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Animal treading stimulates denitrification in soil under pasture

John C. Menneer[a,b,*], Stewart Ledgard[b], Chris McLay[c], Warwick Silvester[a]

[a]*University of Waikato, Private Bag, Hamilton, New Zealand*
[b]*AgResearch Ruakura Research Centre, Private Bag 3123, Hamilton, New Zealand*
[c]*Environment Waikato, P.O. Box 4010, Hamilton, New Zealand*

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Abstract

The effects of animal treading on denitrification in a mixed ryegrass-clover pasture were studied. A single treading event of moderate or severe intensity was applied in plots during spring by using dairy cows at varying stocking rates (4.5 cows 100 m^{-2} for 1.5 or 2.5 h, respectively). Treading caused a significant short-term 21 days) increase in denitrification. Denitrification rates reached a maximum of 52 g N_2O-N ha^{-1} day^{-1} at 8 days after severe treading compared to 2.3 g N_2O-N ha^{-1} day^{-1} under nil treading. Thereafter, denitrification rates declined, and were similar to non-trodden control plots after 28 days. Soil aeration, was significantly reduced by treading as expressed by water-filled porosity. In addition, soil NH_4^+-N and NO_3^--N concentrations were also increased by treading. We propose that the underlying processes involved in increasing denitrification under treading were two-fold. Firstly, treading caused a temporary (e.g. 3 days after treading) reduction in soil aeration through soil physical damage, and secondly, reduced soil N utilisation prompted by reduced plant growth led to increased soil NH_4^+-N and NO_3^--N availability. This study shows that treading, without the influence of other grazing animal factors (e.g. excretion), can cause a large short-term stimulation of denitrification in grass-clover pastures.

Keywords: Denitrification; Animal treading; Soil nitrate; Water-filled porosity; Soil aeration; Plant N uptake

1. Introduction

Losses of nitrogen (N) from soil by denitrification are known to be affected by many soil properties, such as soil water content, forms and amounts of N, soil temperature, pH and available carbon (Groffman et al., 1987). In intensively grazed pastures, the principal regulators of denitrification are soil aeration and soil NO_3^--N availability (Barton et al., 1999; Groffman et al., 1987, 1993; Jarvis et al., 1991). In legume-based systems not receiving fertiliser N, inputs of excreta N by grazing animals potentially provide a large source of soil NO_3^--N for denitrifying microbes. Indeed, studies using synthetic urine applied to soil cores, lysimeters, and directly onto pasture soils (e.g. Clough et al., 1994; Fraser et al., 1994; de Klein and van Logtestijn, 1994; Ryden, 1986) have shown greatly enhanced rates of denitrification.

Under field conditions, various workers (Carran et al., 1995; Luo et al., 1999; Ruz-Jerez et al., 1994) have measured high denitrification rates soon after grazing. In these studies the stimulation of denitrification has been mainly attributed to the direct influence of the N returned in excreta. However, other factors associated with grazing are often thought to contribute to higher denitrification after grazing, and include increased soil NO_3^--N due to limited plant N uptake after defoliation, increased soil carbon availability by deposition of animal excreta, and reduced soil aeration resulting from animal treading and soil compaction (e.g. Carran et al., 1995; Luo et al., 1999; Ruz-Jerez et al., 1994). Very little is known about the effect of these grazing related factors on denitrification or the underlying regulating processes involved.

The aims of the current study were, firstly, to determine the effect of treading on denitrification without the influence of animal excreta inputs, and secondly, to describe the underlying processes that regulate denitrification in soils affected by treading.

* Corresponding author. +64 7 8385130.
E-mail address: john.menneer@agresearch.co.nz (J.C. Menneer).

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2. Materials and Methods

2.1. Experimental site and soil characteristics

The experiment was established on a Te Kowhai silt loam (Typic Ochraqualf, Soil Survey Staff, 1994; Typic Orthic Gley Soil, Hewitt, 1993) with impeded subsoil drainage. Measured soil properties are presented in Table 1. The pasture was a long-term (> 30 years) permanent mixed stand of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). Fertiliser N had not been applied to the site for at least 5 months. Daily mean soil temperature (at 100 mm depth) increased from 11 to 16 °C over the 28 days of the study.

2.2. Experimental design

Treatments consisted of a single treading event of three severities (nil, moderate and severe). A randomised block experimental design was used with eight replicates. Plots were 2.5×7 m long with a 0.5 m buffer strip around each plot. The site was taken out of grazing 5 months prior to commencing the study, and all dung pats removed. Two pre-conditioning harvests were taken from the site during the month prior to commencing the study to reduce variability. In early spring (21st September) 1999, moderate and severe treading treatments were imposed (after the site had been harvested) by walking dairy cows (c. 500 kg liveweight per cow) through the plots at a typical grazing intensity of 4.5 cows 100 m^{-2} for 1.5 or 2.5 h, respectively, to achieve levels of treading damage (Plate 1) that can occur in dairy pasture during wet spring conditions. Rainfall and light irrigation in the days before commencing the experiment meant that the soil was near saturation when the treading treatments were applied. Prior to applying the treading treatments the cows were kept in stockyards overnight to avoid inputs of dung and urine onto the plots during the treading event. In the rare event that animal excretion did occur during the treading event, these were intercepted using a large bucket and removed from the site. This level of cow contact was achieved by allocating three cows per person to observe and intercept excreta. As a result, no urine or dung was deposited on the experimental site. Following the treading event, animals were excluded from the site for the remainder of the study.

Table 1
Soil properties (0–75 mm) at the experimental site measured immediately prior to treatment application

Soil texture	pH[a]	Organic-C (g kg^{-1})	Total N (g kg^{-1})	C:N ratio
Silt loam	5.4	68	5.8	11.7

[a] pH in 1:2.1 soil:water extract.

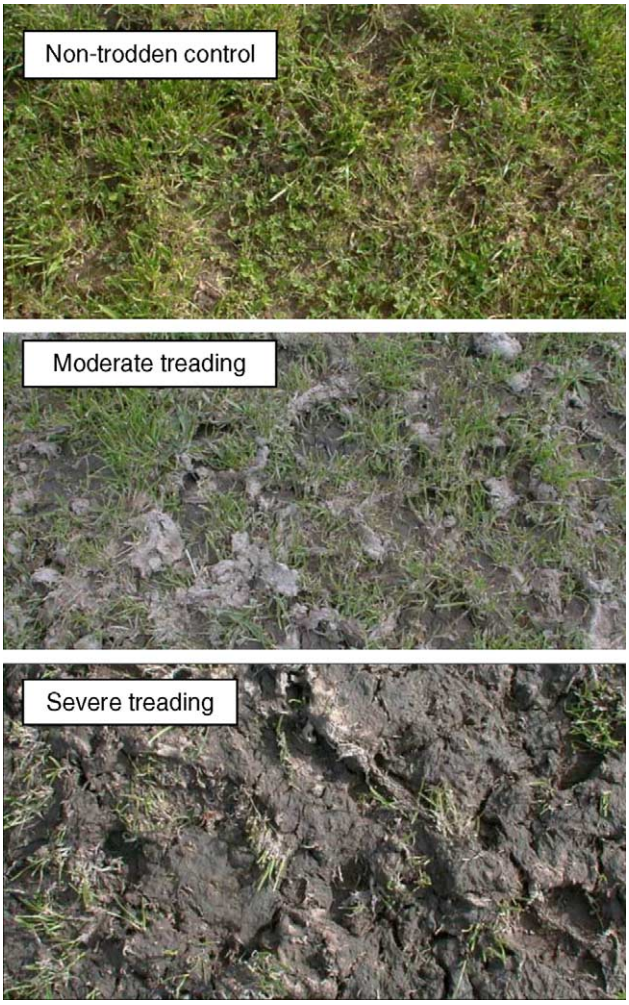

Plate 1. Soil surface characteristics 6 days after treading at 4.5 cows 100 m^{-2} for 1.5 and 2.5 hours, for moderate and severe treading, respectively.

2.3. Denitrification measurements

Denitrification rates were determined over 28 days (on days 3, 8, 14, 21 and 28) after treading using a field soil incubation system, involving acetylene inhibition (Aulakh et al., 1992; Ryden et al., 1987). Minimally disturbed soil cores (65 mm diameter×70 mm depth) were taken from four replicate plots in each treatment and wrapped in tinfoil (to minimise diffusion of atmospheric O_2 into the core), but with the soil surface still exposed, and placed in 10 l preserving jars. Three jars containing two cores were taken from each plot. The jars were closed with a steel lid, fitted with a silicon septum, and sealed with a rubber gasket and a screw band. Acetylene (50 ml, 10% v/v) was injected into each jar through the septum after ejecting an equal volume of headspace to maintain atmospheric pressure. The jars were then incubated in situ in a shallow covered trench on site for 24 h.

After incubation, the headspace of the jars was sampled in duplicate using double-ended sampling needles and pre-evacuated Vacutainer (Becton, Dickinson and Co.,