NITRATE LEACHING AND PASTURE PRODUCTION FROM TWO YEARS OF DURATION-CONTROLLED GRAZING

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Abstract

Duration-controlled grazing practices, in conjunction with cow housing or feedpad facilities, are used in New Zealand to reduce treading damage to pastures during wet periods. Removing cows from pasture also reduces the excreta load returned to the pasture. Simulation models suggest that if the excreta captured on the standoff facility during duration-controlled grazing is stored and uniformly re-applied to paddocks, then duration-controlled grazing can lead to reductions in nitrogen (N) leaching.

A large-scale grazing trial has been in operation at Massey University No. 4 Dairy Farm since June 2008, to investigate the effects of duration-controlled grazing on the concentrations of N, phosphorus (P) and faecal microbes in drainage and surface runoff from grazed pasture. Pasture accumulation between grazings is also being assessed. The experimental area has 14 grazing/drainage plots (each ~850m^2), which provides facilities for continuous monitoring of volumes and flow rates of mole and pipe drainage, and surface runoff water. Seven of these plots are managed under 'duration-controlled' grazing (*DG*; 4 hour day or night graze) and the other seven plots under 'standard' grazing (*SG*; 7 hour day graze, 12 hour night graze). Plots are grazed alternatively between morning and night grazings. Slurry was returned to the *DG* plots in the first season, with a nutrient loading equivalent to approximately the amount of nutrients produced in slurry from about 18 months of *DG* grazing. Consequently, no slurry was applied during the second lactation season.

The 2009 drainage season was uncharacteristically long, beginning in February and ending in December an average of 373 mm of cumulative drainage. The total quantity of nitrate-N leached in drainage water from the *SG* plots during this season was 13.1 kg N/ha, and in comparison, the *DG* plots achieved a 43% reduction (7.5 kg N/ha). In 2010, the drainage season length was more typical with an average cumulative drainage quantity of 316 mm. Nitrate-N leaching from the *DG* plots was 65% lower compared with the *SG* plots, (i.e. 2.8 kg N/ha and 8.0 kg N/ha for the *DG* and *SG* plots, respectively).

Pasture accumulation was similar for both treatments during the 2008/09 lactation season. However, in the 2009/10 lactation season, a 17% reduction in pasture accumulation was observed on the *DG* plots compared with the *SG* plots (10764 kg DM/ha c.f. 12970 kg DM/ha). The smaller pasture accumulation achieved on the *DG* plots in the second season was likely due to less dung and urine deposited during grazing combined with no slurry being returned in that season.

If slurry return can be managed so as to optimise pasture growth on *DG* plots, then *DG* has the potential to be a very useful nitrate leaching mitigation strategy for the dairy industry, particularly in nitrogen sensitive catchments.

Introduction

Cattle urine spots are a major source of the nitrogen (N) leached from New Zealand dairy farms (Cameron *et al.* 2007; Wachendorf *et al.* 2005). Restricting the time that cows spend grazing pastures is one way to decrease the deposition of urine spots in paddocks. Duration-controlled grazing involves reducing the time cows spend grazing pasture with more time spent on feed pads or animal shelter facilities between grazings. While the increased time spent on stand-off facilities results in greater quantities of excreta being collected, as effluent or stored manure, this material can be returned to soils evenly and at relatively low N concentrations. de Klein & Ledgard (2001) found that, compared with a conventionally grazed system, restricting the grazing time of cows in the autumn in Southland led to a 35-50% reduction in nitrate (NO_3^-) leaching.

This paper discusses the nitrate leaching and pasture dry matter (DM) accumulation results from two years of a three year-long field trial established to assess the impacts of year-round, duration-controlled grazing on the quantities of N, phosphorus (P) and faecal microbes lost in drainage and runoff from a dairy farm.

Methods

Trial site

A three year field trial is being conducted 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*). The trial was established on a mole-pipe drained, Tokomaru silt loam soil, a Fragic Perch-gley Pallic Soil (Hewitt 1998).

The research area consists of fourteen plots (~850 m^2/plot), each with an isolated mole and pipe drain system. Mole channels, ~ 40 m long, were installed at a depth of 0.45 m with an interval between moles of 2 m. Drainage from the mole channels is intercepted by a collecting perforated pipe drain (0.11 m diameter) installed perpendicular to the moles at a depth of 0.60 m. Further description of the topography and soil properties of the site can be found in Houlbrooke *et al.* (2004).

Experimental design

The trial consists of two treatments. The Standard Grazing (*SG*) treatment involves a grazing duration of ~7 hours for day grazings and ~12 hours for night grazings. The other treatment is Duration-Controlled Grazing (*DG*) 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. There are approximately 9 grazings a year.

The trial site was established during the summer of 2008 and grazing treatments commenced on 3 September 2008 (Table 1 and Table 2). In the first year of the trial, urea (30 kg N/ha) was applied to all 14 plots in mid-September 2008 and again in mid-November 2008. Superphosphate (30 kg P/ha) was applied to all 14 plots in mid-November 2008. The drainage season commenced on 13 February 2009 and finished on 30 December 2009.

In the second year of the trial, urea (25 kg N/ha) was applied in mid-August 2009, sulphate of ammonia (30 kg N/ha) in mid-September 2009, and urea (20 kg N/ha) in mid-November 2009. Urea (25 kg N/ha) was also applied in late-April 2010, and 30% sulphur superphosphate (200 kg/ha) was applied in late-April 2010. The 2010 drainage season began on 15 June 2010 and finished on 12 October 2010.

At each grazing, cows were offered 5-6 kg DM/cow as pasture from the treatment plots and another 2-3 kg DM/cow from another source. Prior to grazing the *SG* plots, cows were fed 2-3 kg DM/cow as supplementary feed on a feed pad. The cows grazing the *DG* plots were removed from the plots after 4 hours and given the remainder of their feed requirements (either pasture or supplement), which simulated their return from grazing to a standoff facility.

Estimated pasture dry matter accumulation, cow intakes and dung deposition

A rising-plate pasture height meter was used pre- and post-grazing to estimate the quantity of pasture dry matter on all plots at each grazing. An average of sixty rising-plate measurements was used to provide a value for pasture mass per plot. These measurements were used to estimate pasture DM accumulation between grazings and cow intakes at each grazing.

The dung pats deposited on each plot were counted to give an indication of the total amount of excreta, including urine, returned to the plots. Future work on the relationship between dung and urine return rates, and the use of dung pat counts to estimate urine return is planned. The difference in average dung depositions between the two treatments was used to guide the return of excreta collected on the feed pad and returned to the *DG* treatment plots in the form of a slurry. One application of slurry was applied to the *DG* treatment plots at an application depth of 5-10 mm during mid-December 2008.

Drainage water volume measurements and water analysis

Drainage water from plots was 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 and ammonium-N using colorimetric methods on a Technicon Auto Analyser (Blakemore *et al.* 1987).

Results & Discussion

The time spent grazing *DG* plots was shorter than the grazing time on *SG* plots, while the stocking intensity at each grazing was the same for both treatments (Table 1 and Table 2). Dung deposition was 46% less on *DG* plots than *SG* plots, as described in Christensen *et al.* (2010). As stated above, it is assumed that the differences in grazing times will also be reflected in urine deposition, as it has for dung deposition.

Grazing	Time of Day	Trt	Time (Hrs)	Cows/ha
1	Day	DC	4.00	270
3/09/2008		S	6.62	270
2	Night	DC	4.12	350
26/09/2008		S	12.35	350
3	Day	DC	3.72	367
30/10/2008		S	5.97	367
4	Night	DC	3.93	293
24/11/2008		S	12.23	293
5	Day	DC	4.12	226
17/12/2008		S	7.42	226
6	Night	DC	4.37	372
26/01/2009		S	12.40	372
7	Day	DC	4.02	282
3/03/2009		S	7.35	282
8	Night	DC	3.98	270
8/04/2009		S	12.83	270
9	24-hour	DC	7.72	206
29/05/2009		S	22.28	206

Table 1: 2008/09 lactation season grazing durations (hrs) and stocking intensity (cows/ha).

Grazing	Time of Day	Trt	Time (Hrs)	Cows/ha
1	Night	DC	4.10	297
8/09/2009		S	12.20	297
2	Day	DC	4.07	390
9/10/2009		S	6.13	390
3	Night	DC	4.05	393
10/11/2009		S	11.78	394
4	Day	DC	4.00	256
8/12/2009		S	6.32	256
5	Night	DC	4.10	294
12/01/2010		S	13.38	292
6	Day	DC	4.03	256
24/02/2010		S	7.07	256
7	Night	DC	4.03	210
20/04/2010		S	13.27	210
8	24-Hr	DC	8.47	174
9/06/2010		S	23.72	174

Table 2: 2009/10 lactation season grazing durations (hrs) and stocking intensity (cows/ha).

The 2009 drainage season began uncharacteristically early, and ended later than usual (30 December 2009). Cumulative drainage from the *SG* plots was slightly less than that from the *DG* plots (Christensen *et al.* 2010), with an average value for all plots of 373 mm (Figure 1). The 2010 drainage season occurred only from June to October, with an average cumulative drainage of 316 mm. Again, on average, the *SG* plots had slightly less drainage than the *DG* plots (Figure 3).

There was a large difference between the effect of treatments on the concentrations of nitrate-N in drainage water at the beginning of the 2009 drainage season, with the *DG* plots having lower concentrations on average (Figure 1); described in more detail in Christensen *et al.* 2010). From August onwards, the concentrations of nitrate-N in drainage water in 2009 were very low for both treatments, except for a small increase in late November. This increase is probably due to a combination of the mid-November grazing event, N fertiliser being applied, and perhaps the N that was newly mineralised because of increasing soil temperature. Nevertheless, nitrate-N levels did not increase above 2 ppm at this time, and although the quantity of drainage from August onwards represented more than 50% of total 2009 drainage, it contained less than 6% of the season's nitrate-N loss, on average over both treatments.

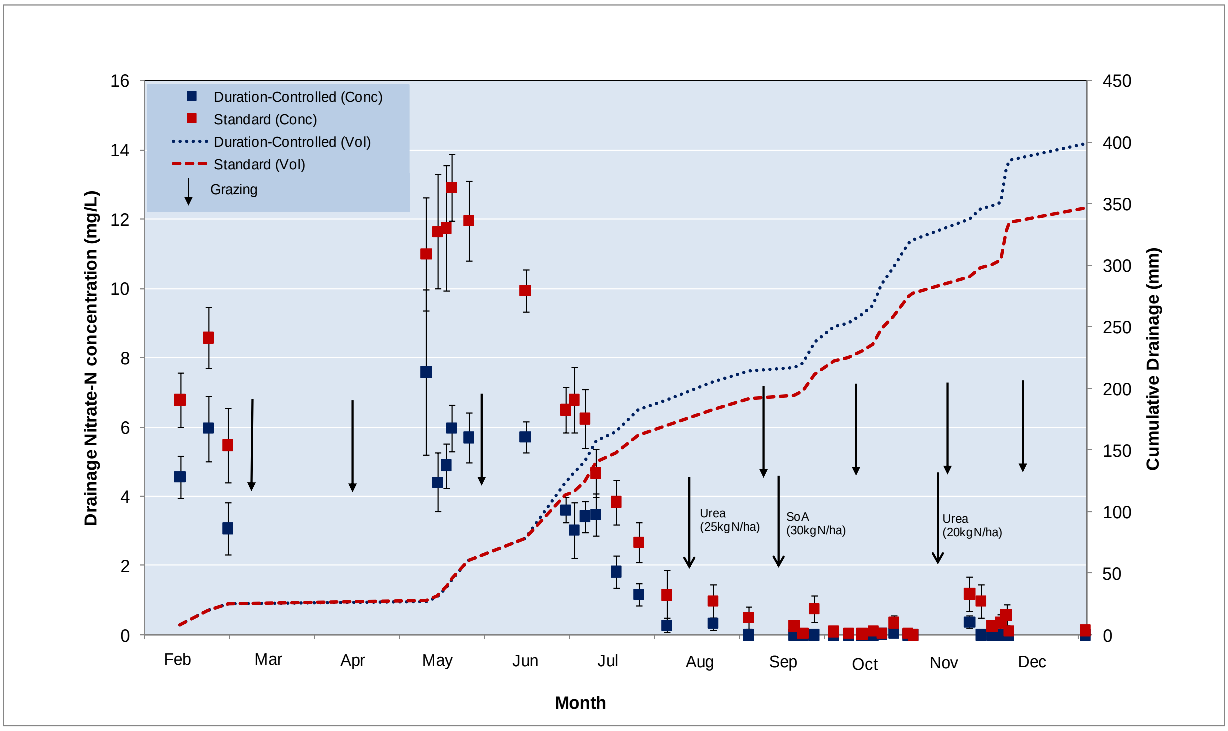

Figure 1: 2009 Nitrate-N concentration (ppm) in drainage water and cumulative drainage (mm) for duration-controlled and standard grazing treatments.

In 2009, the total nitrate-N lost from the *DG* treatment plots was 7.5 kg N/ha, which was 43% lower than the 13.1 kg N/ha lost from the *SG* plots on average (Figure 2). Most of this nitrate-N lost was prior to August, when concentrations of nitrate-N in drainage were higher at this time (Figure 1 and Figure 2).

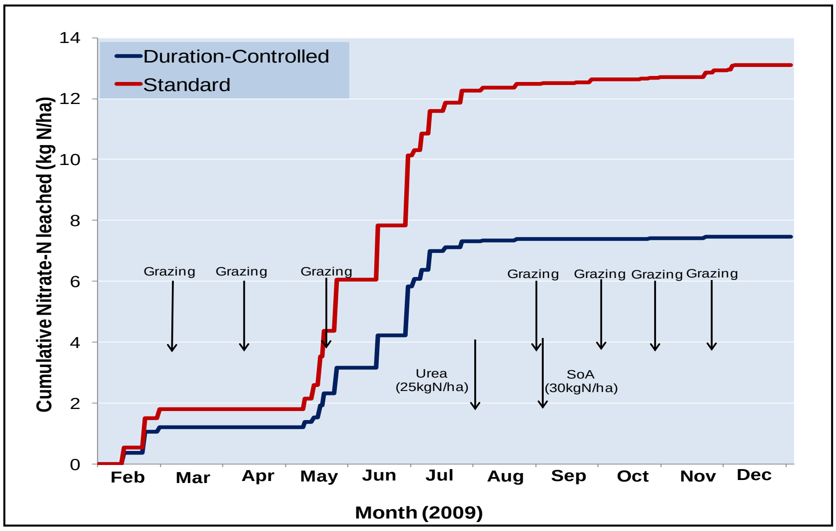

Figure 2: 2009 cumulative nitrate-N leached (kg/ha) in drainage water for duration-controlled and standard grazing treatments.

In 2010, nitrate-N concentrations in drainage showed a similar trend to previous years, with the greatest concentrations at the beginning of the drainage season. Similar to 2009, there was a large difference in concentrations between treatments, with *DG* plots having much lower concentrations than *SG* plots (Figure 3). However, the overall concentrations were lower in 2010 than in the previous year (Christensen *et al.* 2010), with the highest average concentrations being 9.0 ppm and 4.2 ppm for the *SG* and *DG* plots, respectively.

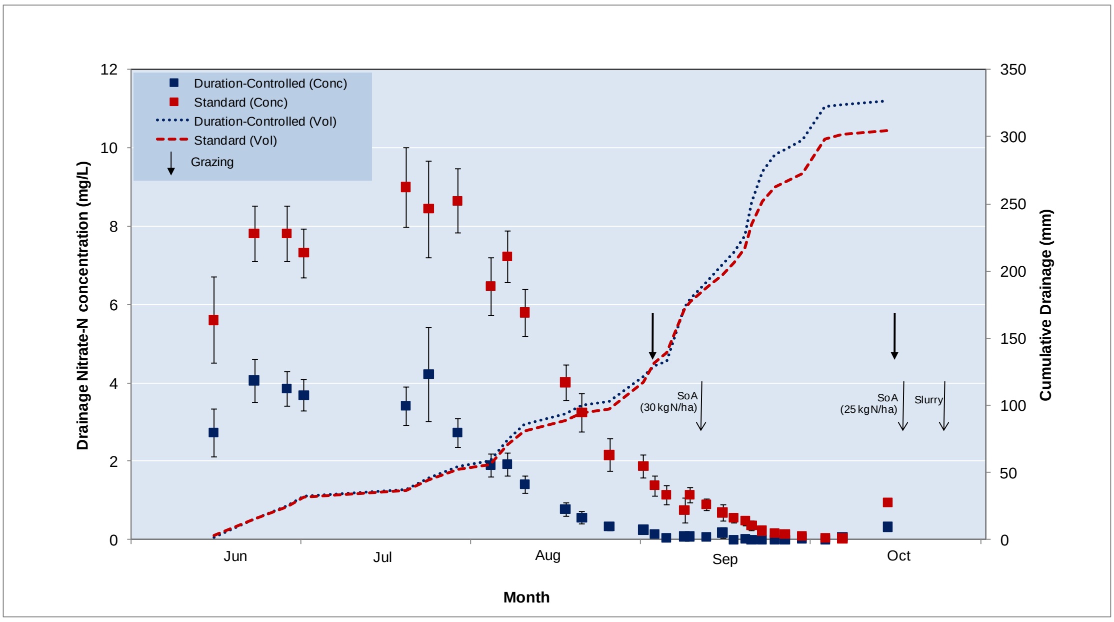

Figure 3: 2010 Nitrate-N concentration (ppm) in drainage water and cumulative drainage (mm) for duration-controlled and standard grazing treatments.

The cumulative nitrate-N (kg N/ha) lost in drainage in 2010 was also lower (Figure 4) than that seen in previous years (Christensen *et al.* 2010). Overall however, the difference in cumulative nitrate-N lost between treatments was larger, with a 65% reduction from the *DG* plots (2.8 kg/ha), compared with the *SG* plots (8.0 kg/ha).

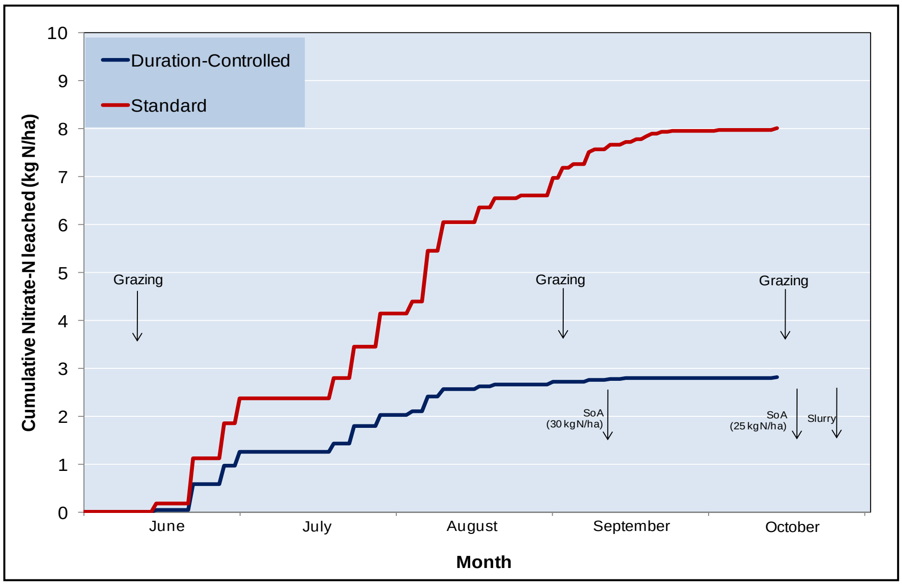

Figure 4: 2010 cumulative nitrate-N leached (kg/ha) in drainage water for duration-controlled and standard grazing treatments.

On average over the two year of the study the overall nitrate reduction was around 50%, which is in line with the dairy industry's target of a 50% reduction in nitrate-N leaching by the year 2020.

Pasture accumulation in the 2008/09 lactation season was similar for both treatments (Figure 5), as discussed in Christensen *et al.* (2010). However, in the 2009/10 lactation season, average pasture accumulation was significantly ($P<0.05$) lower in the *DG* plots (10764 kg DM/ha) than in the *SG* plots (12970 kg DM/ha) and this difference was increasing with time (Figure 6).

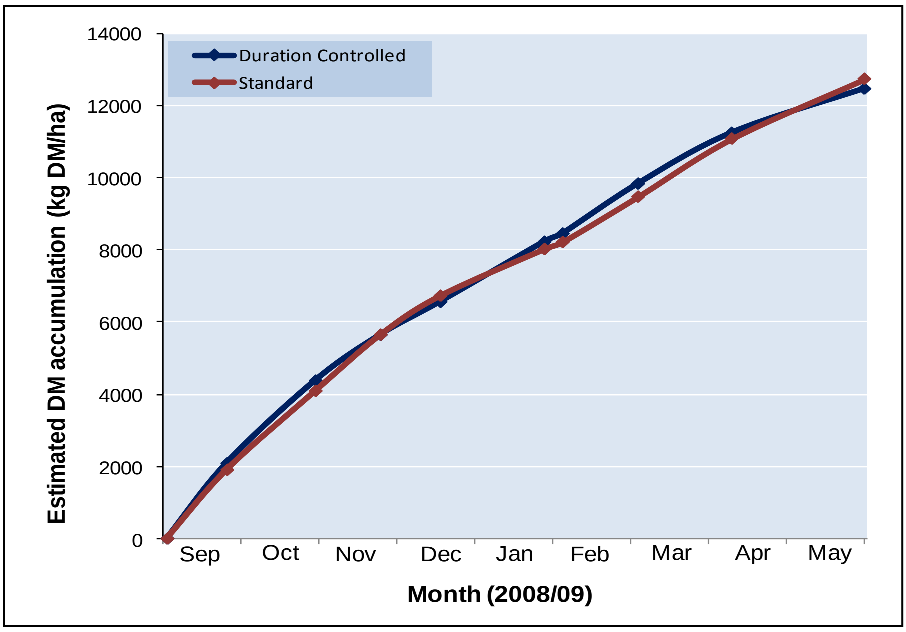

Figure 5: Pasture accumulation over 2008/09 lactation season for duration-controlled and standard grazing treatments.

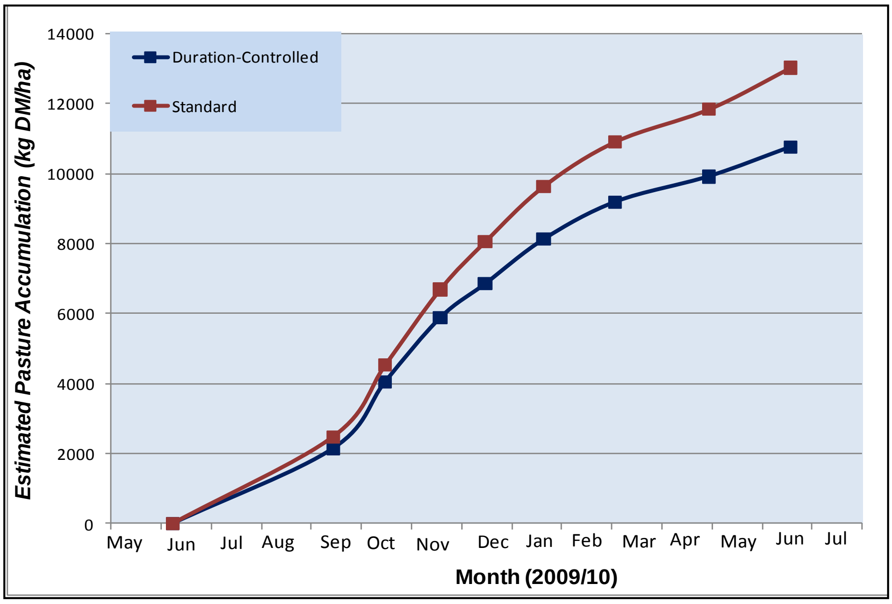

Figure 6: Pasture accumulation over 2009/10 lactation season for duration-controlled and standard grazing treatments.

Slurry was applied to *DG* plots in December 2008 (details of application rates are given in Lindsay *et al.*, (2009)). As the application rate of slurry in 2008 was equivalent to the amount produced from 18 months of duration-controlled grazing, no slurry was applied in the 2009/10 lactation season. Smaller, more regular applications are currently being applied in the 2010/11 lactation season (at the time of publication).

Although the slurry applied to *DG* plots in 2008 meant large amounts of nutrients (181 kg N/ha) were added (Lindsay *et al.* 2009), this did not prevent a pasture accumulation decline in the *DG* plots compared to the *SG* plots in the subsequent lactation season. This may have been due to most of the N present in the slurry being in an organic form, becoming immobilised and unavailable to plants after application.

Conclusions

Duration-controlled grazing has the potential to reduce nitrate-N leaching by ~50% on dairy farms (relative to standard grazing management). Therefore, it has the potential to be an important mitigation strategy, particularly in nitrogen-sensitive areas. However, before farmers adopt this practise they will need to be convinced that they can do so without compromising pasture production. To this end, the effectiveness of smaller, more regular applications of slurry to the *DG* plots is currently being assessed.

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