THE CHALLENGE OF LATE SUMMER URINE PATCHES IN THE WAIKATO REGION

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Abstract

Artificial urine (800 or 400 kg N/ha) was applied to separate replicated plots on the Horotiu silt loam at monthly intervals from February to July 2010. Nitrogen loads leached below 60 cm during the drainage period were calculated using a combination of porous ceramic cups installed in each plot and drainage measured from lysimeters of the same soil-type. Drainage of 465 mm was measured between early June and early October. Mineral N leached predominantly as NO_3-N. There was a significant (P <0.01) interaction of time and rate of urine application on the amount of mineral N leached during the drainage period. There was a tendency for mineral N leaching to increase approximately linearly between the February and May urine applications. Leached N values for the February and May applications were 317 and 445 kg N/ha (800 rate) and 83 and 173 kg N/ha (400 rate); thus the contribution to N leaching from February deposited urine can be large, especially at higher urinary N rates. Halving the N load in the urine patch more than halved N leaching from the patch. For urine applications after May, not all of the urine N had been eluted from the profile by the time drainage stopped in October. Losses were 212 and 86 kg N/ha (800 rate) and 84 and 48 kg N/ha (400 rate) for applications in June and July, respectively. Combined, data from experiments in 2009 and 2010 indicate a significant contribution to N leaching from urine deposited in February/March and, by extrapolation, months before this – especially at the 800 kg N/ha rate which is equivalent to a dairy cow urine patch. Further work is required to test if this holds for other regions within New Zealand where climate and pasture growth patterns will differ.

Introduction

Earlier exploratory work (Bryant & Snow, 2009) using Taupo soils and climates simulated the fate of large urea fertiliser applications (to represent equivalent urine applications) applied at monthly intervals through the year. The results suggested that N deposited in March-April was the most susceptible to over-winter nitrate leaching. Shepherd *et al*. (2010) undertook an experiment on a Horotiu silt loam in the Waikato region. They confirmed that the amount of N leached from urine N (equivalent application rate 800 kg N/ha) in the winter after application was similar for applications in March, April and May. This means that mitigations such as autumn/winter DCD application or wintering-off of animals might not be targeting the most critical period of urine deposition. This is in contrast to the findings of Cuttle & Bourne (1993) who measured a greater nitrate leaching risk from urine applied in the autumn than when applied in summer, albeit at a much lower rate of 300 kg N/ha. The field experiment described here follows on from the experiment undertaken in 2009 (Shepherd *et al*., 2010) to obtain measurements of nitrate leaching from urine applied at monthly intervals from February through to July at different urine-N rates. The objectives of the experiment were: to test the hypothesis that summer urine deposition can be a greater source of nitrate leaching than later depositions; and to provide data to calibrate/test the APSIM model for Waikato conditions (Snow *et al*., 2011).

Method

The site chosen was pasture on a Horotiu silt loam (Typic Orthic Allophanic soil: Hewitt, 1993) at DairyNZ's Scott Farm near Hamilton (New Zealand). The typical soil particle size distribution for Horotiu soils in this locale is: (0-15 cm) 22% clay, 47% silt and 31% sand; subsoil (30-50 cm) 1% clay, 57% silt and 42% sand (Shepherd *et al.*, 2010). The sward composition was predominantly ryegrass with < 5% clover. The terrain was flat.

Artificial urine (adapted from Fraser *et al.*, 1994) was applied to plots of 2.5 m x 1.5 m with 0.5 m between the plots. There were 6 urine application times (one each month, February to July) at two rates of applied N (400 and 800 kg N/ha), plus a control with 0 N. The treatments were allocated in a complete randomised block design. To halve the N application rate, the 800 kg N/ha rate was diluted so that the same volume of liquid was applied (10 mm application depth). This was applied in the middle of each month using watering cans, two days after cutting the pasture.

Four porous cups (Webster *et al.*, 1993) were installed in each plot to a depth of 0.6 m (at a 45 degree angle) for leachate collection. The porous cups were sampled after approximately every 30-40 mm rainfall, by applying a suction of c. 0.6 bar overnight and removing all of the collected soil solution the next day. There were 11 sampling rounds between June and October. The leachate was frozen for storage after collection ($<-4\ ^{o}C$). After thawing, leachate from individual porous cups was analysed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N). Drainage volumes for calculating N leaching loads were taken from pasture lysimeters of the same soil-type based 2 km away.

Pasture was cut at 3-4 weekly intervals, depending on rate of growth. Each plot was mown to c. 4 cm height, the pasture weighed and sub-sampled for measurement of dry matter and %N. The pasture was removed and the site remained ungrazed so that we could trace the effects of the added urine. The soil was sampled for mineral N measurement (NH_4-N plus NO_3-N) in November, after the end of drainage. Soil was sampled at 5 depths, comprising 5 replicate cores from each of the plots, of 0.15 m intervals to 0.6 m deep and a final 0.3 m increment to 0.9 m deep. The sandy subsoil made it difficult always to collect accurate samples from the 0.6-0.9 m layer. Thus, this depth is described as 60~90 cm.

Results

Weather

Figure 1 summarises the total rainfall and average air temperature by month for 2010, and the 10-year average. After storms in January, there was an extended period of dry weather through February to April. Soil moisture deficits were such that the lysimeters did not start draining until June after greater than average rainfall in May and June. The drainage period extended through to October, mainly due to August and September being wetter than average. Drainage amounts were calculated using a water balance model (Woodward *et al.*, 2001) and compared well with measurements from the pasture lysimeters (modelled 477 mm vs measured 465 mm); the measured lysimeter data were used for calculating N loads leached.

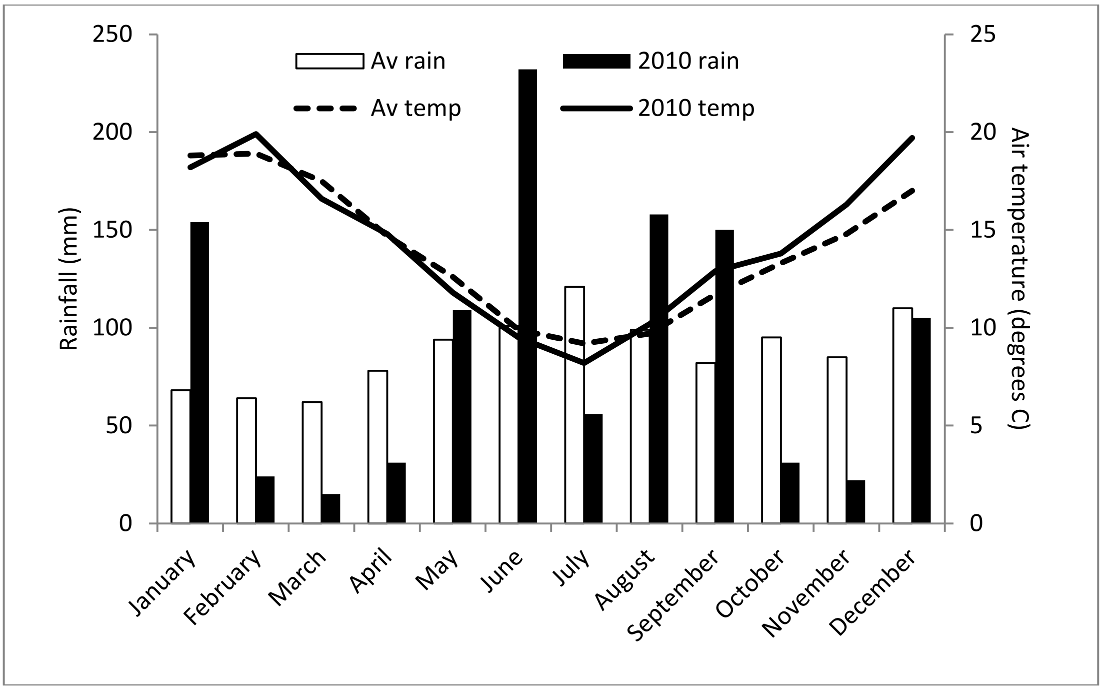


Figure 1. Weather summary for the experimental site during 2010 compared with the 10 year average.

Mineral N concentrations in drainage

Mineral N leached predominantly as NO_3-N, with >98% of leached mineral N present as NO_3-N. Mineral N concentrations in leachate at 60 cm depth for the June-October drainage period showed similar trends for the February- to April-applied urine at the 800 kg N/ha rate, despite application dates spanning 2 months (Figure 2). For all three treatments, N concentrations started at c. 1 mg N/l, peaked at about 150-180 mg N/l after 170-220 mm drainage and decreased to <10 mg N/l at the end of drainage. This N concentration curve is indicative of classic convection-dispersion movement of N through the soil. Leachate from May-applied urine followed a similar N concentration curve (peak concentration c. 200 mg N/l), but was offset due to the later application date. The concentration curves indicated that not all of the N had leached from the June and July-applied urine by the end of drainage in October.

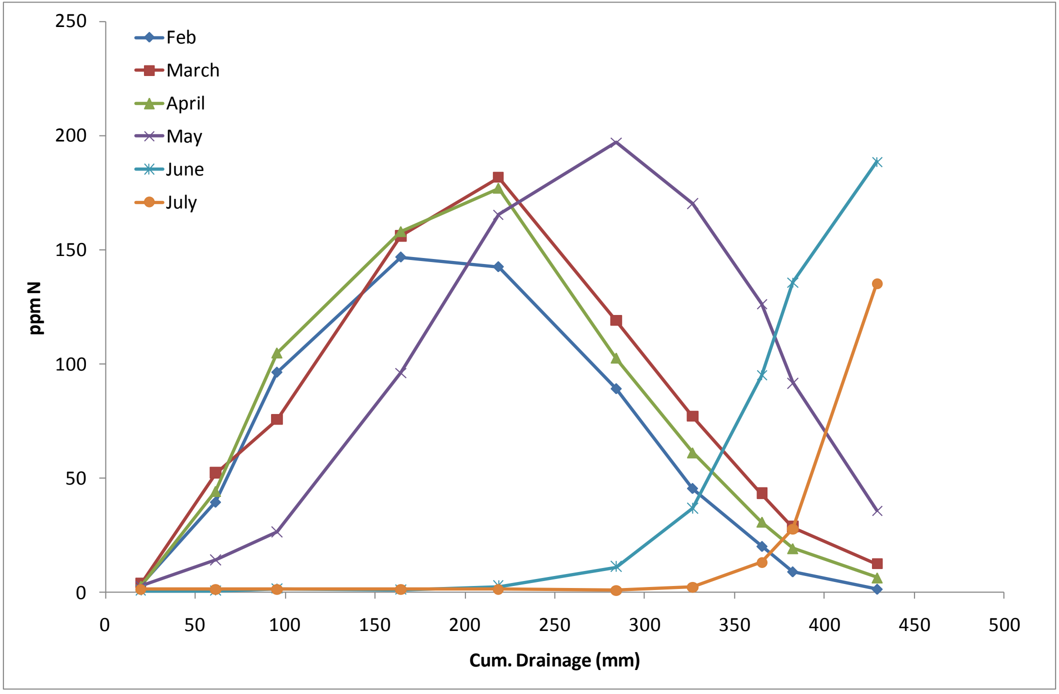
Peak concentrations for the leaching curves from the 400 kg N/ha rate were generally half those of the 800 kg N/ha rate (Figure 2). There was also more differentiation between N leaching curves from the February to April applications than was noted with the higher application rate. However, the general trends were similar, showing that leaching from June and July-applied urine was not complete by the end of drainage in October.

Soil mineral nitrogen

Soil mineral N measured at the end of drainage confirmed the N leaching was incomplete by the end of the drainage in October (Figure 3). There was minimal soil mineral N remaining in the soil from the February-May applications, and it appeared that the later the urine application, the greater the mineral N remaining in the soil at the end of drainage. This was mainly present as NO_3-N.

Although a considerable amount of mineral N remained in the soil after the end of drainage from the June and July applications, particularly for the 800 kg N/ha rate of urine, Figure 3 shows that it was well distributed down the soil profile. Approximately 70% and 40% of the mineral N was measured below 45 cm for the June and July-applied urine, respectively.

(a) 800 kg N/ha



(b) 400 kg N/ha

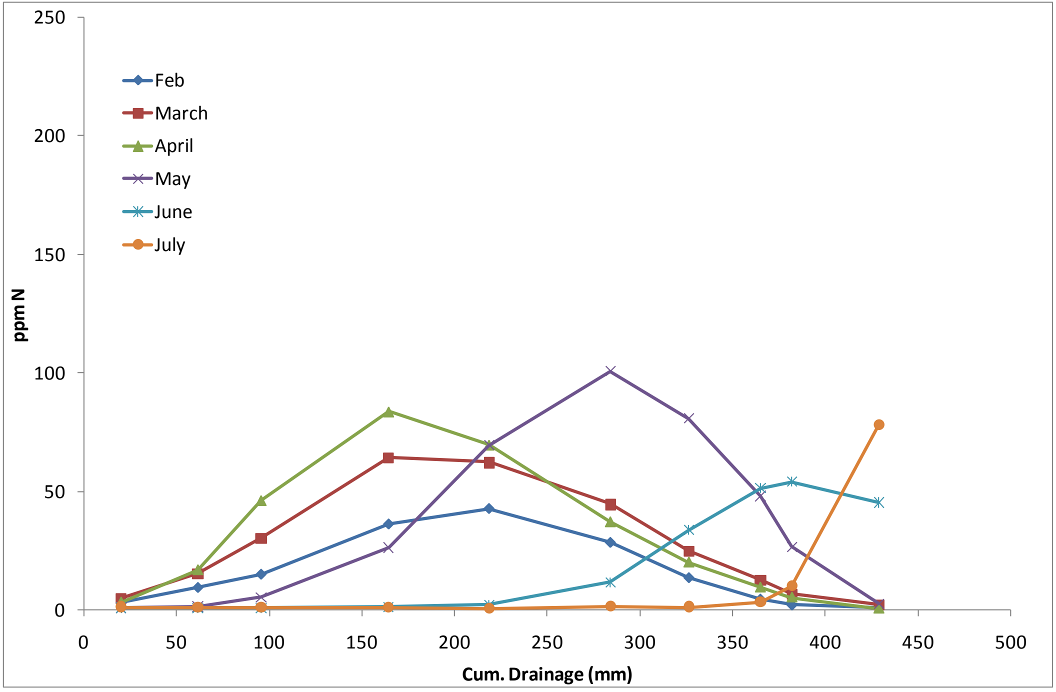


Figure 2. Mineral N concentrations in drainage water after each urine application, plotted against cumulative drainage (May-October) for both rates of urinary N.

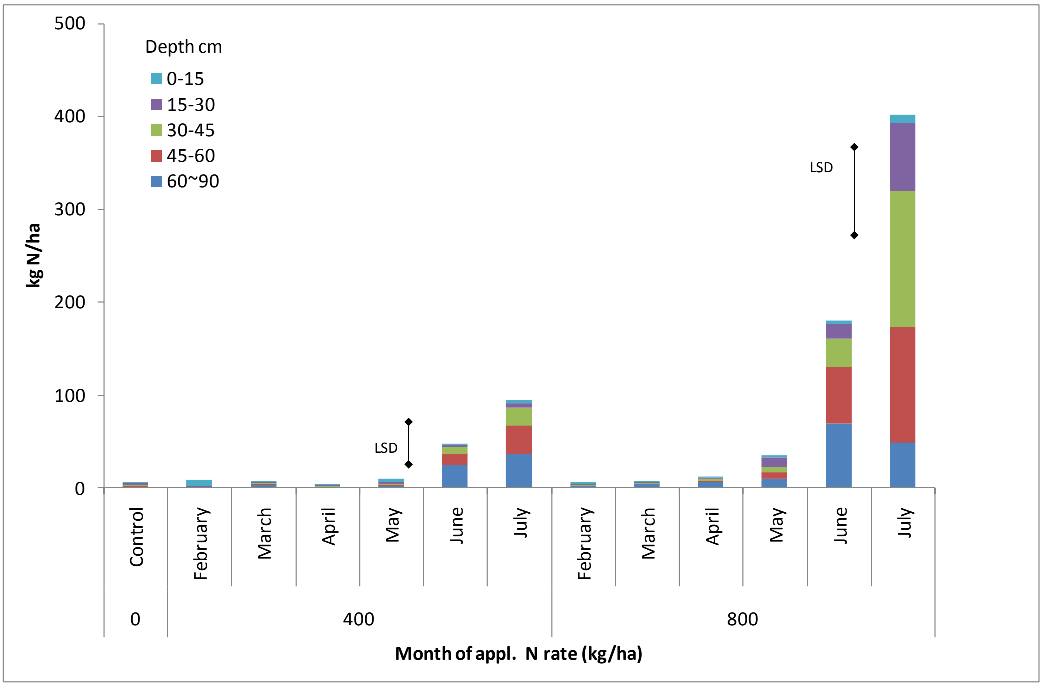


Figure 3. Measured soil mineral N content at the end of drainage (measured in November) by depth increment.

Calculated NO_3-N leaching load

The amount of mineral N leached below the depth of the porous cups (based on lysimeter drainage and measured N concentrations in the leachate) varied with application time and application rate (Figure 4). There was a highly significant interaction of these two factors ($P < 0.001$).

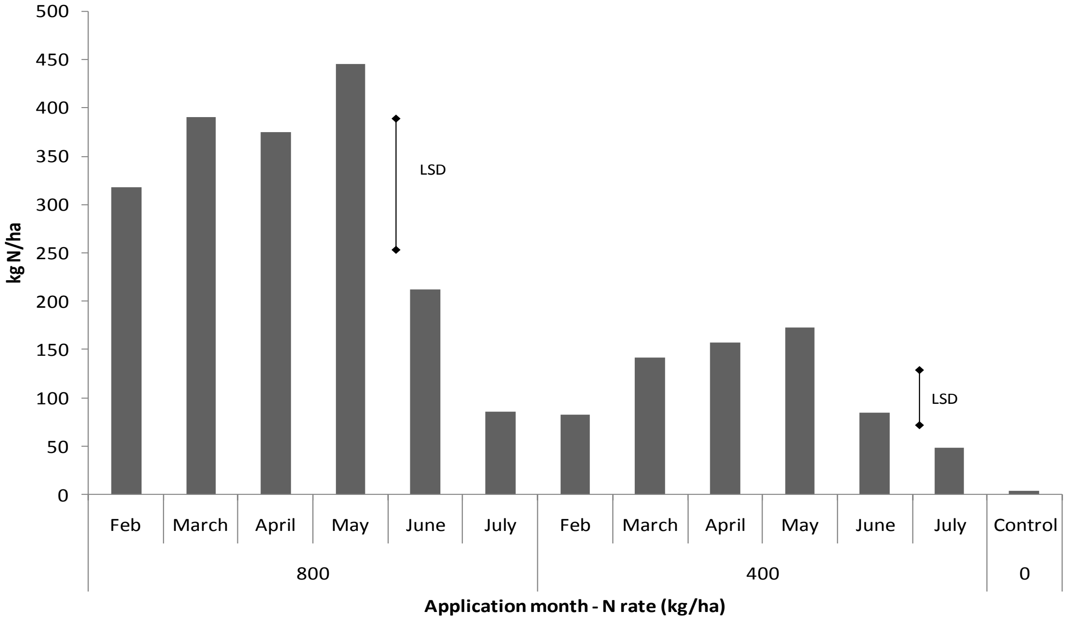


Figure 4. Calculated mineral N leaching losses (kg/ha) from urine treatments and control (control excluded from the statistical analysis). The least significant difference (LSD) is provided for the 2 urine N application rates.

Nitrogen losses from the control were <5 kg N/ha, indicating that most of the N leaching was attributable to the urine. Largest losses were from the May applications (440 and 168 kg N/ha for the 800 and 400 kg N/ha rates, respectively, after correction for the control losses). This was equivalent to 55% and 42% of the applied N for the higher and lower application rates, respectively.

Most of the urinary N available for leaching had been leached below 60 cm in the soil profile by the end of drainage for the February-May applications for both application rates, according to the soil mineral N measurements (Figure 3). There was an approximately linear relationship between month of application and calculated N loss for these 4 months at both N application rates, with losses peaking for the May application (Figure 4).

Herbage Growth Rates

The pasture growth rate for the first harvest after each urine application was consistently greater for the 400 kg/ha N rate than for the 800 kg/ha N rate, as well as showing seasonal variation (Figure 5). Rate and seasonal effects were highly significant ($P<0.001$). In February, the 800 N application rate scorched the pasture and restricted growth; this did not occur at the 400 N rate. One possible reason was the high temperatures combined with the high osmotic stress caused by the salt loading at 800 kg N/ha (Rhoades & Loveday, 1999). Urine scorch was also noted in the adjacent pasture where dairy cows had urinated around the same time that the treatment was applied.

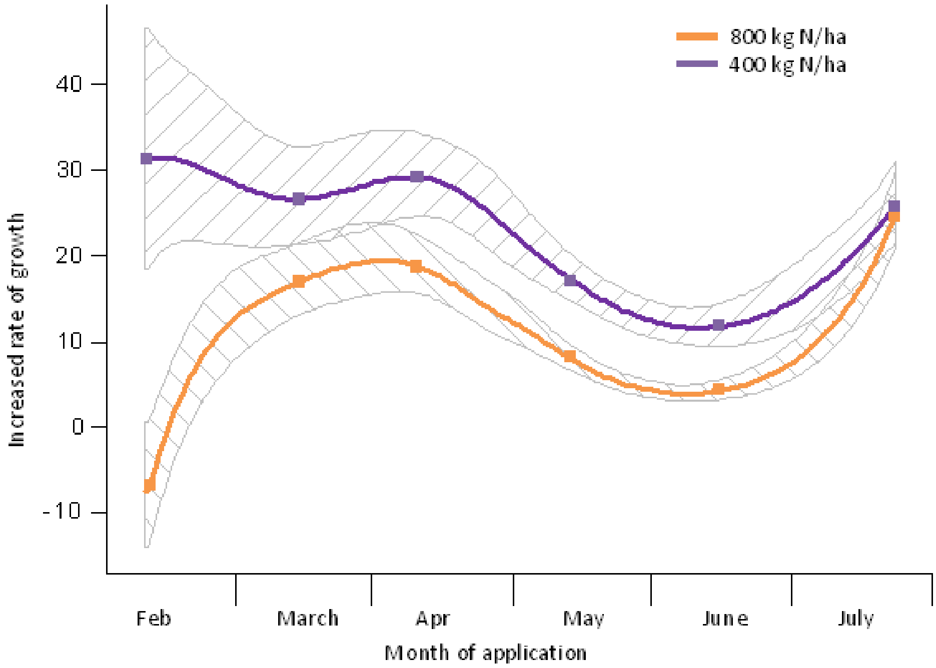


Figure 5. Nitrogen response (expressed as additional daily dry matter accumulation above the unfertilized control, kg DM/ha/day) for the first harvest after each urine application. 95% confidence intervals shown.

Discussion

These results, following on from data reported by Shepherd *et al*. (2010), suggest a high risk of nitrate leaching from urine deposited in late summer. Cuttle & Bourne (1993) found a generally greater leaching risk the later urine was deposited when they tested applications from July to November in the northern hemisphere. However, Cuttle & Bourne applied 300 kg N/ha, whereas we aimed to simulate dairy cow urine patches (800 kg N/ha; Haynes & Williams 1993); and we also applied half that rate to test the effect of N rate.

At both 800 and 400 kg N/ha we can hypothesise that the urine applied considerably more N than could be utilised by the pasture, even when deposited in February. Thus, although the greatest loss was from a May application (at both rates), there was significant N leaching from earlier applications, especially at the 800 kg N/ha rate. Pasture growth from the February-applied urine (800 kg N/ha) was affected by the dry weather immediately after application, and there was some indication of scorch following urine application. However, dry spells in summer are not uncommon in the Waikato region; the fact that urine scorch was also noted in the adjacent grazed paddock indicates that this is a real phenomenon (not an artefact of the experiment) under hot, dry conditions.

We need to be cautious of inferring that no further N leaching will occur from urine deposited in late winter/early spring after the end of the main drainage period. Further loss could occur if there are e.g. summer storms that initiate further drainage. However, perhaps a greater risk of subsequent N leaching is mineral N displaced deep down the soil profile; if this cannot be recovered by the pasture during the subsequent growing season, then it will be leached in the following winter; monitoring will continue through this second winter to investigate this risk.

The implication of these results is that mitigations must target these late summer urine deposits if N leaching is to be substantially reduced from paddocks grazed by dairy cows. Given that halving the N concentration in the urine patch more than halved subsequent N leaching, this suggests that decreasing the N load per urine patch would be of benefit, as postulated by Bryant *et al.* (2007).

The absolute amounts of N leached reported here are specific to the Horotiu soil in this season. Further study is required to test the same hypothesis for different soil types and regions (climates). Furthermore, the experiment focuses on N leaching from a single urine patch, but the whole paddock effect will be tempered by (a) the amount of N deposited in urine each month and (b) the concentration of that N in individual urine patches. Animal N balances (N eaten in feed minus N used in product and/or animal maintenance) are routinely used to estimate N excretion and partitioning between urine and dung (e.g. OVERSEER®; Wheeler *et al.*, 2006). This experiment, comparing losses from 400 and 800 kg N/ha, showed that the N rate per urine patch influences the amount lost, as does the work of Bryant *et al.* (2006). Thus, if the dairy cow urinary N concentration varies from the 800 kg N/ha load assumed for this experiment, then this will modify the amounts leached accordingly. We would argue, therefore, that the single urine patch effects have to be combined with these two other key factors to fully assess the effect of time of urine deposition on N leaching patterns: amount of N deposited each month and variation in N concentration per urine patch, which can vary even within a day (Hoogendoorn *et al.*, 2010).

Acknowledgements

This work was funded by the P21 Environment Programme, jointly funded by FRST, DairyNZ, Fonterra and Meat & Wool New Zealand.

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