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Agriculture, Ecosystems and Environment 109 (2005) 202–212

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Reducing environmental impacts of agriculture by using a fine particle suspension nitrification inhibitor to decrease nitrate leaching from grazed pastures

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Received 13 September 2004; received in revised form 10 March 2005; accepted 23 March 2005

Abstract

Nitrate (NO_3^-) leaching from intensively grazed pasture systems, e.g. dairy farming, is of increasing environmental concern worldwide. The major source of the NO_3^- leached in grazed pastures is the nitrogen (N) returned in the urine from the grazing animal. The objective of this study was to use undisturbed soil monolith lysimeters to quantify the effectiveness of treating a grazed pasture soil with a fine particle suspension (FPS) nitrification inhibitor, dicyandiamide (DCD), in decreasing NO_3^- leaching losses from a deep sandy soil with a mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture. The application of DCD as a FPS at 10 kg ha^{-1} in autumn (May) and late winter (August) decreased NO_3^-–N leaching from 134 kg N ha^{-1} year^{-1} to 43 kg N ha^{-1} year^{-1} (equivalent to a 68% reduction) from the dairy cow urine N applied in the autumn (May) at the rate of 1000 kg N ha^{-1}. This reduced the annual average NO_3^-–N concentration under the urine patch from 43 mg NO_3^-–N L^{-1} to 18 mg NO_3^-–N L^{-1}. The DCD FPS also reduced Ca^{2+} leaching by 51% and Mg^{2+} leaching by 31%. In addition, herbage dry matter yield in the urine patch areas was increased by 33%, from 15.3 t ha^{-1} year^{-1} without DCD to 20.3 t ha^{-1} year^{-1} when DCD was applied at 10 kg ha^{-1}. However, DCD applied at 5 kg ha^{-1} (May and August) did not provide significant environmental and agronomic benefits under the experimental conditions. Results from this study when compared with those reported previously show that DCD, when applied as a FPS at 10 kg active ingredient ha^{-1}, is just as effective in reducing NO_3^- leaching in grazed pasture soils, as when it is applied as a solution.

Keywords: Nitrate leaching; Pasture yield; Dairy pastures; Water quality; Environment; Soil; Nitrification inhibitor; Dicyandiamide; Cation leaching

1. Introduction

Diffuse-source contamination of ground- and surface-water resources by nitrate (NO_3^-) from land use activities is a major environmental concern around the world (Jarvis et al., 1995; Addiscott, 1996; Cameron et al., 2002; Di and Cameron, 2002a). Nitrate, when

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0167-8809/$ – see front matter
doi:10.1016/j.agee.2005.03.006

present at high concentrations in drinking water, can be a health hazard for humans, particularly for infants (WHO, 1984). Nitrate drained into surface waters can also cause the deterioration of water quality, causing eutrophication, leading to algal blooms and fish poisoning (Howarth, 1988).

Most of the NO_3^- in ground and surface waters is derived from leaching or runoff from agricultural land. In New Zealand, the predominant land use is grazed grassland where animals graze outdoor pastures all year round. In such grazed pasture systems, the major source for NO_3^- leaching is the N deposited in the animal urine patch areas (Ryden et al., 1984; Scholefield et al., 1993; Ledgard et al., 1999; Cameron et al., 1999; Silva et al., 1999; Di and Cameron, 2002a). Direct leaching losses of NO_3^- from applied fertilizer N are relatively small compared with the leaching losses from cow urine (Di and Cameron, 2002a). The N loading rate under a cow urine patch may range from 700 to 1200 kg N ha^{-1} and this amount is well in excess of that which can be taken up by the pasture in a growing season (Haynes and Williams, 1993; Jarvis et al., 1995). The surplus N, when converted to NO_3^-, is thus prone to leaching when there is drainage through the soil profile. The leaching potential is particularly high during the autumn–winter–spring period in New Zealand (May to September) when the soil is wet and excess water drains from the rooting zone. Therefore, in a grazed pasture system, efforts to reduce NO_3^- leaching should be aimed at reducing losses in the urine patch areas, particularly during autumn to spring.

Some of the soil and farm management measures that have been shown to be effective in reducing NO_3^- leaching in arable cropping systems include growing a winter cover crop, and delaying ploughing of soil in the autumn until mineralization rates are low because of low soil temperatures (Di and Cameron, 2002a). However, until now, few new practical technologies have been developed that could be used to dramatically decrease NO_3^- leaching from intensively grazed pasture systems where the leaching loss is predominantly from animal urine patch areas rather than from the fertilizer per se. One of the measures that was explored in arable cropping to increase the efficiency of fertilizer N applied was to coat the fertilizer with nitrification inhibitors to slow down the conversion of NH_4^+ to NO_3^-. Because most soils in temperate regions of the world have a net negative charge, NH_4^+ is adsorbed onto the soil exchange surfaces, giving a greater opportunity for it to be taken up by plants, immobilised into soil organic matter, or fixed into certain 2:1 type clay mineral interlayers, rather than being leached. One of the nitrification inhibitors is dicyandiamide (DCD) which inhibits the first stage of nitrification, the oxidation of NH_4^+ to NO_2^- (Amberger, 1989). Dicyandiamide has been used in the past to increase the efficiency of N supply from fertilizers or manures with variable results (e.g. Amberger, 1989; Wadman and Neeteson, 1992; Davies and Williams, 1995; Williamson et al., 1998). However, until recently its potential to reduce nitrate leaching losses from grazed pasture systems had not been rigorously tested.

Recently, Di and Cameron (2002b, 2004b) reported a study of the effectiveness of treating grazed pasture soils, including animal urine patches, with a solution of dicyandiamide to reduce NO_3^- leaching and N_2O emissions. This work involved direct measurements of NO_3^- leaching and N_2O emissions from soil lysimeters and the results showed that by treating the grazed pasture soil with a dicyandiamide solution, both NO_3^- leaching and N_2O emissions were reduced dramatically. However, there is a lack of information on possible rates and forms at which DCD may be applied to achieve desired environmental outcomes. This paper reports a follow up study which was designed to determine the effect of the rate and form of DCD application on its effectiveness in reducing NO_3^- leaching from grazed pasture soils. The DCD in this study was applied in a fine particle suspension (FPS) (as compared with the solution form applied previously) and at two different rates: 5 and 10 kg DCD ha^{-1} per application. The FPS form of application was specifically developed to enable the DCD to be applied by commercial spray contractors using small volumes of water (e.g. 10 kg ha^{-1} in 100 L of water).

2. Materials and methods

2.1. Soil and pasture

The soil used was a Templeton fine sandy loam (Immature Pallic soil, Hewitt, 1998; Udic Haplustepts, Soil Survey Staff, 1998) located near Lincoln University on the Canterbury plains of New Zealand. The soil