# THE USE OF DCD TO REDUCE NITROGEN LOSSES FROM INTENSIVE WINTER GRAZING BLOCKS: A REVIEW OF THE LITERATURE

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**Abstract**
The intensification of modern pastoral systems has led to increased nitrate ($NO_3^-$-N) leaching and nitrous oxide ($N_2O$) emissions from animal grazing. The use of nitrification inhibitor technology in New Zealand dairy pastoral systems has proven to reduce $NO_3^-$-N and $N_2O$ emissions from animal urine patches. The objective of this study was to review recent trials which evaluated the effectiveness of dicyandiamide (DCD) to reduce N losses from urine patches deposited during winter grazing of forage crops.

Intensive winter grazing trials have been conducted using field lysimeters comparing four general treatments: (i) control (i.e. no urine), (ii) control + DCD, (iii) urine, and (iv) urine + DCD. Urine was applied at an N loading rate of 300 kg N ha$^{-1}$ for sheep, 580 kg N ha$^{-1}$ for beef cattle and 1000 kg N ha$^{-1}$ for dairy cattle. DCD was applied as a liquid at the recommended rate of 10 kg ha$^{-1}$ using a fine suspension spray or at 15 kg N ha$^{-1}$ for the granular formulation. Three main trials have been analysed in this paper.

The results from these initial trials show that the use of DCD under intensely grazed winter forage systems can be an effective way to reduce nitrogen losses. Reductions of between 39 and 70% in $NO_3^-$-N leaching and over 70% in $N_2O$ emissions have been measured from animal urine patches in these winter grazing block lysimeter studies. Further research in this winter grazing system area is required as these grazed forage blocks are ‘hotspots’ for very large N losses. Mitigating N losses from these areas can have a significant effect on total farm N losses.

**Keywords:** nitrate leaching, nitrous oxide, dicyandiamide (DCD), winter grazing systems.

## Introduction
Nitrogen (N) leaching from agricultural systems has led to increasing nitrate concentrations in underground and surface waterways globally (Di & Cameron, 2002a). A contributing factor to increasing nitrogen losses is winter-grazed forage systems. These intensive systems are managed differently to the traditional rotational grazed pasture system. In the Southern parts of New Zealand, it is common practice for stock to be grazed on forage crops for between one and two months, due to minimal pasture growth during the winter months. Generally, these forage crops are intensively grazed once, which entails large numbers of animals grazing the crop in narrow strips (McDowell & Houlbrooke, 2009).

N losses are high under winter grazing blocks due to extremely high stocking rates, e.g., 2000 s.u. $ha^{-1}$ in some situations, (Wild, 2009), high urine patch area coverage and substantial trampling damage. Furthermore, soil moisture conditions are close to, or at field capacity, with high drainage (and thus leaching) occurring around the time of grazing. These grazed winter forage blocks are 'hotspots' for very large N losses. Mitigating N losses from these areas can have a significant effect on total farm N loss. Research has shown that cow urine patches are the main source of $NO_3^-$-N leaching and $N_2O$-N losses, as a result of an oversupply of N relative to plant uptake. The application of dicyandiamide (DCD) has been proven to reduce $NO_3^-$-N leaching from cow urine patches by up to 70% and to reduce $N_2O$-N emissions by up to 72% in grazed pastoral systems (Di & Cameron, 2002a, 2004a&b, 2005, 2006). These results provide evidence that DCD is a successful solution to reduce N losses, and therefore, the use of this mitigation strategy could be successful in reducing N losses from intensive winter grazing systems.

Published data on inhibitor use in winter grazing blocks is limited. However, initial research, for example Moir *et al*. (2010) & Wild (2009), show that DCD can be used as a mitigation strategy to reduce nitrogen losses. The objective of this study was to review recent trial data to evaluate the effectiveness of using DCD to reduce N losses from urine patches deposited during grazing of winter brassica crops, and to identify possible future research.

## Generalised Materials and Methods

Studies of N losses in winter grazing system trials (McDowell & Houlbrooke (2009); Ravensdown (2005) and Wild (2009)) have all been carried out using field lysimeters. Experimental designs were made up of the following treatments: control (no urine), control + DCD, urine alone and urine + DCD. Urine was applied at an N loading rate of 300 kg N $ha^{-1}$ for sheep, 580 kg N $ha^{-1}$ for beef cattle and 1000 kg N $ha^{-1}$ for dairy cattle. Winter selected species included Perennial Ryegrass + White Clover pasture mix (Wild, 2009); Tabu Annual Ryegrass (Ravensdown, 2005) and Triticale forage crop (McDowell & Houlbrooke, 2009).

Moir *et al.* (2010), Ravensdown (2005) and Wild (2009) applied DCD at 10 kg $ha^{-1}$ in autumn using a fine suspension spray, whereas McDowell & Houlbrooke (2009) used 15 kg N $ha^{-1}$ of granular formulated DCD. All winter runoff studies used four replicates of each treatment. The majority of publications applied two applications of DCD to extend the period effectiveness. Most trials applied 10 mm of water (stimulating rainfall) once treatments had been applied to rinse the DCD into the soil as per Di & Cameron (2007).

### *Measurements and Data Analysis*

Drainage water was collected from the base of each lysimeter on a one to twice weekly basis, or whenever a high amount of rainfall caused a significant amount of drainage to occur. Flow injection analysis was used to determine the concentration of $NO_3^-$ and $NH_4^+$ in the leachate following Cameron *et al.* (2007) and Di & Cameron (2002b, 2004b). For most of the trials gas samples were taken twice per week for the first month and then once per week for the next three months, or until background emission levels were reached. Gas samples were collected at 0, 20 and 40 minute intervals using a syringe to transfer the gas into glass vials. The concentration of $N_2O$ in each gas sample was determined by gas chromatograph analysis following Clough *et al.* (2007).

## Results and Discussion

### *Nitrate Leaching*

Intensive winter sheep grazing studies by Moir *et al.* (2010) and Wild (2009) found that DCD significantly (P<0.01) reduced $NO_3^-$-N leaching losses. The application of 10 kg DCD $ha^{-1}$ over 300 kg N $ha^{-1}$ of sheep urine did not have any significant reduction the amount of $NO_3^-$-N leached by 70%; i.e. from 147.3 kg N $ha^{-1}$ to 44.8 kg N $ha^{-1}$ (Figure 1). Over the four month trial period, the total amount of $NO_3^-$-N leached was minor from the control (1.06 kg N $ha^{-1}$) and the control + DCD treatment (0.71 kg N $ha^{-1}$) as seen in Figure 1. Unsurprisingly, the reduction between these two treatments was not significant.

Total leaching losses (Figure 1) were found to be 1.7 times greater than losses from 1000 kg N $ha^{-1}$ of cow urine on the same soil type (Di & Cameron, 2002b). This loss could have been due to a higher rainfall input being used by Wild (2009) and the lysimeters being shallower. Further explanation for higher leaching, is that treatments were simulated with treading. Treading of wet soils by stock in the winter has been linked as a contributing factor of increased $NO_3^-$-N leaching (Drewry & Paton, 2005). Winter break feeding of sheep has been identified as an important source of $NO_3^-$-N leaching losses. Therefore, this paper demonstrates that DCD, when effectively applied upon the sheep urine, is a successful solution to reducing nitrate leaching from this sheep winter grazing systems.

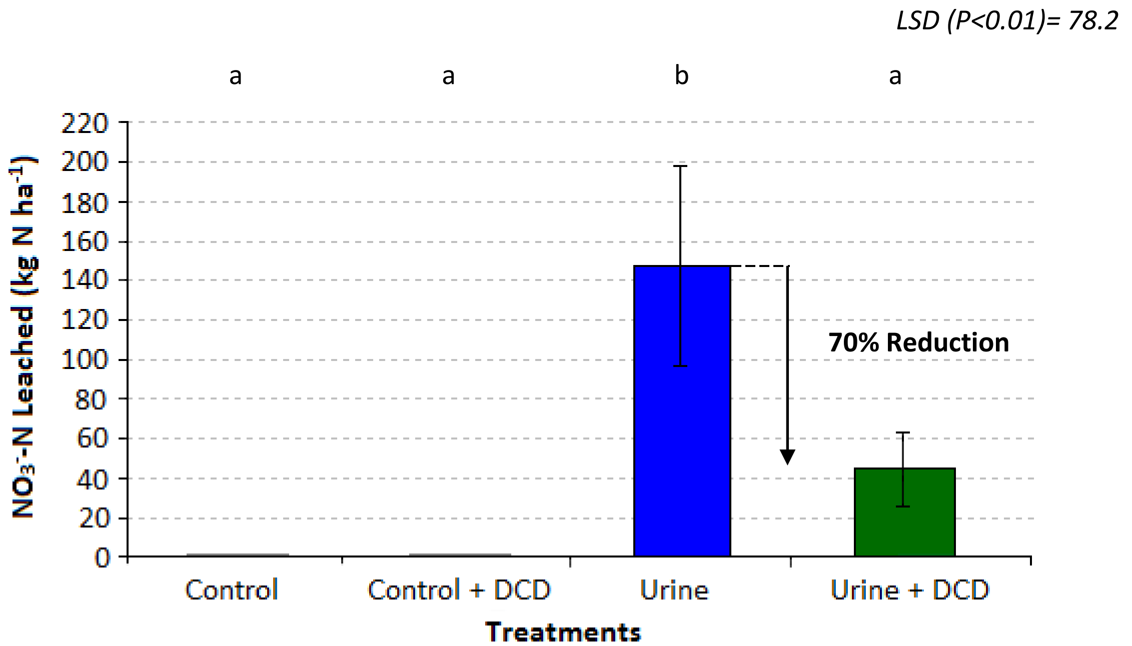


**Figure 1: Average total $NO_3^-$-N leaching losses (kg N $ha^{-1}$) from all lysimeter treatments. Letters above bars indicate significant differences based on a 5% LSD test (From Wild, 2009).**

A winter runoff lysimeter study conducted by Ravensdown (2005) found that $NO_3^-$-N leaching was reduced by up to 40% (Figure 2) with the application of DCD under cattle winter break feed 'runoff' conditions. The reductions, under winter break feed conditions, are similar to those achieved with DCD used on grazed dairy pasture systems (Cameron & Di, 2002a, 2004a&b, 2005, 2006). Total $NO_3^-$- N leaching losses were reduced from 352 kg N $ha^{-1}$ to 140 kg N $ha^{-1}$(Figure 2).

Therefore, these results show that the large leaching losses that occur from winter break-fed areas can be significantly reduced by treating the soil with DCD, even with a delay of 18 days after grazing of the forage (Figure2).

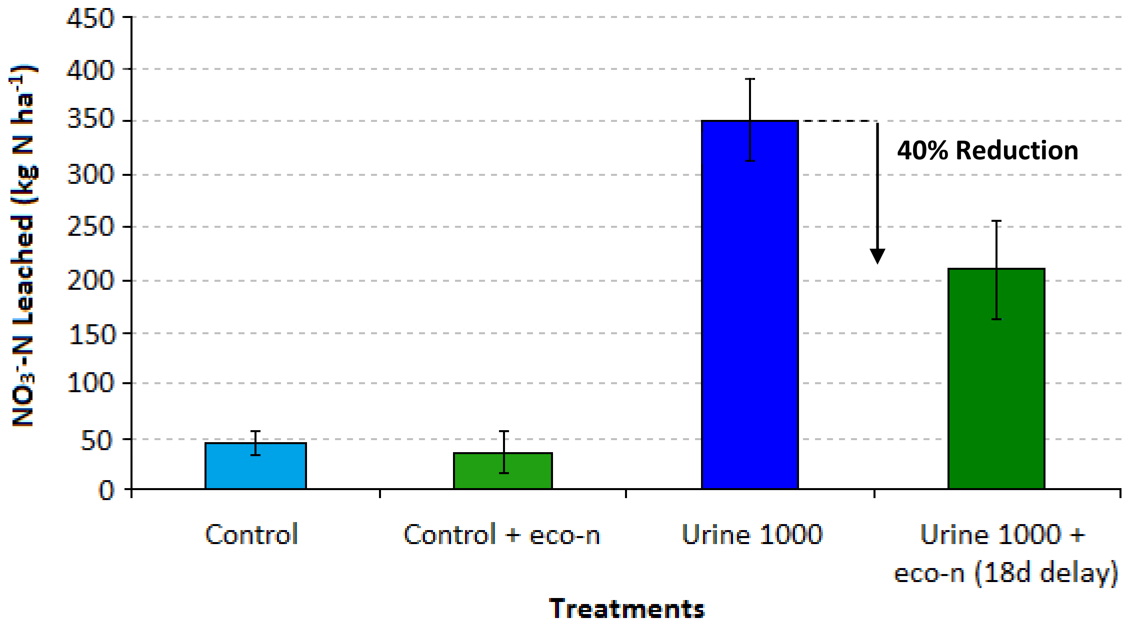


**Figure 2:** **Total $NO_3^-$-N (kg N ha$^{-1}$) leached from the Templeton winter runoff lysimeters (Adapted from Ravensdown, 2005).**

In addition, a North Otago study by McDowell & Houlbrooke (2009) indicated that DCD significantly ($P<0.05$) reduced $NO_3^-$-N leaching from sheep and cattle grazed winter forage crops. A granulated DCD applied to urine treated lysimeters, reduced $NO_3^-$-N leaching losses by 39% as shown in Figure 3. However, DCD was applied at 15 kg ha$^{-1}$. This study further supports previous studies showing leaching reductions.

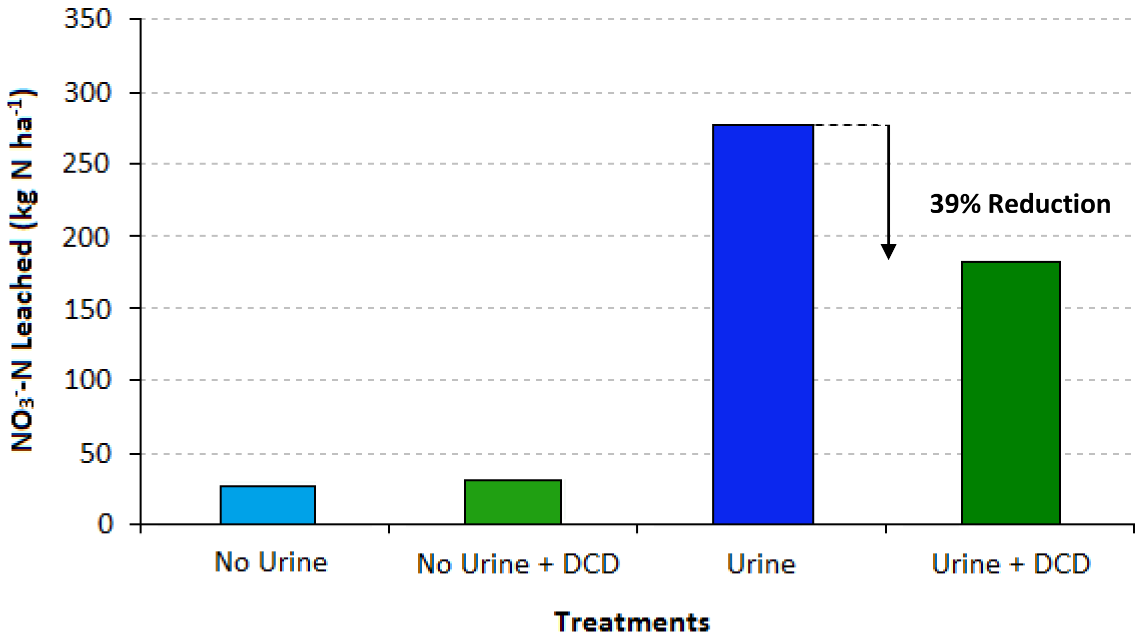


**Figure 3:** **The effect of DCD on reducing $NO_3^-$-N (kg N ha$^{-1}$) leaching lost from a winter forage crop (Adapted from McDowell & Houlbrooke, 2009).**

***Nitrous Oxide Gas***

A study conducted by Wild (2009) illustrates that treating soils with a nitrification inhibitor is an effective $N_2O$-N emission mitigation strategy from winter deposited sheep urine patches. In this study, the application of DCD) was found to significantly (P<0.01) reduce the $N_2O$ emissions by 72% (Figure 4) from sheep urine (300 kg N $ha^{-1}$) applied in the late autumn under winter forage grazing conditions, i.e. from 4.55 kg $N_2O$-N $ha^{-1}$ without DCD to 1.31 kg $N_2O$-N $ha^{-1}$ with DCD over the four month experimental period (Figure 4). Conclusions formed by Wild (2009) are similar to outcomes (Figure 5) of previous studies by Ravensdown (2005).

In the Ravensdown (2005) trial, DCD was applied to cattle urine patches during the winter while the cattle were on annual ryegrass winter breaks. Results showed at a 73% reduction in $N_2O$-N emissions occurred from the nitrification inhibitor treatment. As seen in Figure 5, these emissions were reduced significantly from 20 kg $N_2O$-N $ha^{-1}$ to 5.7 kg $N_2O$-N $ha^{-1}$. This was still the case when DCD was applied 18 days after grazing instead of within the recommended seven days of grazing (Cameron *et al.* 2004). Ravensdown (2005) stated that large emissions were attributed to intensive trampling of wet soil, which enhances the anaerobic/denitrification conditions.

Additionally, both studies (Ravensdown (2005) and Wild (2009)) are similar to published data by Hoogendoorn *et al.* (2008). Hoogendoorn *et al.* (2008) reported a 40% (Invermay) and 60-80% (Ballantrae) reduction in sheep urine patch emissions. The sheep urine N loading rate and concentration was identical to Moir *et al.* (2010) and Wild (2009), yet artificial urine was used instead of natural urine. The three studies previously mentioned support each other and provide evidence that DCD effectively reduces $N_2O$-N emissions from winter fed 'hot spots'.

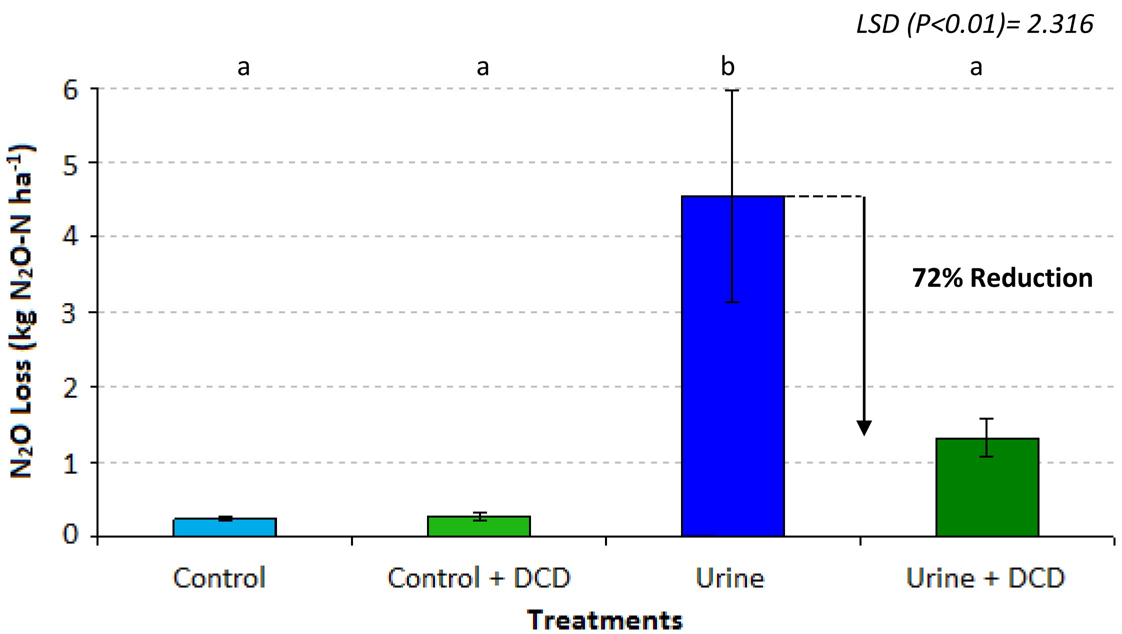


**Figure 4: Average total $N_2O$ gas losses (kg $N_2O$-N $ha^{-1}$) from all lysimeter treatments. Letters above bars indicate significant differences based on a 5% LSD test (Adapted from Wild, 2009).**

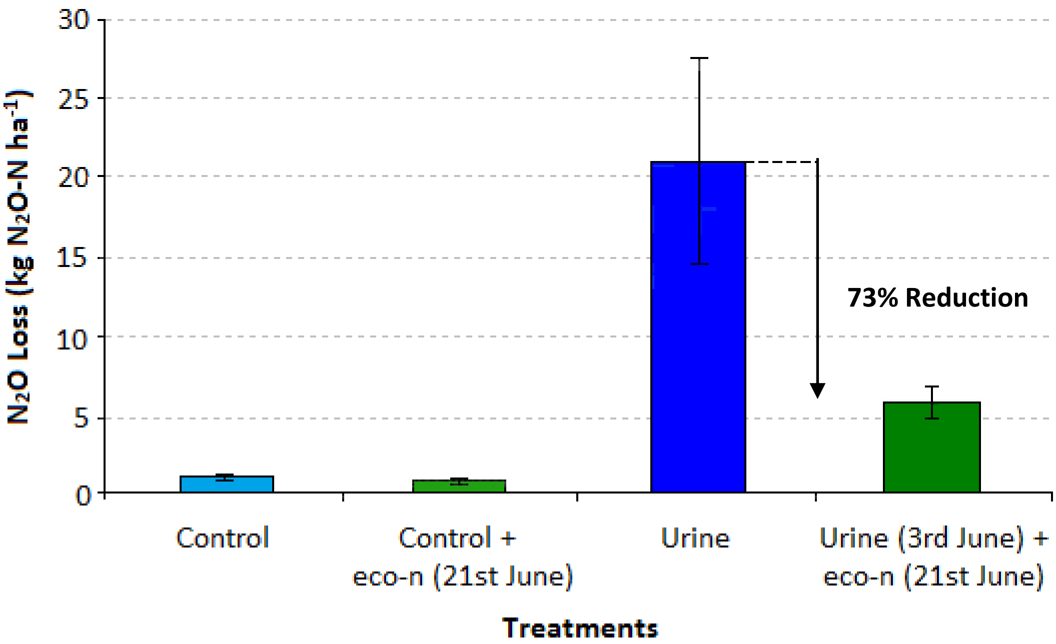


**Figure 5: Total $N_2O$ emissions (kg $N_2O$-N $ha^{-1}$) from the Templeton soil lysimeters, as affected by winter grazing and eco-n treatments (Adapted from Ravensdown, 2005).**

## Conclusion

Preliminary studies show that the use of the nitrification inhibitor DCD is a useful mitigation strategy to reduce $NO_3^-$-N leaching and $N_2O$ gas emission losses from intensive winter grazing systems, These grazed winter forage blocks are 'hotspots' for very large N losses. Mitigating N losses from these areas can have a significant effect on total farm N losses.

Results from Moir *et al.* (2010) and Wild (2009) clearly indicate great potential for the use of nitrification inhibitor technology in the sheep industry with significant ($P<0.01$) 70% reductions in $NO_3^-$-N leaching losses and 72% reductions in $N_2O$ gas emitted with the application of DCD at 10 kg $ha^{-1}$ on sheep urine patches (300 kg N $ha^{-1}$) deposited in May. Forage studies by McDowell & Houlbrooke (2009) and Ravensdown (2005) also found that the use of DCD had a significant effect on N losses from cattle urine.

### *Suggestions for Further Research*

- An area requiring research is the long term effect of application of DCD on 'winter runoffs' if pasture or a crop is absent in spring to uptake accumulated N.
- Further investigation should look at the potential benefit of DCD on replacement crops or pasture yields after the initial winter crop has been grazed.
- Field trials are needed to measure the $NO_3^-$-N and $N_2O$ losses from the whole paddock which sheep and/or cattle are grazing with and without DCD, instead of just the losses from urine patches.
- Research is also needed to quantify the amount and placement of DCD to improve the economic variability of applying DCD for sheep farmers. Furthermore, increasing the frequency or application rate of DCD could be investigated, given that these are relatively small areas to treat.

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