The effect of timing on DCD application relative to urine deposition on nitrous oxide mitigation

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Final Report:

THE EFFECT OF TIMING ON DCD APPLICATION RELATIVE TO URINE DEPOSITION ON NITROUS OXIDE MITIGATION

Project Code CC MAF POL_0708-79 (INVENT-21A)

to

Ministry of Agriculture and Forestry

(Nov 2008)

Prepared by

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Lincoln University

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IDENTIFICATION

PROJECT CODE	**CC MAF POL_0708-79**
PROJECT TITLE	**Effect of Timing of DCD Application Relative to Urine Deposition on Nitrous Oxide Mitigation**
RESEARCH LEADER	**Professor Keith Cameron, Lincoln University**
DATE	**30 May 2008**
INSTITUTION	**Lincoln University**

EXECUTIVE SUMMARY

This research programme determined the influence of elapsed time, between the deposition of urine and the application of the nitrification inhibitor (DCD), on the effectiveness of DCD to mitigate nitrous oxide (N_2O) emissions from agricultural soils.

Specialist gas sampling rings and gas chambers were used to measure N_2O emissions from field plots treated with cow urine, with and without DCD application, applied at a range of times (0, 3, 7 and 14 days) after the urine application, and 7 days before urine application. Soil samples were collected from companion plots to determine the change in DCD content over time and to determine the influence of DCD on the nitrification rate.

Results show that DCD applied at different times, ranging from 0 to 14 days after urine application and 7 days before urine application, are all effective in inhibiting the nitrification process, and reducing nitrate production in the soil.

Nitrous oxide gas samples were collected at frequent times after treatment application and analysed by gas chromatography. The results show that, DCD applied between 0-14 days after urine application significantly reduced N_2O emissions from urine patches. In particular, the DCD applied within 7 days of grazing (i.e. urine deposition) was shown to produce the greatest reductions in N_2O emissions.

Application of DCD within the recommended time period of 7 days after grazing (i.e. urine deposition) significantly reduced the EF_3 value by between 67 to 31 %, with an average reduction of around 50%. These results confirm the appropriateness of the current ‘best practice’ recommendation of applying DCD within 7 days of grazing to ensure that the greatest mitigation effect is obtained.

1. Goal

To determine the influence of elapsed time between urine deposition and the application of a nitrification inhibitor (DCD) on the effectiveness of DCD to mitigate nitrous oxide (N_2O) emissions from agriculture.

2. Rationale

There was uncertainty about the influence of timing of nitrification inhibitor (DCD) application relative to urine deposition on the effectiveness of the DCD to mitigate N_2O emissions from agriculture.

Cow urine patches represent New Zealand's greatest anthropogenic source of N_2O emissions therefore this study focused on cow urine patches. In addition, because c. 90% of dairy land in New Zealand has free-draining soil, this study was conducted on a free-draining Templeton silt loam.

The current recommendation for 'best practice' use of DCD requires it to be applied within 7 days of grazing. This ensures the urine deposited during grazing is treated before nitrification occurs in the soil. Therefore, the treatments focused on a 0 to14 day period after urine deposition. (There was also a treatment whereby DCD was applied 7 days before urine deposition.)

This programme supports the Climate Change Plan of Action research programme in the following areas:

- Targets key theme – Agricultural mitigation.
- Fits within requirement for: Technology development & applied research.
- Does not duplicate existing work.

3. Approach

The goal was to determine the influence of elapsed time between urine deposition and nitrification inhibitor (DCD) application on the effectiveness of DCD to mitigate N_2O emissions from agriculture.

Gas chamber methods were used to measure N_2O emissions from treated pasture plots on Lincoln University Dairy Farm. Gas measurements were made from areas defined by gas tight rings inserted into the ground (Plate 1). These rings have water troughs on top which form a gas-tight seal when headspace chambers are fitted during N_2O emission measurements.

In order to ensure that rainfall during the initial treatment phase did not affect the results, rain-covers were placed over the plots (Plate 1). These covers were removed once the final DCD treatments were applied (i.e. 14 days after urine application).

Plate 1. Gas chamber methods were used to measure nitrous oxide emissions on Lincoln University Dairy Farm.

The treatments were:

- Control (no urine)
- Urine alone (applied on 6th May 2008)
- Urine plus DCD applied on the same day as the urine
- Urine plus DCD applied 3 days after urine
- Urine plus DCD applied 7 days after urine
- Urine plus DCD applied 14 days after urine
- DCD applied 7 days before urine

There were 4 replicates of each treatment (giving 28 plots).

4. Measurements

Gas emission measurements were started immediately after the urine was applied. Gas samples were collected on Day 0, 1, 3, 5, 7, 10, 14 then twice per week for the remainder of the first month and once per week for subsequent months. Gas sampling continued until background emission levels were reached (about 4 months).

On each sampling day, N_2O measurements were carried out once between 12 noon and 2 p.m. Three headspace gas samples were taken from each chamber with syringes, and 12 ml of the gas sample was transferred into a 6 ml septum-sealed screw-capped glass vial.

Gas samples were analysed using gas chromatographs equipped with ^{63}Ni-electron capture detectors (ECD) with oxygen-free N_2 carrier gas.

In order to provide greater certainty to our interpretation of the results, companion plots were established next to the gas chamber plots.

These companion plots enabled soil samples to be collected from 0-7.5 cm depth in order to measure: (i) changes in the DCD content of the soil over time and (ii) changes in soil ammonium and nitrate contents (this provided a direct measure of the soil nitrification rate). Soil moisture content and soil temperature (10 cm depth) were measured and rainfall recorded at the site.

In addition, the results also allow an assessment of the N_2O emission factor (EF_3) for the different treatments and thus assist the development of protocols that will meet international good practice for capturing the effect of DCD mitigation into the NZ GHG inventory.

5. Milestones

- Trial site established (achieved).
- Gas rings manufactured and inserted in soil (achieved).
- Treatments applied according to the schedule (achieved).
- Gas chambers used to make direct measurements of N_2O emissions mitigation (achieved).
- First seven weeks of gas measurements completed (achieved).
- Interim Final Report submitted to MAF for comment and approval (achieved).
- Five months of gas measurements completed (achieved).
- Final Report and Summary Report submitted to and accepted by MAF (on-track).

6. Results

6.1 Soil sampling data – nitrate and ammonium

The differences in the amount of nitrate detected in the soil clearly indicate that the nitrification process was significantly inhibited with the application of DCD (Figure 1).

The DCD was highly effective at inhibiting the nitrification process even when applied over a range of times, from 0 to 14 days after urine application and 7 days before urine application. These results are particularly encouraging in view of the fact that, in practice, DCD is recommended to be applied within seven days of grazing, i.e. the time gap between urine deposition and DCD application is less than 7 days.

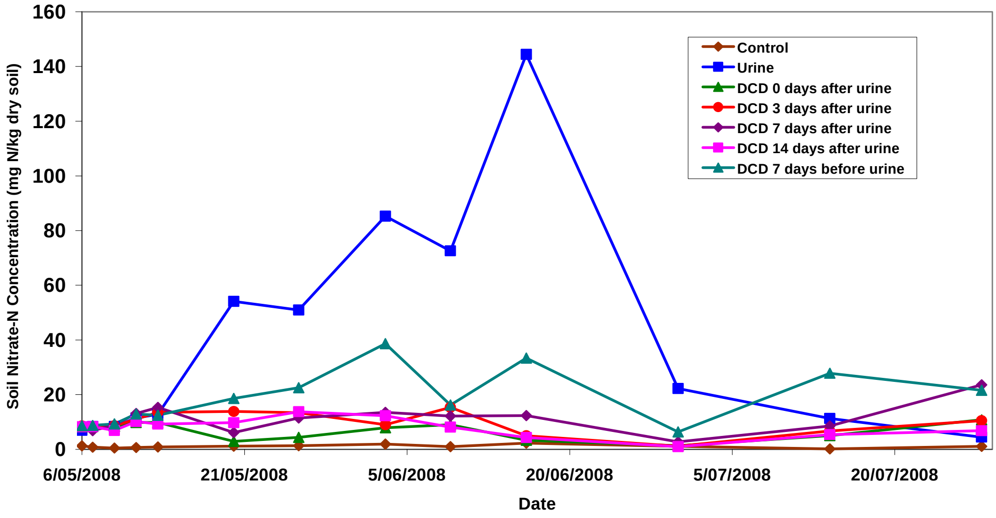

Figure 1. Nitrate-N concentrations in the soil as affected by urine application and DCD applied at different times in relation to urine application.

The soil ammonium data in Figure 2 also confirm that the nitrification process was significantly inhibited by the application of DCD. This is shown by the greater amounts of ammonium detected in the DCD treated soils compared to the soil treated with urine alone.

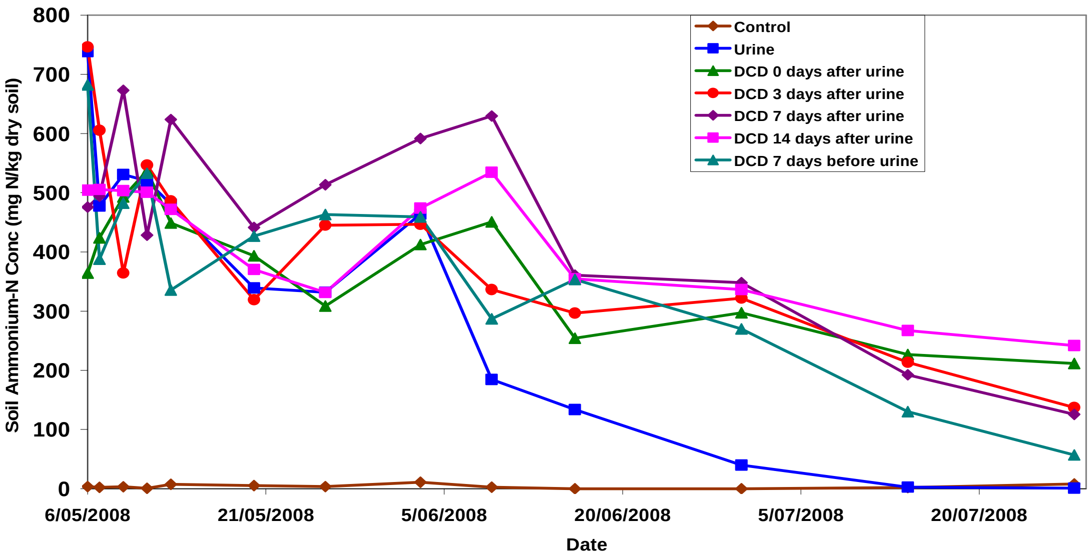

Figure 2. Ammonium-N concentration in the soil as affected by urine application and DCD applied at different times in relation to urine application.

6.2 Soil sampling data - DCD

Soil analysis showed that DCD was detected in the 0-7.5 cm depth of soil in each of the plots that were treated with DCD and that, as expected, the DCD concentrations declined with time (Figure 3).

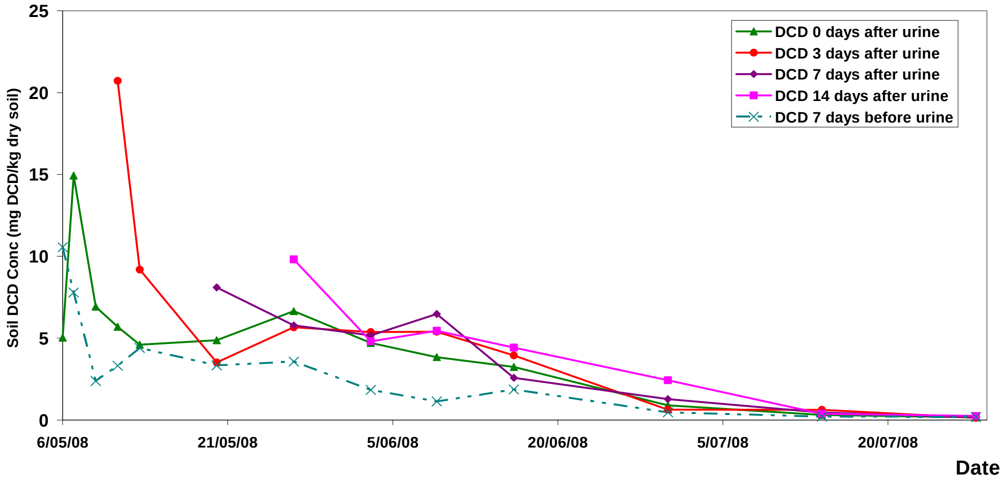

Figure 3. Soil DCD concentrations in the top 7.5 cm as a function of time.

6.3 Soil temperature and rainfall plus irrigation inputs

At the time of DCD application the average soil temperature was less than 10 °C and falling (Figure 4). The soil temperature remained below 10 °C until the end of August.

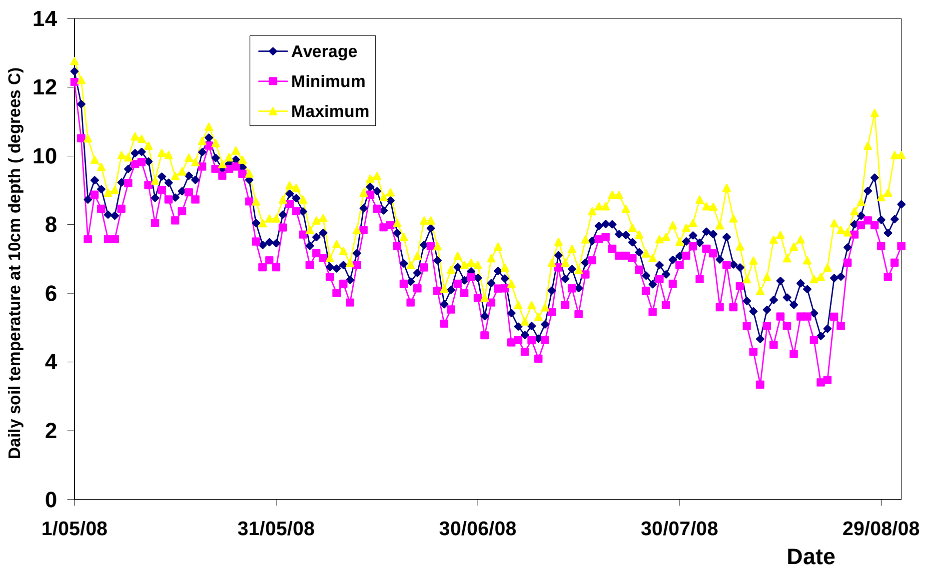

Figure 4. Soil temperature measured at 10 cm depth at 9 a.m. each day.

Daily rainfall plus irrigation data are shown in Figure 5.

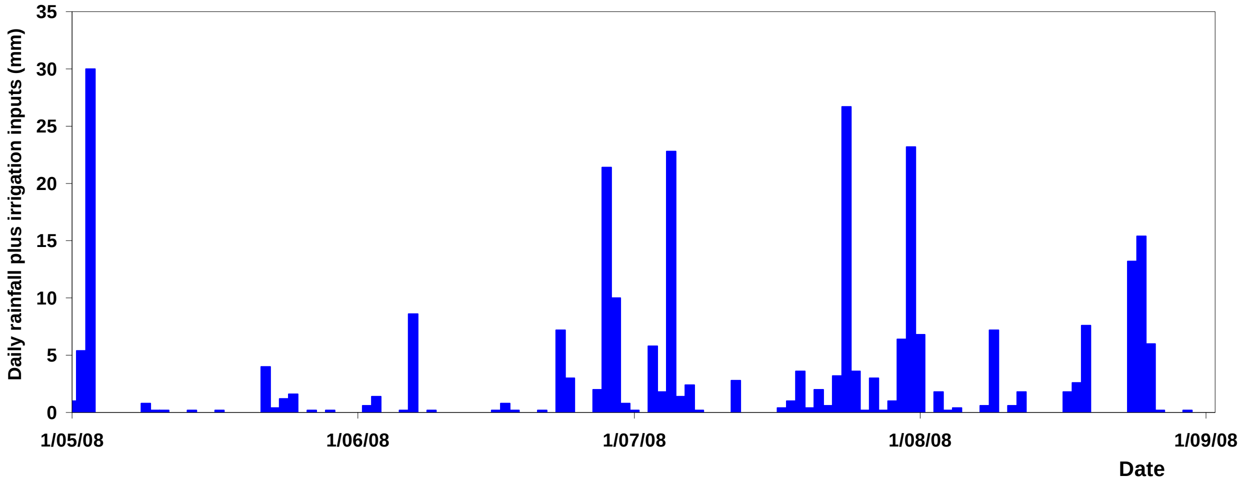

Figure 5. Daily rainfall plus irrigation data over the period of the trial.

Over the period of the trial the cumulative input of rainfall plus irrigation was equivalent to 280 mm (Figure 6).

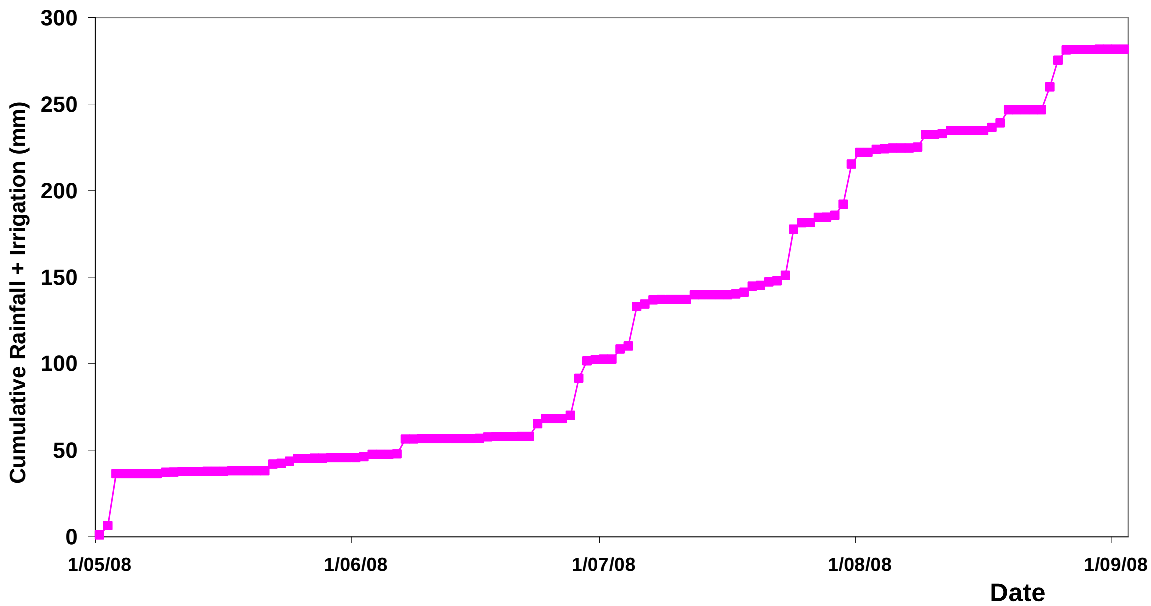

Figure 6. Cumulative rainfall and irrigation inputs over the period of the trial.

6.4 N_2O emissions as affected by urine application and DCD applied at different times

The gas sampling results show that all treatments with DCD applied between 0-14 days after urine application reduced the N_2O emissions compared to the urine only N_2O fluxes (Figures 7-10).

When DCD was applied within the recommended 7 days following urine application it produced the greatest reductions in N_2O emissions. The N_2O emissions from the DCD treatments also reached background (control) emission levels before the urine only treatments and then followed those background emission levels for the remainder of the measurement period.

When DCD was applied 14 days after urine it was less effective in reducing the N_2O emissions emphasising the benefits of applying DCD as recommended (i.e. within 7 days of grazing).

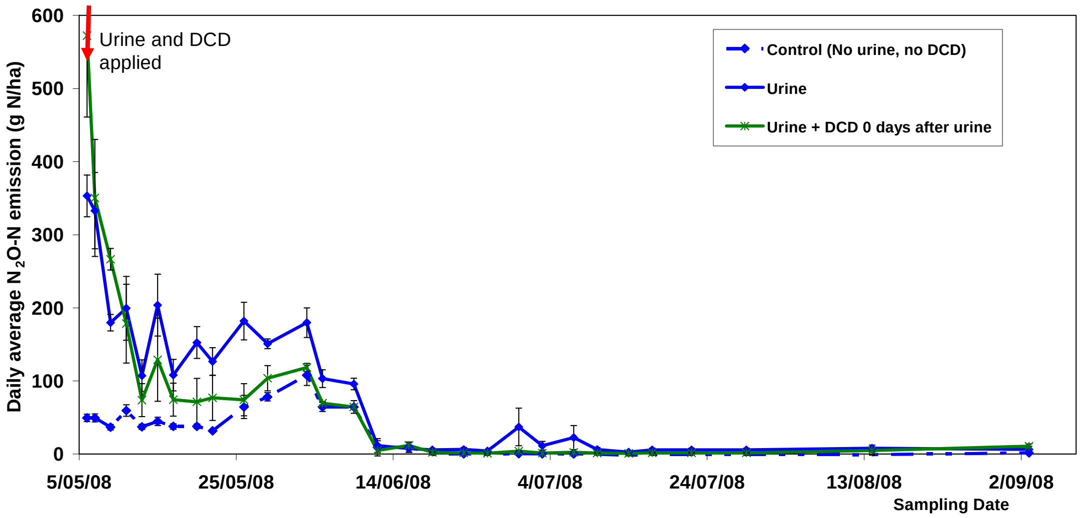

Figure 7. Nitrous oxide emissions from the soil as affected by urine application and DCD applied on the same day as urine.

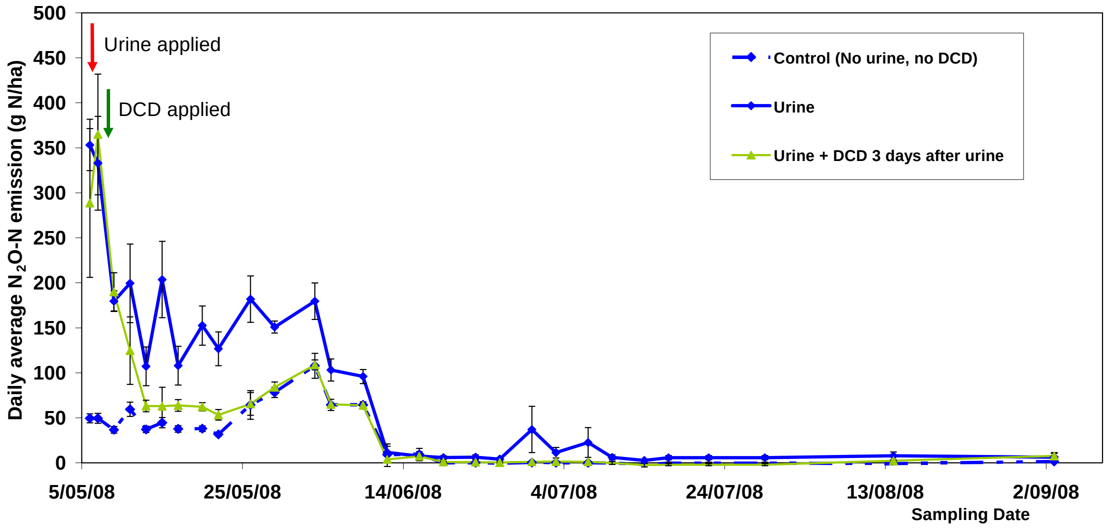

Figure 8. Nitrous oxide emissions from the soil as affected by urine application and DCD applied 3 days after urine.

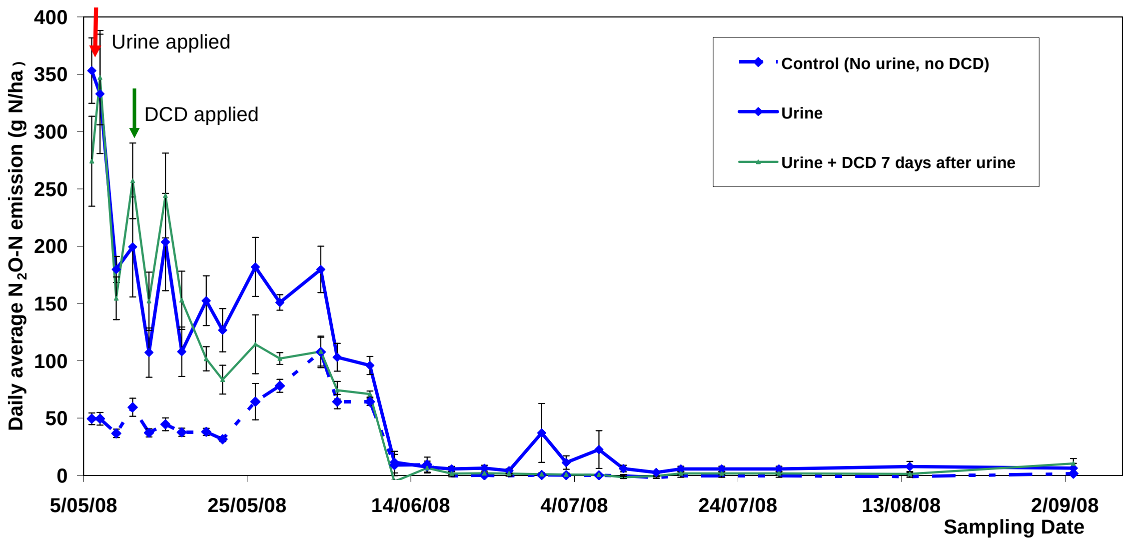

Figure 9. Nitrous oxide emissions from the soil as affected by urine application and DCD applied 7 days after urine.

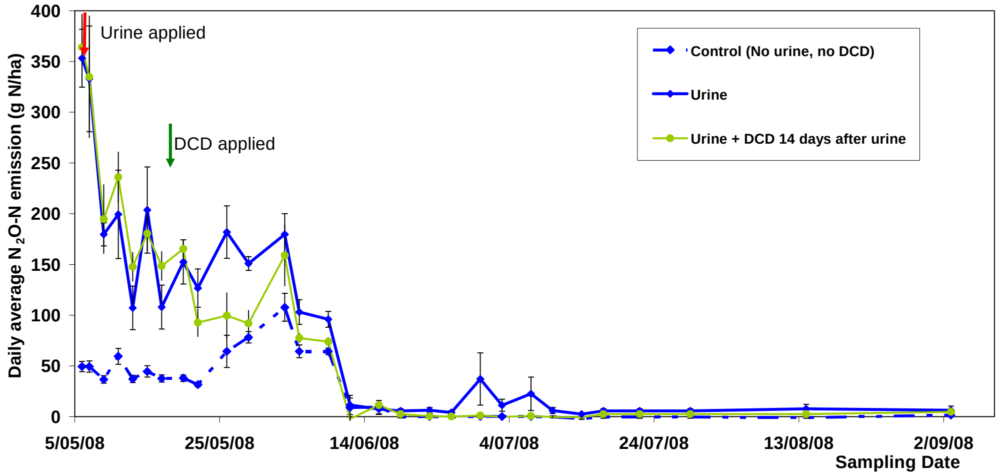

Figure 10. Nitrous oxide emissions from the soil as affected by urine application and DCD applied 14 days after urine.

6.5 *Effect of DCD on the total amount of nitrous oxide emitted*

Application of DCD significantly reduced the total amount of N_2O emitted (Figure 11). The greatest reduction occurred when DCD was applied 3 days after urine deposition, however there was still a significant reduction even when the DCD was applied 14 days after urine deposition.

(The result for the DCD treatment 7 days before urine is omitted from the graph because of initial technical problems with treatment application and sample collection. Results for a '7 days prior to urine' application will be reported in the companion Spring DCD timing report; where a 50% reduction has occurred).

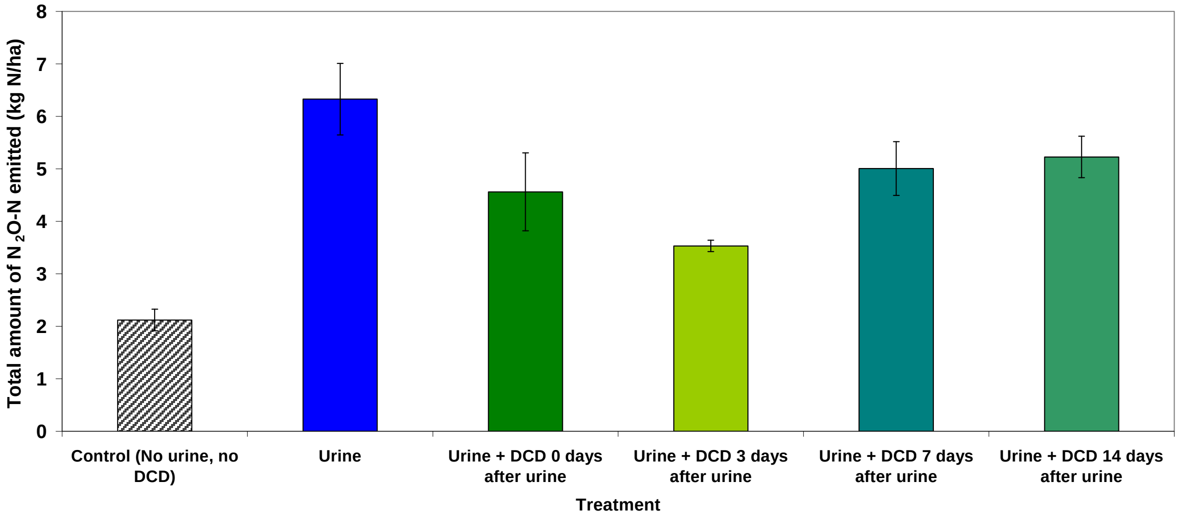

Figure 11. Total amount of nitrous oxide emitted from soil as affected by urine application and DCD applied at different times following urine application.

6.6 Reduction in EF_3 achieved by applying DCD at different times after grazing (i.e. urine deposition).

Application of DCD within the recommended time period of 7 days after grazing (i.e. urine deposition) significantly reduced the EF_3 value by between 67 to 31%, with an average reduction of around 50% (Figure 12). These results confirm the appropriateness of the current recommendation of applying DCD within 7 days of grazing.

Nevertheless, application of DCD 14 days after grazing still significantly reduced the EF_3 value by about 25%.

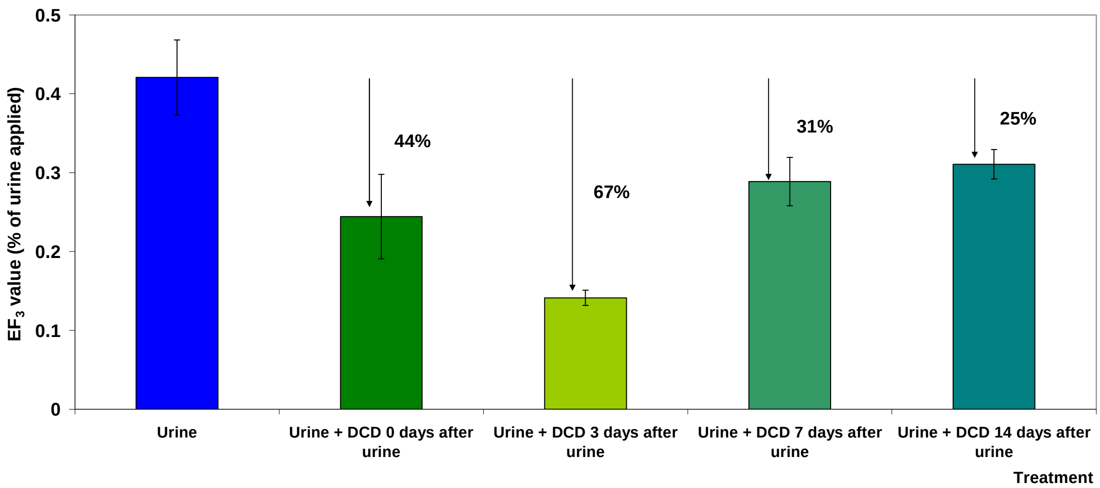

Figure 12. Reductions in the EF_3 value achieved by applying DCD at different times after urine deposition.

7. Discussion

Level of emissions from the non-urine plot

In the 'control' non-urine treatment we applied an equivalent volume of water to the volume of urine liquid applied in all the other treatments. This was done to create the same soil moisture status and thus redox potential in the control soil as would occur in the urine treated soil. Because the summer/autumn was very dry the application of water probably generated a flush of mineralisation & nitrification resulting in the N_2O emission from the control soil.

Emission factor for the urine alone plot

This value will vary depending on specific soil and environmental factors. For example, in Table 3 in our 2007 paper (Di et al., 2007, Soil Use and Management 23, 1-9) we reported a range of value from 0.1% to 2%.

Emission reduction at 3 days and 0 days

The result for the ‘day 0’ and ‘day 3’ may not be significantly different and is probably best regarded as being part of a range of emissions reduction that can be achieved when the inhibitor is applied within 7 days of grazing. Data in the Spring Timing trial show that the ‘day 0’ application is greater than the application on ‘day 3’.

Impact on the recommendation for BMP

If we regard the datasets as being part of a range of emissions reduction that can be achieved when the inhibitor is applied within 7 days of grazing then there should be no impact on the BMP recommendation.

The overall % reduction

The actual % value will be influenced by the wide range of soil and environmental conditions, nevertheless, a 50% reduction is still a very considerable reduction. This set of data should be regarded as one set amongst the other studies that have been reported previously.

Impact of the background emission levels on the emission factor

We recognise that there is debate about the appropriateness of subtracting background emission values when calculating the reduction in EF3 value, however as discussed above we believe that this is the correct thing to do. The high background emissions probably would not have much of an impact on the emission factors as they would be expected to be the same in the other treatments.

Deriving a mean national emission reduction factor for DCD use

We suggest that the ‘within 7 days 50% reduction’ dataset is added into the consolidated dataset from all the trials that have been conducted.

8. Conclusions

- The soil results show that DCD applied at different times, ranging from 0 to 14 days after urine application and 7 days before urine application, was highly effective at inhibiting the nitrification process. This is shown by the lower concentrations of nitrate and the higher concentrations of ammonium detected in the DCD treated soils compared to the soil treated with urine alone.

- The gas measurements show that DCD applied at different times, ranging from 0 to 14 days after urine application, was effective in significantly reducing N_2O emissions from urine treated soil.

- When DCD was applied within the recommended period of 7 days after grazing (i.e. urine deposition) the DCD was found to produce significant reductions in the amount of N_2O emitted and this resulted in an average reduction in the EF_3 value for urine of around 50%.