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An investigation into the agronomic and environmental benefits of applying the nitrification inhibitor dicyandiamide (DCD) on Irish grasslands

Key external stakeholders:

Scientists, Fertiliser industry, Farmers

Practical implications for stakeholders:

- The application of DCD to urine patches did on occasions increase herbage production and influence other parameters such as N uptake, soil mineral N content and herbage CP but the results were inconsistent between sites and years.
- Dosing DCD into the rumen of dry dairy cows did not affect the digestibility of the ingested grass, did not affect rumen pH or rumen function.
- During the 6-day treatment and measurement stage, the average recovery of the dosed DCD in urine was 82.3%, with a further 2.1% recovered in the faeces.

Main results:

- The results of the plot experiments show that the application of DCD to urine patches did on occasions increase herbage production and influence other parameters such as N uptake, soil mineral N content and herbage CP but the results were inconsistent between sites and years.
- The pulse-dosing of DCD into the rumen of cows can be achieved without deleterious effect on rumen function, and 84.4% of the DCD was recovered in six days.
- There were no deleterious effects of pulse dosing DCD into the rumen of cows on the blood plasma parameters, rumen function and diet digestibility measured in the experiment.
- The use of urine from cows pulse-dosed with DCD reduced nitrous oxide emissions and nitrate leaching by 57-84% and 86-91%, respectively, depending on soil type.

Opportunity / Benefit:

Dicyandiamide application to urine patches can reduce nitrate leaching and nitrous oxide emissions but there are small and inconsistent benefits in terms of herbage production. Passage of DCD through the rumen did not negatively impact on herbage digestibility. Further research is required to examine the amount of time required for the DCD concentrations in urine and faeces to reach zero and to examine whether DCD fed to dairy cows would be excreted in the milk of lactating animals.

Collaborating Institutions:

UCD
NUI Maynooth

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1. Project background:

Urine excreted by dairy cows is a source of nitrogen (N) to the sward in grazed grassland. The N content of urine is high, up to 1000 kg N ha^{-1}. Nitrogen supplied by urine is usually in excess of sward requirements and so the excess N is potentially lost through means such as nitrate leaching and nitrous oxide emissions. Dicyandiamide (DCD) is a nitrification inhibitor used in the agricultural industry in parts of New Zealand to reduce nitrate leaching and nitrous oxide emissions. In New Zealand DCD has also been shown to increase N availability for herbage production by slowing the conversion of ammonium to nitrate.

2. Questions addressed by the project:

Will applying DCD to urine patches in autumn increase grass growth on these areas over winter?
If DCD is dosed into the rumen of dairy cows, will it affect rumen function and what will the recovery of DCD in the urine be?
Will applying urine from dry cows dosed with DCD into the rumen reduce nitrate leaching and nitrous oxide emissions?

3. The experimental studies:

Four experiments were undertaken:
Experiment 1 examined the effect of applying DCD to urine and non-urine patches on grass plots with and without fertiliser on two soil types (free draining and heavy soil) over a two year period. The treatments (+/- urine +/- DCD) were applied in September, October or November each year. Half of the plots received a second application 90 days after the first. Herbage production, herbage N content and herbage N uptake were measured from February to October in year 1 and February to April in year 2. Soil N content was measured from November to April.
Experiment 2 examined the effect of applying DCD to urine and non-urine patches on grass plots receiving fertiliser N on two soil types (free draining and heavy soil) over a two year period. The treatments (+/- urine +/- DCD were applied in July, August or September each year. Half of the plots received a second application 90 days after the first. Herbage production, herbage N content and herbage N uptake were measured from February to October each year. Soil N content was measured from November to April.
Experiment 3 investigated the effect of pulse-dosing DCD into the rumen of non-lactating dairy cows on rumen function and the recovery of DCD. Rumen fistulated dairy cows were placed in stalls and fed fresh grass harvested daily. Cows were dosed into the rumen with DCD dissolved in water, or with distilled water only. Rumen samples were collected on three days and faeces and urine were collected, weighed and sampled for 6 days. The quantity of DCD in the rumen fluid, faeces and urine was then measured.
Experiment 4 quantified nitrate leaching and nitrous oxide emissions from lysimeters treated with urine from cows dosed with DCD or not dosed with DCD in *Experiment 3*. The lysimeters contained a free draining soil or a heavy soil. *Experiment 4* also examined the effect of urine from cows dosed with DCD or not dosed with DCD on herbage production on the free draining soil only.

4. Main results:

Experiment 1: Applying DCD did not increase spring herbage production. Over the two years, the application of 5 or 10 kg DCD/ha increased annual herbage production when applied to October and November deposited urine patches on the free draining soil when no fertiliser N was applied to the plots. Urine application increased herbage production in spring and annually on both soil types when no fertiliser N was applied, and increased herbage crude protein content and herbage N uptake in treatments receiving urine. The application of urine increased soil ammonium and total oxidised N content in the 0–100 mm horizon on both soil types.
Experiment 2: Applying DCD in August at a rate of 10 kg/ha significantly increased spring and annual herbage production by 14% and 15%, respectively, on the free draining soil type when applied following urine application in year 1. There was no effect of DCD applied in year 1 on herbage production on the heavy soil type. The application of DCD in August resulted in lower soil total oxidised N content up to sampling day 56 post urine application, on the free draining soil type in year 1, retaining higher N content in

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the soil. There was no effect of DCD on any of the parameters measured in year 2 at either site. Urine application did not increase spring herbage production. Urine significantly increased annual herbage production on the free draining soil type only in year 1. Urine application increased annual herbage N uptake, herbage crude protein content and soil mineral N at both sites in both years.
Experiment 3: The administration of DCD into the rumen of dry cows resulted in no deleterious effect on blood metabolites, rumen function and diet digestibility, as all were not significantly different from the control treatment and were within the normal biological range. During the 6-day treatment and measurement stage, the average recovery of the dosed DCD in urine was 82.3%, with a further 2.1% recovered in the faeces. No DCD was recovered in the urine and faeces 10 days following the cessation of dosing.
Experiment 4: Total nitrate leaching losses from the free draining and heavy soil types were reduced from 100 and 81 kg nitrate/ha on the urine only treatment, respectively, to 9 and 11.6 kg nitrate/ha on the urine with DCD treatment, respectively. This equated to a 91% and 86% reduction, respectively. Total nitrous oxide emissions during the study were significantly reduced by applying urine with DCD on both the free draining and heavy soil types; from 13.6 and 12.1 kg nitrous oxide/ha on the urine only treatment, respectively, to 2.23 (-84%) and 5.24 (-57%) kg nitrous oxide/ha on the urine with DCD treatment, respectively. The addition of urine to grass plots increased soil N concentration. Urine with DCD inhibited the nitrification process of ammonium to total oxidiseable N for up to 56 days after treatment applications. There was no significant effect on herbage production when urine with DCD was applied to grass plots.

5. Opportunity/Benefit:

Overall this project shows that the effects of applying DCD to urine patches on herbage production, herbage CP content, herbage N uptake and soil mineral content in the rooting zone were not consistent, and so DCD cannot be recommended as a tool to increase herbage production and N uptake. The pulse-dosing of DCD into the rumen of cows can be achieved without deleterious effects on rumen function, and 84.4% of the DCD was recovered in six days. Dicyandiamide can provide a successful mitigation strategy to reduce the environmental emissions of urine deposited by cows in the Irish dairy industry but the method of using animals to excrete DCD with urine to pastures requires further research for adaptation by the agricultural industry. It will be important to investigate if DCD could be fed to lactating cows, and the likelihood of residual DCD being present in meat or milk following feeding to livestock.

6. Dissemination:

An overview of the project was given at the Moorepark Open Day in 2009 and 2011. Visitors to Moorepark, both national and international, received presentations on the project and many interesting discussions took place. Poster and oral presentations were made at the Agricultural Research Forum, British Grassland Society Research Conference, and EGF Conference. Three papers have been published from this project, and one more is in preparation.

Main publications:

P.J. O'Connor, D. Hennessy, M.B. Lynch, H. Slattery, E. Lewis. The effect of pulse-dosing non-lactating dairy cows with the nitrification inhibitor dicyandiamide (DCD): the recovery of DCD and DCD effects on blood metabolites, rumen function and diet digestibility. *Livestock Science.* 155: 30–37.
O'Connor, P.J., Hennessy, D., Brophy, C., O'Donovan, M. and Lynch, M.B. (2012) The effect of the nitrification inhibitor dicyandiamide (DCD) on herbage production when applied at different times and rates in the autumn and winter. *Agriculture, Ecosystems and Environment*, 152: 79– 89
P.J. O'Connor, M.B. Lynch, E. Cahalan, M. O'Donovan and D. Hennessy. The effect of the nitrification inhibitor dicyandiamide (DCD) on spring and annual herbage production in urine patches when applied in late summer or early autumn. *Grass and Forage Science (published on line* - DOI: 10.1111/gfs.12011)

Popular publications:

O'Connor, P.J., Hennessy, D., Cahalan, E., O'Donovan, M. and Lynch, M.B. (2012). The effects of nitrification inhibitor dicyandiamide (DCD) on herbage nitrogen uptake when applied in late summer or early autumn. In: Proceedings of the 24th General Meeting of the European Grassland Federation, Lubin, Poland, 3-7 June 2012, 17: 628-630.
O'Connor, P.J., Hennessy, D., O'Donovan, M. and Lynch, M.B. (2011) The effect of the nitrification inhibitor dicyandiamide (DCD) applied in late summer, autumn and winter on soil ammonium and total oxidisable nitrogen. British Grassland Society 10th Research Conference, Le Mon Hotel and Country Club, Belfast and Agri-Food and Biosciences Institute, Hillsborough, Belfast, Northern Ireland, 20th - 21st September 2011. pp. 123-125.
O'Connor, P.J., Hennessy, D., O'Donovan, M. and Lynch, B. (2010) The effects of the nitrification inhibitor dicyandiamide on herbage production when applied at varying time points and rates in autumn. In:

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'Advances in Animal Biosciences – Food, Feed, Energy and Fibre from Land – A vision for 2020' - Proceedings of the British Society of Animal Science and the Agricultural Research Forum 2010. p. 318.

7. **Compiled by:** Deirdre Hennessy

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