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EVALUATION OF THE EFFECT OF SOIL COMPACTION ON URINE PATCH AREA AND PLANT RECOVERY OF URINE-NITROGEN

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Abstract

Recent research has indicated that higher stocking rates may, in certain cases, result in lower nitrogen (N) leaching losses. One possible explanation for this is that higher stocking rates can increase soil compaction. This can reduce soil porosity and surface infiltration rates and could increase the area covered by individual urine patches, due to greater dispersion following deposition. Increased urine spread would result in reduced urine-N deposition rate and potential for greater uptake of urine N by pasture.

A plot trial was established on a ryegrass/white clover pasture on a Te Kowhai soil in the Waikato in late autumn 2017. Four treatments were applied: compacted or uncompacted, and with or without urine. Compaction was carried out using a roller to apply a pressure similar to that exerted by a 500 kg dairy cow. Two litres of artificial urine (35 °C) was applied to the centre of a 1 m^2 plot according to a standard cow height and time interval for each of the urine treatment plots. The area covered by the urine patches was measured using an infra-red camera and soil samples were collected to measure physical properties. Four pasture harvests were taken from the plots following treatment application and pasture dry matter and N content were measured.

Before urine application, the compacted soil had significantly fewer pores in the greater than 30 micron range (commonly referred to as macroporosity) than the uncompacted soil and this was reflected in the approximately 40% greater area covered by the urine applied to the compacted plots. There was no significant difference in pasture N concentration between compaction treatments at any harvest but the urine treatments did produce significantly more dry matter than non-urine (control) treatments at the first two harvests (24%). At the first harvest the compacted control treatment produced less dry matter (15%) than the uncompacted control. However, the compacted urine treatment produced the same amount of dry matter as the uncompacted urine treatment at the same harvest. Recovery of urine-N in herbage was the same in the compacted and uncompacted plots over all harvests. Further research is needed to understand the potential effects on leaching of surplus urine-N through these soils as affected by the differences in urine-N deposition rate and soil physical properties associated with the soil compaction.

Introduction

Increased stocking rates on dairy farms are often associated with increases in N leaching losses. However, recent research (McCarthy et al., 2015; Roche et al., 2016) has suggested that higher stocking rates may, in some cases, result in similar or reduced N leaching losses. A possible partial explanation for this is that higher stocking rates may increase surface soil compaction.

This can reduce soil porosity and surface infiltration rates and could increase the area covered by individual urine patches, due to greater dispersion following deposition. The urine patch is considered to be the largest source of N loss from intensively managed pasture systems (Scholefield et al. 1993; Ledgard et al. 1999; Di and Cameron 2002). Increased urine spread would result in a reduced urine-N loading rate and increase the potential uptake of urine N by pasture (e.g. Ledgard et al. 2015). Increasing cattle stocking rates has previously demonstrated an increase in soil compaction (as measured by soil macroporosity) while decreasing plant production potential (Houlbrooke et al. 2011).

The aim of this study was to evaluate the effect of soil compaction on urine patch area and plant recovery of urine N.

Method

In 2017 a trial was set up on an established ryegrass/white clover pasture on a Te Kowhai silt loam (Typic Orthic Gley) in the Waikato. The trial area was fenced to exclude cattle and was ungrazed for five months leading up to the start of the trial in late autumn. Soil samples (0-7.5 cm) were taken to determine the nutrient status of the site (Table 1).

Table 1. Initial soil test results from trial site (0–75 mm).

pH	P Olsen ug/ml	K MAF QT	Ca MAF QT	Mg MAF QT	$S(SO_4)$ ppm	Organic matter %	Total C %	Total N %	C/N
5.9	33	12	8	23	7	12.9	7.5	0.72	10.4

Cation concentrations are in MAF quicktest units.

The trial design utilised a randomised block layout with five replicates of four treatments. The treatments were: compacted (C) and uncompacted (U) soils, with (+N) or without (-N) added urine. Plots were 1 m x 1.25 m, with one square metre reserved for urine treatment application and the remaining area used for destructive sampling. A covariate cut (55 mm mowing height) was made prior to treatment application.

On the compaction treatments, a wheel was rolled across the plots to apply a uniform pressure of 172 kPa, similar to that exerted by the hoof of a mature dairy cow. Following this, the urine treatments received two litres of artificial urine applied to the centre of the reserved portion of the plot from a height of 1.5 m, applied over a duration of approximately 15 seconds. The artificial urine composition is given in Table 2.

Table 2. Artificial urine composition in g/L. Based on Barton et al. (2000).

Urea	Glycine	Potassium bicarbonate	Potassium sulphate	Potassium chloride	Potassium bromide
11.7	2.89	12.00	1.61	2.94	1.50

Analysis of the urine showed an N content of 5843 mg N/L. The urine was heated to a temperature of 35 °C before application to approximate the temperature of real cow urine. Immediately after application, an infrared photo was taken of the patch to determine the area affected. The area was also determined manually by outlining the wetted area with a chain, overlaying a grid and counting the squares within. An automated algorithm was used to calculate the urine patch areas in the infra-red photos and the results of the manual measurements were used to calibrate this. Soil samples (0-7.5 cm) were collected from the area of the plots set aside for destructive sampling and were analysed for bulk density, porosity and saturated hydraulic conductivity (Ksat).

The 1 m^2 reserved portion of the plots was harvested four times (August 1, October 11, November 15 and December 12) with samples analysed for dry matter and N concentration. After the final harvest, soil samples (0-60 cm) were taken from the mown areas of the plots and analysed for ammonium and nitrate. Analysis of variance was carried out on all data using the Genstat statistical program (version 18.1.0.17005; VSN International, 2015).

Results and Discussion

Total rainfall from June through September 2017 was 500 mm, just above the long term average of 450 mm (Figure 1).

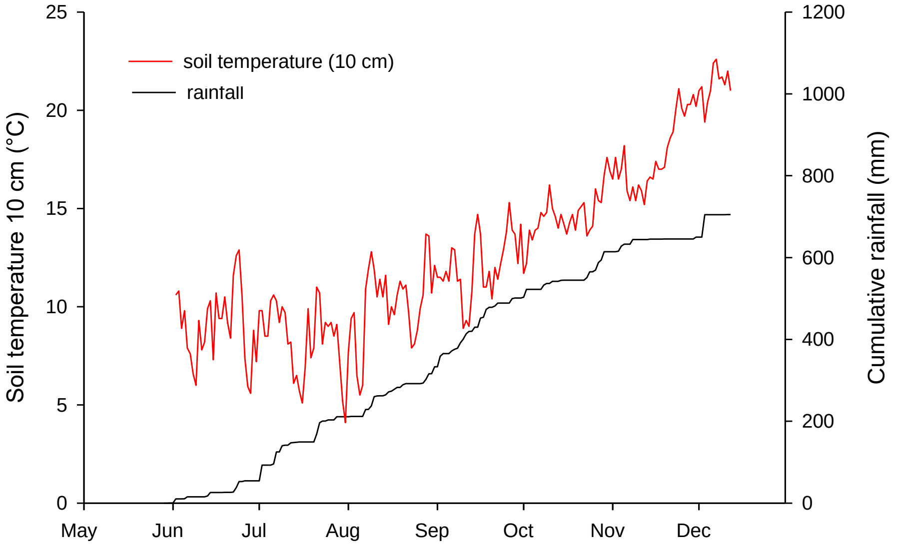

Figure 1. Daily soil temperature (9 a.m.) and cumulative rainfall 29 May – 12 Dec. 2017.

Compaction significantly (*P*<0.05) altered soil pore size distribution with an increase in pores of less than 30 µm and a decrease in pores of bigger than 300 µm (Table 3). Average bulk density was higher and Ksat lower on the compacted plots but these differences were not statistically significant. The average urine patch area on the compacted plots was significantly greater than the patch area on the uncompacted plots at 0.27 and 0.19 m^2, respectively (LSD 0.08). This resulted in N loadings of 631 and 436 kg N/ha on the uncompacted and compacted urine treatments respectively. However the compacted treatment had soil macroporosity levels much greater than would typically be considered to represent a compacted state (<10% v/v as described by Houlbrooke et al. 2011) suggesting that the role of soil compaction on determining urine patch size could be larger than demonstrated in this study.

Table 3. Soil physical properties. LSD least significant difference at *P*=0.05.

	Uncompacted	Compacted	LSD
Total porosity (%) v/v	72.5	73.4	0.97
Pores >300 µm	13.1	11.3	1.65
Pores 30-300 µm	6.4	5.7	0.68
Pores <30 µm	53.9	55.5	1.32
Bulk density (g/cm^3)	0.70	0.73	0.03
Ksat (mm/hr)	1026	710	486

Four harvests were taken from the trial but there was no response to the urine or compaction treatments after the second harvest (October), so dry matter and N recovery data are only presented for the first two harvests. N concentrations in herbage were higher ($P<0.001$) on the urine plots than the non-urine plots at the first harvest (2.92 versus 2.49%, respectively) but otherwise there were no other significant differences in herbage N concentration between either the urine or compaction treatments.

On the non-urine treatments, the compacted plots produced significantly lower dry matter yields at both the first and second harvests (Figure 2A). However, on the urine treatments there was no dry matter yield difference between compaction treatments at the first harvest. At the second harvest the C+N treatment produced significantly less dry matter than the U+N treatment and the total over both harvests was lower on the C+N treatment than the U+N treatment.

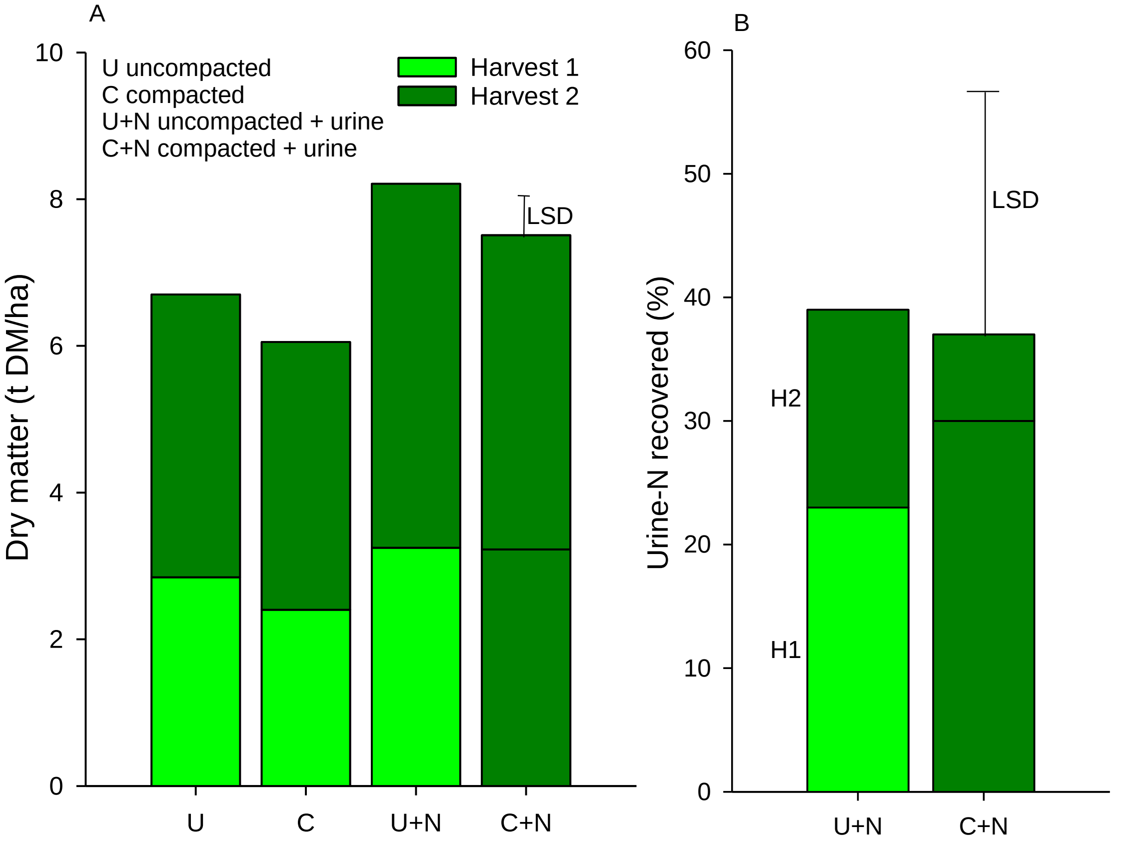

Figure 2. Dry matter yield (A) and apparent recovery of applied urine-N (B) at the first and second harvests.

Apparent N recovery (N harvested in the urine treatments minus N harvested in the equivalent non-urine treatments) at the first harvest was higher in the C+N treatment than the U+C treatment but the difference was not statistically significant (Figure 2B). At the second harvest N recovery in the C+N treatment was much lower than in the U+C treatment and overall there was no significant difference in N recovery in the pasture between the two treatments. Smearing or compaction of the soil surface when the soil is wet can lead to reduced pasture production (Menneer et al. 2005) and this is what occurred on the non-urine treatments. However, the wider spread of the urine on the C+N treatment (relative to the U+N treatment) appears to have counteracted this effect at the first harvest by making the urine-N available to more of the pasture. This effect had disappeared by the following harvest. Research has shown that soil compaction can increase gaseous N losses (Beare et al., 2009; Groenigen et al., 2005; Harrison-Kirk et al., 2015; Li et al., 2014) and the wet soils and rising soil temperatures from August to October 2017 would have provided good conditions for denitrification.

Soil samples taken at the end of the trial showed no significant differences in ammonium or nitrate concentrations between treatments.

Summary

This trial showed that surface soil compaction can increase the area of urine patches excreted by grazing animals and hence decrease the urine-N loading. There was a trend toward increased urine-N recovery by the pasture in the compaction treatment at the first harvest after urine application. However, any apparent short-term benefit due to compaction disappeared at the second harvest, possibly due to increased gaseous N losses and overall there was no difference in apparent N recovery due to compaction. These results were based on a single, artificial compaction event and further research is needed to determine how applicable this is to farms where higher stocking rates have been in place for more than one year and the soils are in a more permanently compacted state.

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