THE ROLE OF INHIBITORS IN MITIGATING NITROGEN LOSSES FROM CATTLE URINE AND NITROGEN FERTILISER INPUTS IN PASTURES

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Jagrati Singh

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Abstract

The major land use in New Zealand is pastoral farming of sheep and cattle. In intensively grazed dairy-pasture systems, animals graze on nitrogen (N)-rich legume-based pastures, but do not efficiently utilize the N they ingest. On average only 10.5% of the N in forage-based animal feed is converted into milk and the remainder is excreted in dung and urine. In the pastures, a cow urine patch can typically contain up to 1000 kg N ha^{-1}. Nitrogen input, either in the form of cow urine or fertilizer, often exceeds immediate plant requirements and hence is susceptible to losses as ammonia (NH_3) volatilisation and nitrous oxide (N_2O) emissions and removal in drainage water through nitrate (NO_3^-) leaching. This loss of N from grazed pastures causes detrimental environmental impacts in the form of acidification and eutrophication of the soil and water bodies, global warming, destruction of stratospheric ozone, and NO_3^- toxicity.

Various approaches have been attempted to mitigate the economic and environmental impacts of N losses. One such approach is the use of Urease (UIs) and Nitrification (NIs) inhibitors. There have been extensive studies on the value of UIs in arable farming and NIs in grazed pastures. However, only limited work on the impact of UI and NI alone and in combination in influencing the N dynamics, and thus mitigating N gaseous losses from pastures, has been conducted.

This thesis examines the impact of UI (Agrotain; N-(n-butyl) thiophosphoric triamide) and NI (Dicyandiamide, commonly known as DCD), when applied alone or in combination to cow urine and urea fertiliser, on N losses through NH_3 and N_2O emissions and NO_3^- leaching, and on herbage production under glasshouse conditions and a field-plot study. The degradation rate of DCD, and its effect on nitrification and on N_2O emissions from four soils varying in their physical and chemical properties was also examined under laboratory incubations. The results from the field-plot study were then used to predict the effect of DCD on N_2O emissions reductions from urine by adapting the process-based NZ-DNDC model.

Both NH_3 and N_2O emissions have common sources in agriculture. Therefore, chambers were adapted to measure their emissions simultaneously using active and passive gas sampling. Active sampling involved continuous air flow and the use of acid

(0.05 M H_2SO_4 and 2% H_3BO_3) traps for NH_3 measurements and passive sampling involved collecting three gas samples over a one-hour period from a static chamber used for N_2O emissions.

The first glasshouse experiment used UI with urine or urea to assess its effect on NH_3 and N_2O emissions, changes in soil mineral-N and N uptake by pasture plants. The UI treatments also involved two commercial products, Sustain Yellow (urea coated with Agrotain and elemental S) and Sustain Green (urea coated with Agrotain). The use of UI effectively decreased total NH_3 emissions, as well as delaying the time of maximum NH_3 emissions from both urea (600 kg N ha^{-1}) and urine (476 kg N ha^{-1}) by 27% and 22%, respectively. The UI-induced decrease in NH_3 volatilization ranged from 42-48% when urea was applied @ 100 kg N ha^{-1}. Urease inhibitor was also effective in decreasing N_2O emissions significantly from urine and urea applied @ 100 kg N ha^{-1}. The addition of UI increased dry matter yield by 13-19% as compared to the urea-alone treatment.

In the second glasshouse study, NI (DCD) was added @ 25 kg ha^{-1} to urea (@ 25, 50 and 75 kg N ha^{-1}) and urine (@ 144, 290 and 570 kg N ha^{-1}) applied at different rates. Addition of DCD reduced N_2O emissions from both urea and urine and NO_3^- leaching from urine. Dicyandiamide reduced N_2O emissions by 34-93% from the added urea and 33-80% from the added urine. However, its use increased the amount of ammonium (NH_4^+) present in the soil by 3 to 13% both in the urea and urine treatments, and this NH_4^+ was susceptible to leaching and volatilisation losses. The addition of DCD, however, resulted in a 60-65% reduction in NO_3^- leaching from urine applied to pasture soil cores. It also caused a significant reduction in NO_3^--induced cation leaching. Leaching of K^+, Mg^{+2} and Ca^{+2} ions was reduced by 36-42%, 33-50% and 72%, respectively, with DCD applied to cattle urine (290 and 570 kg N ha^{-1}).

The combined use of UI and NI was more effective in controlling N gaseous losses than using them individually. The combination of UI and NI retarded NH_3 emissions by 70% in the urea treatment and by 4% in the urine treatment (field-plot study). It also considerably reduced N_2O emissions (50-51%) following the application of urea and urine (field-plot study) to pasture soil. With the combined inhibitors, there was a 14 and 38% increase in herbage yield from added urea and urine (field-plot study), respectively.

A laboratory incubation experiment was undertaken to study the effect of soil types and the rate of DCD application on the degradation kinetics of DCD. The rate of degradation of DCD varied among the four soils studied. The degradation was slowest (half-life period of 6 to 11 days) in an allophanic soil with a high concentration of organic matter. The effectiveness of DCD in inhibiting nitrification also varied depending on the nature and amount of soil organic matter and clay content. The maximum inhibition was observed in a soil with low organic matter and high clay content.

Finally, 'NZ-DNDC', a process-based model, was adapted and used to simulate the effect of DCD on emissions reduction using DCD inhibition values that vary according to different soil types. This model effectively simulated the effect of DCD on N_2O emissions reductions in Tokomaru silt loam following urine application. However, more field data are required from a range of pasture soils with contrasting amount of soil organic matter and clay content under differing climatic conditions to further test this model modification to predict emission-reductions with DCD application in different soil types

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Table of Contents

List of Tables

List of Figures

List of Plates