

Urine patch and fertiliser N interaction: Effects of fertiliser rate and season of urine application on nitrate leaching and pasture N uptake

L.E. Buckthought^a, T.J. Clough^c, K.C. Cameron^c, H.J. Di^c, M.A. Shepherd^b

Show more

Share Cite

<https://doi.org/10.1016/j.agee.2015.01.019>

[Get rights and content](#)

Highlights

- We measured the effects of fertiliser-N+urine on NO_3^- leaching and plant N uptake.
- Urine+the higher **fertiliser rate** (400kg N ha^{-1}) increased total NO_3^- leaching.
- Urine+the lower **fertiliser rate** (200kg N ha^{-1}) did not increase N leaching.
- Fertiliser N recovered in drainage was <2.2% and not affected by fertiliser rate.
- Cumulative fertiliser N recovered in pasture uptake was up to 52%.

Abstract

Urine patches are the primary source of N loss from pastoral systems due to the high N loading that occurs over a relatively small area. However, few studies have sought to determine the effect of concurrently deposited urine and fertiliser on the fate of N in pastoral systems, even though the application of fertiliser soon after grazing is commonly practised, while no studies have examined seasonal effects of any interaction.

The objective of this study was therefore, to understand how the combination of fertiliser-N and urine affected fertiliser-associated NO_3^- leaching losses and plant uptake of N. A two year lysimeter study was undertaken with urine (800kg N ha^{-1}) applied in either autumn or spring. Urea fertiliser enriched with ^{15}N was applied to these lysimeters at rates equivalent to 200 or 400kg N ha^{-1} per year according to the standard regional practice.

Urine and fertiliser at the 400kg N ha^{-1} rate increased total NO_3^- leaching by up to 58kg ha^{-1} ($P < 0.001$), from urine applied in either autumn or spring. Fertiliser applied at 200kg N ha^{-1} did not increase N leaching from urine patches. Fertiliser ^{15}N recovery in drainage was <2.2% and was not affected by fertiliser rate. Pasture uptake accounted for up to 52% of the fertiliser ^{15}N recovery and this increased with increasing fertiliser rates, even in the presence of urine. Recovery of fertiliser ^{15}N in the soil at the end of the experiment averaged 22% with the majority of this in the top 10cm soil.

These results indicate that the potential for leaching of fertiliser N, applied to a urine patch, is low, and that avoiding fertiliser application over urine patches, reduces leaching losses of fertiliser-N by <2%, which is minimal in terms of total N loss mitigation. However, at high fertiliser application rates to urine patches (i.e. 400kg N ha^{-1}), the total N leaching from non-fertiliser (non ^{15}N -enriched) sources can increase. Further work is required to quantify these effects at the paddock scale. The results also show that NO_3^- leaching losses were greater from autumn applied urine compared to spring applied urine by up to $306\text{kg NO}_3^- \text{N ha}^{-1}$.

Introduction

The mitigation of nitrate (NO_3^-) leaching is a significant challenge facing the New Zealand agricultural industry, and it has been a focus of research over the past two decades. Loss of nitrogen (N), as NO_3^- , reduces soil fertility and potential productivity, while also posing an environmental threat (Cameron et al., 2013). Nitrate leaching may accelerate eutrophication of surface water bodies, resulting in water quality deterioration and subsequent effects on aquatic habitats, recreational use and aesthetics (Sutton et al., 2011).

Ruminant urine deposition and the application of urea fertiliser in dairy farming systems contributes to N leaching losses from pastures (Cameron et al., 2013). Urine-N is the dominant NO_3^- leaching source in grazed dairy pastures because the urine-N rate exceeds the pasture's ability to utilise it. Urine-N induced NO_3^- leaching losses are more likely in late autumn, winter and early spring, when temperatures are cooler, plant N demand is low and soil drainage occurs due to rainfall exceeding evapotranspiration (Wild and Cameron, 1980). Conversely, fertiliser-N leaching losses can be low, if timing of fertiliser-N application and rates match plant demand (Di and Cameron, 2002b, Cameron et al., 2013).

Despite numerous suggestions that fertiliser application onto urine-affected areas (i.e. grazed pasture) will lead to an increased risk of N leaching and decreased fertiliser N use efficiency (Silva et al., 1999, de Klein et al., 2001, Silva et al., 2005, Mackenzie et al., 2011, Cameron et al., 2013), few studies have quantitatively investigated the interaction between concurrent mineral fertiliser-N application and urine-N deposition with respect to N leaching (Silva et al., 1999, Leterme et al., 2003, Decau et al., 2004, Silva et al., 2005). Furthermore, no studies have partitioned the fertiliser contribution to N leaching under concurrently applied urine and fertiliser. Understanding the relative contributions of fertiliser-N and urine-N is crucial if N leaching is to be successfully mitigated.

Various mitigation strategies to reduce N leaching from pastoral systems have been proposed (Addiscott, 1996, Di and Cameron, 2002b), including developing precision technology for applying fertiliser-N while avoiding urine and dung patches (Yule and McVeagh, 2011, Mackenzie et al., 2011). Such technologies would, theoretically, increase fertiliser-N use efficiency in pastoral systems if fertiliser-N was preferentially lost under urine patches. However, knowledge of the urine patch-fertiliser-N interaction and the respective contributions to N leaching is extremely limited, and by default so are the economic and environmental benefits such technologies may provide.

Thus, the primary objective of this study was to understand how fertiliser-N interacted with urine to affect NO_3^- leaching losses and plant uptake of N, when fertiliser was applied following urine deposition in either autumn or spring, and to determine to what extent, if any, fertiliser-N enhanced leaching of N from under a urine patch. It was hypothesised that (i) increased fertiliser associated leaching would occur under urine patches with increasing rates of fertiliser application, and (ii) that leaching would be greatest under an autumn deposited urine patch when compared to a spring deposited urine patch.

Section snippets

Soil description and lysimeter collection

Thirty six large, undisturbed soil monolith lysimeters (50cm diameter×70cm deep) were collected on 14 December 2010 from the AgResearch No. 1 Dairy Farm, at the Ruakura Research Centre, Hamilton, New Zealand (latitude 37.779°S, longitude 175.315°E). The soil at the collection site was a moderately permeable, well drained Horotiu silt loam (Typic Orthic Allophanic Soil) (Singleton, 1991, Hewitt, 1998). The soil was under a ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*) pasture ...

Climate data

Over 554 days, total rainfall was 2230mm, with 1410mm rainfall in the first year, and 820mm in the remaining six months (Fig. 2a). This was higher than the annual average rainfall for Hamilton (1200mm), which is spread evenly throughout the year (100mm per month). There was uncharacteristically high rainfall in December 2011 (220mm) and early January 2012 (130mm) that resulted in summer drainage (Fig. 2a). The daily air temperature ranged from 1.0 to 23.5°C and averaged 12.6°C. Daily soil ...

Discussion

Despite a number of studies investigating leaching losses under urine patches amended with fertiliser, and a number of these using ¹⁵N enrichment of the urine to determine their role in NO₃⁻-N leaching (e.g. Decau et al. (2004), Silva et al. (2005), Leterme et al. (2003) and Silva et al. (1999)), this is one of the first studies to specifically partition the fertiliser component of the urine patch-fertiliser combination to determine its effect on NO₃⁻-N leaching.

There was little variation in ...

Conclusions and general implications

When urine and fertiliser were deposited concurrently prior to winter drainage, the fertiliser-N made a negligible contribution to the total inorganic-N leaching pool with <2.17% of the ¹⁵N applied as fertiliser recovered in the leachate after 554 days. These results conflict with the commonly held belief that fertiliser applied over a urine patch will simply exacerbate the fertiliser's contribution to the NO₃⁻-N leaching load because the N supplied from the urine patch is already surplus to ...

Acknowledgements

This research was funded by the Pastoral 21 programme, a collaborative venture between DairyNZ, Fonterra, Dairy Companies Association of New Zealand, Beef+Lamb NZ and the Ministry of Business, Innovation and Employment. We acknowledge and thank John Waller for statistical analyses, and Stuart Lindsey and Roger Cresswell for chemical and ¹⁵N analyses ...

[Recommended articles](#)

References (41)

N.S. Bolan *et al.*

[Dissolved organic matter: biogeochemistry, dynamics and environmental significance in soils](#)

R.J. Haynes *et al.*

(1993)

M.J. Hutchings *et al.*

[Foraging in plants: the role of morphological plasticity in resource acquisition](#)

T.M. Addiscott

Fertilizers and nitrate leaching

A.S. Black *et al.*

Effect of timing of simulated rainfall on ammonia volatilization from urea, applied to soil of varying moisture content

J. Soil Sci. (1987)

P.D. Brooks *et al.*

Diffusion method to prepare soil extracts for automated nitrogen-15 analysis

Soil Sci. Soc. Am. J. (1989)

M.L. Cabrera *et al.*

Review and simplification of calculations in N tracer studies

Fert. Res. (1989)

K.C. Cameron *et al.*

Lysimeters without edge flow: an improved design and sampling procedure

Soil Sci. Soc. Am. J. (1992)

K.C. Cameron *et al.*

Nitrogen losses from the soil/plant system: a review

Ann. Appl. Biol. (2013)

B.B. Casper *et al.*

Plant competition underground

Annu. Rev. Ecol. Syst. (1997)



View more references

Effect of graphene on the performance of nickel foam-based CoNi nanosheet anode catalyzed direct urea-hydrogen peroxide fuel cell

2020, International Journal of Hydrogen Energy

[Show abstract](#) ▾

Annual nitrogen dynamics and urea fertilizer recoveries from a dairy pasture using 15N; effect of nitrification inhibitor DMPP and reduced application rates

2016, Agriculture Ecosystems and Environment

Citation Excerpt :

...The vast majority of this was recovered in the top 10 cm suggesting that despite the high rainfall experienced at the site NO₃⁻ movement down the soil profile was minimal. This is similar to the <1 kg N ha⁻¹ leached from a New Zealand silt loam (Buckthought et al., 2015), lower than the 4.3–22 kg N ha⁻¹ leached from a clay loam (Eckard et al., 2004) and the 100–600 kg N ha⁻¹ associated with urine patches on stony soils (Silva et al., 2000; Di and Cameron, 2002a). While it is possible that some N was displaced down the profile and subsequently denitrified or moved below the sample depth of 1 m, the extremely low concentrations recovered below 50 cm suggest leaching was a minimal N loss mechanism in this soil....

[Show abstract](#) ▾

Nitrate leaching and residual effect in dairy crop rotations with grass-clover leys as influenced by sward age, grazing, cutting and fertilizer regimes

2015, Agriculture Ecosystems and Environment

[Show abstract](#) ▾

Different effects of sheep excrement type and supply level on plant and soil C:N:P stoichiometry in a typical steppe on the loess plateau ↗

2021, Plant and Soil

Milk yield and nitrogen excretion of dairy cows grazing binary and multispecies pastures ↗

2017, Grass and Forage Science

Soil gas diffusivity controls N₂O and N₂ emissions and their ratio ↗

2016, Soil Science Society of America Journal



[View all citing articles on Scopus](#) ↗

[View full text](#)

Copyright © 2015 Elsevier B.V. All rights reserved.



All content on this site: Copyright © 2026 Elsevier B.V., its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the relevant licensing terms apply.

