-November. Superphosphate was applied to all plots at a rate of 30 kg P/ha in mid-November 2008. In 2009, all plots received N fertiliser at 25 kg N/ha, as urea, in early-August and 30 kg N/ha, as sulphate of ammonium, in mid-September. An application of slurry, sourced from excreta deposited on the farm feed-pad, was applied to *DCG* plots in mid-December 2008, at an average application depth of ~7.5 mm, which applied on average, 181, 41 and 61 kg/ha of N, P and K, respectively. The slurry was applied to plots to return the approximate amount of manure that would have been collected from standoff facilities from the use of duration-controlled grazing.

Drainage water volume measurements and water analysis

Drainage water from plots is channelled through drainage pipes into tipping-bucket flow meters located in sampling pits nearby. Each tipping-bucket was calibrated dynamically to account for higher tip volumes at higher flow rates. All tipping buckets were instrumented with data loggers to provide continuous measurements of flow rate. During each drainage event a proportion (c. 0.1%) of the drainage water from every second tip of the tipping bucket flow meter was automatically collected to provide a volume-proportioned, mixed sample for water quality analysis. Drainage water samples were filtered through a 0.45 µm filter and the filtrate analysed for nitrate-N (NO_3^--N) and ammonium-N (NH_4^+-N) using colorimetric methods on a Technicon Auto Analyser (Blakemore *et al.* 1987).

Results

Drainage events occurred over two distinct periods in 2009. The first drainage period consisted of three drainage events (total 25mm drainage) in late summer/early autumn. While drainage at this time of year is not typical in the Manawatu region, it provided an insight into the impacts of late spring/early summer duration-controlled grazing and the early summer application of slurry on nitrate accumulation in the soil. The second drainage period started in mid-May and was not finished at the time this paper was submitted (30 October 2009). Therefore, the drainage results up to early October 2009 are reported. Average cumulative drainage for 2009 (up to early October) was 236 mm (Figure 1).

NO_3^- -N concentrations were lower in drainage from the *DCG* treatment during the first drainage period, indicating that a combination of *DCG* and slurry return resulted in lower accumulation of nitrate in the soil by late summer/early autumn, than that of *SG*. Lower nitrate leaching occurred on the *DCG* plots despite a relatively high rate of N (average 181 kg N/ha) being applied as slurry in early summer. This indicates that returning cow excreta to pasture as slurry reduces the risk of nitrate leaching compared to excreta deposited directly to the paddock by the cow.

At the start of the winter drainage season in May, the nitrate concentrations in drainage from the *DCG* treatment were similar to those measured in the first drainage period; however, the concentrations for the *SG* treatment had increased. These results demonstrate that *SG* in autumn led to an increased accumulation of nitrate in the soil, thereby increasing the risk of nitrate leaching when winter drainage commenced.

The drainage water concentrations of NO_3^- -N for both treatments gradually decreased with successive drainage over the first few months of the winter drainage season, reaching low levels by August, which is a trend typical of this site (Houlbrooke *et al.* 2008). Throughout the winter period, the *DCG* treatment maintained lower NO-N concentrations, compared with the *SG* treatment. NO_3^- -N concentrations remained low for both treatments through late winter and early spring, indicating that there may be little benefit to using duration-controlled grazing, or any other nitrate leaching mitigation strategy, during this period. In addition, the applications of N fertiliser did not appear to increase NO_3^- -N concentration in drainage water.

By early October of the 2009 drainage season, a total of 7.4 and 12.6 kg NO_3^- -N was lost in drainage water from *DCG* and *SG* treatment plots, respectively. In other words, duration-controlled grazing reduced nitrate losses by 41%.

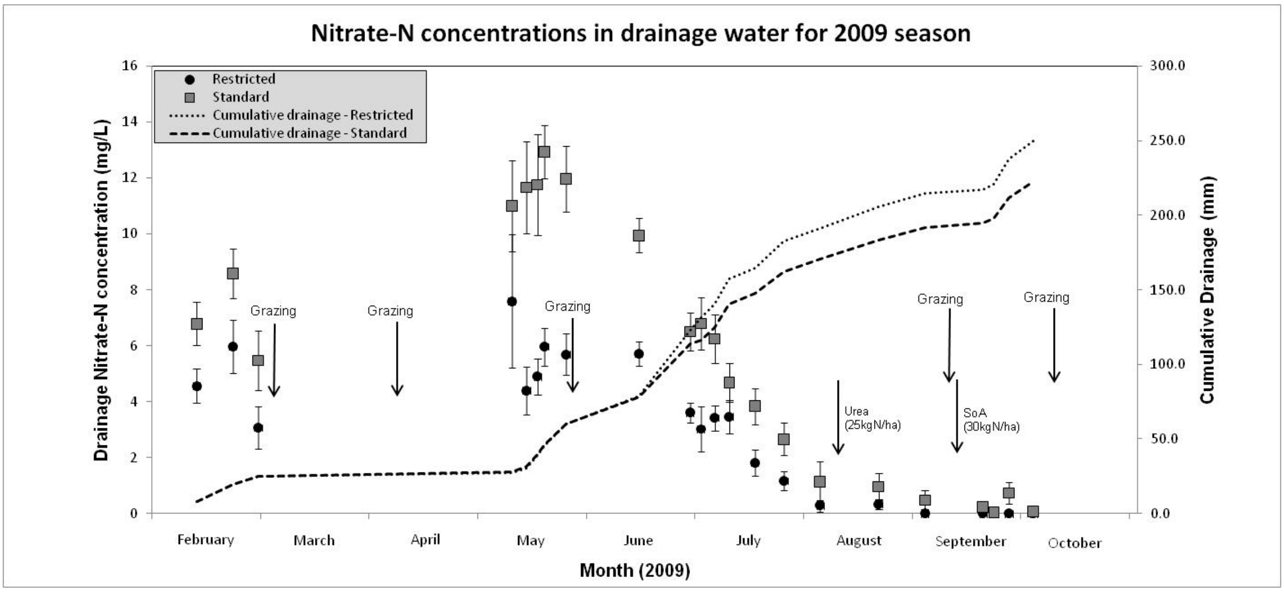

Figure 8. Cumulative drainage (mm) and drainage water nitrate-N concentration during the 2009 drainage season.

Conclusion
Restricting the time cows spend in the paddock, and therefore reducing urine deposition in the paddock, has markedly decreased NO_3^- -N leaching losses from a mole and pipe drained soil. In particular, duration-controlled grazing in the summer and autumn periods had the greatest effect on N leaching losses. It is important to continue the trial to assess the impact of duration-controlled grazing on drainage water quality and soil productivity in the longer term.

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