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WHAT FRACTION OF A URINE PATCH CAN BE INTERCEPTED BY A TARGETED INHIBITOR APPLICATION?

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Abstract

Urine patches are potential hot spots for N losses via gaseous emissions and leaching in grazed pastures. These losses may be reduced by the application of inhibitors that slow down particular transformations of the urine-N (e.g. urease inhibitors, nitrification inhibitors). Technologies exist that can detect urine patches and target the inhibitor application specifically to the patches, thereby avoiding the need to apply the inhibitor over the entire paddock. In practice, however, there will be some time delay between the grazing event and the inhibitor application. This delay could result in some physical separation between the urine and the inhibitor in the soil, which would limit the potential effectiveness of the inhibitor.

In this study we used the HYDRUS 2D/3D model to simulate the movement and transformation of urine-N down the soil profile for two different soils at two different moisture levels. We then simulated the application of the nitrification inhibitor dicyandiamide (DCD) at two different volumes applied 24h after the urine to estimate the proportion of urine-N captured by the DCD. The model simulations showed that 100% of the DCD remained in the top 2cm of the soil profile 8h after application, while the measurements (made 4–18h post application) found on average 69% of the recovered DCD was in the top 2cm. However, below 2cm depth the average DCD concentration was < 3 mg/kg soil. Over the same time period the model simulated 25–35% of the urine-N would remain in the top 2cm of the soil.

Methodology

Field experiment

The experiment was carried out at two sites in the Manawatū. One was on a well-drained soil (Manawatū silt loam) and the other a poorly drained soil (Tokomaru silt loam). 2L urine were applied by pouring from a height of 1.2m, in a manner as close as possible to a natural cattle urine deposit. 24 hours later DCD was applied using a Spikey® spray unit using either 30mL or 60mL of solution. Initially it was planned to use two different soil moisture levels and three replicates. However, there was little difference in the soil moistures achieved on the well-drained soil (27.4% and 28.8% volumetric moisture content). The difference was slightly larger in the poorly drained soil (29.9% and 34.2% volumetric moisture content). As the soil moisture was found to have little effect (data not shown), it was decided to combine these two treatments.

4–18 hours after DCD application, 17 soil cores (length 10cm) were removed from each patch. Each soil core was cut into three parts (0–2, 2–5, and 5–10cm) and analysed for DCD. The experimental method is described in more detail in Portegys et al. (2020).

Modelling

The model simulations were performed using the HYDRUS 2D/3D model that simulates the 3-dimensional transport of water, solutes, and heat in porous media. We have previously parameterised this for urine patches in these soils (Giltrap et al. 2020). HYDRUS can simulate simple first-order chemical transformations. In our simulations we included the hydrolysis of urea to NH_4^+ and nitrification of NH_4^+ to NO_3^-. Denitrification was not included due to the short time frame of our experiment. NH_3 volatilisation was neglected as HYDRUS was not capable of simulating the changes in pH that drive NH_3 emissions. While neglecting NH_3 emissions might have significant impact on the total amount of urine-N remaining in the soil, it should have less effect on the relative distribution of the urine-N.

Giltrap et al. (2020) did not include the addition of DCD. For these simulations we used a water diffusion coefficient of 0.036 cm^2/h and an adsorption of 0.26 cm^3/g based on Bishop (2010).

In the simulations, 2L urine were applied to the soil surface at 0h with the initial patch area calculated using the method in Giltrap et al. (2020). At 24h, either 30 or 60 mL DCD (concentration 0.0167 g/mL) were applied over an area of $0.5m^2$ around the urine patch. The simulation was run for a further 8 hours and the proportion of DCD and urine-N (as urea, NH_4^+, or NO_3^-) by depth calculated.

Results

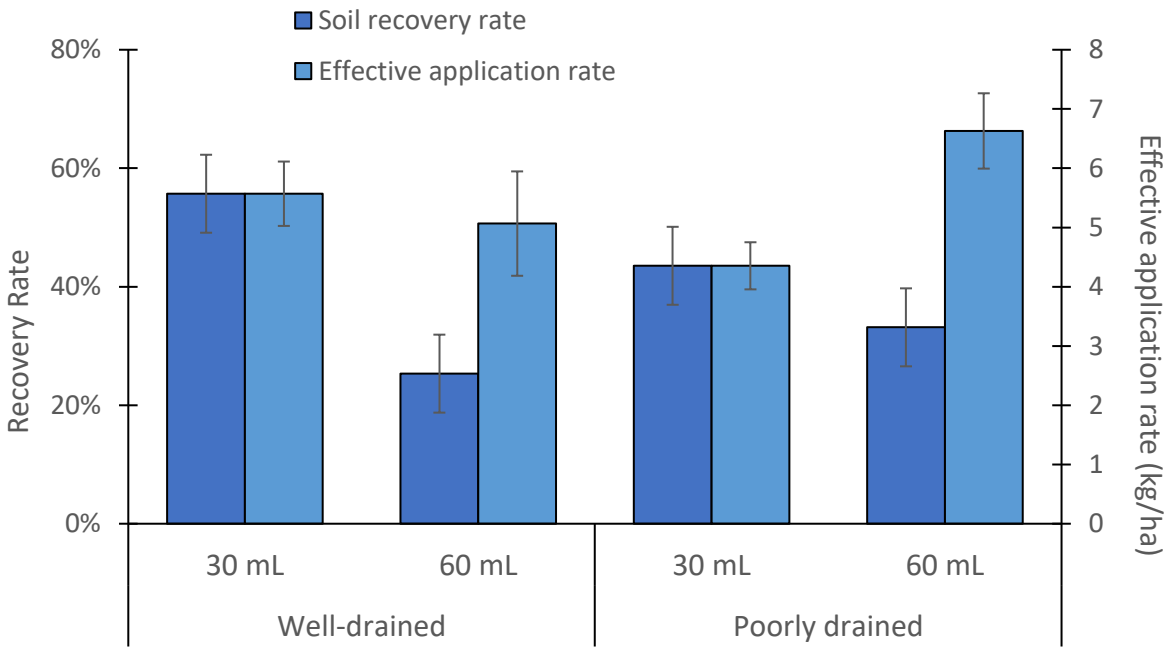

Figure 1: Percentage of DCD recovered from the soil and the effective application rates for nominal application rates of 10 kg/ha (30 mL) and 20 kg/ha (60mL). Error bars represent 1 standard error.

Figure 1 shows the recovery rate (fraction of the applied DCD recovered in soil samples) of DCD in the soil and the corresponding effective application rate. The relatively low recovery

rates are due to a combination of atomised spray failing to reach the ground, DCD being trapped on the plant surface, and DCD binding to the soil. This meant the effective application rates ranged from 4 to 7 kg DCD/ha.

Figure 2 shows the measured distribution of the recovered DCD with depth. On average 64–71% of the recovered DCD was within the top 2cm of the soil. The HYDRUS simulations showed 100% of the DCD remaining in the top 2cm, which suggests there could have been some preferential flow in the field. However, as the average measured concentration of DCD in the lower depths ranged from 0.9 to 2.3 mg DCD/kg soil, it is unlikely to have been very effective at these depths (Fig. 3).

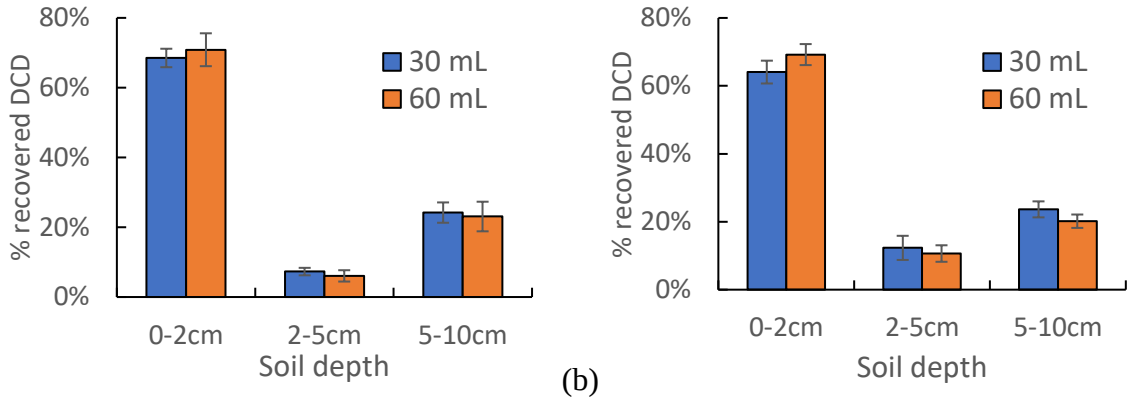

Figure 2: Measured distribution of the recovered DCD by depth for (a) well-drained and (b) poorly drained soil. Error bars represent 1 standard error.

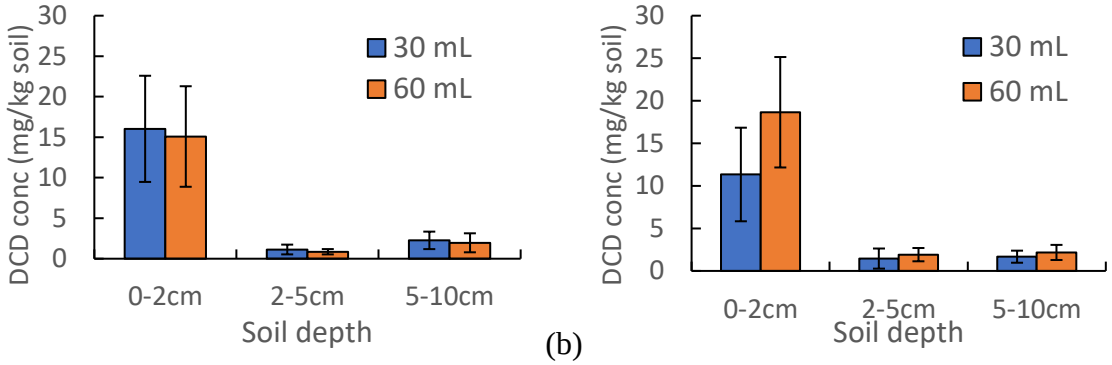

Figure 3: Measured mean DCD concentration by depth in soil for (a) well-drained and (b) poorly-drained soil. Error bars represent 1 standard error.

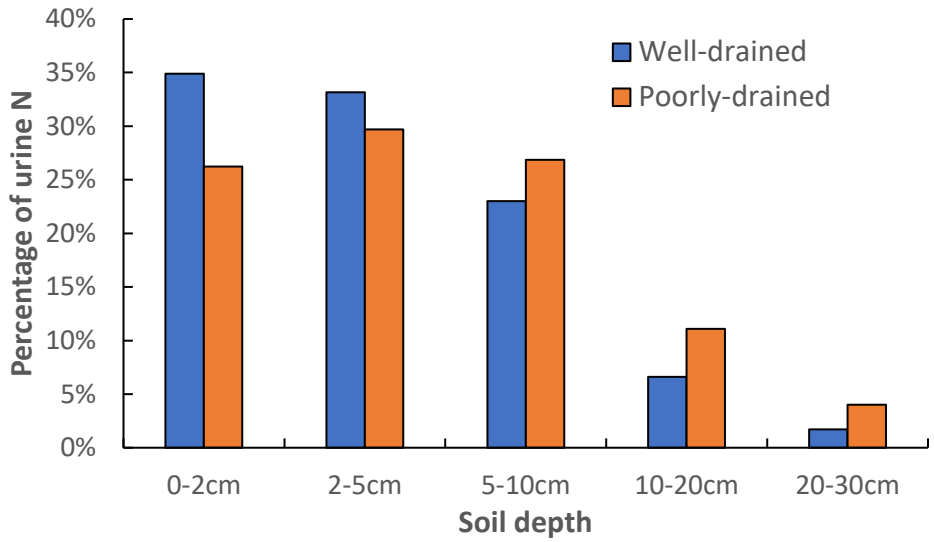

Figure 4: Simulated distribution of urine-N 32 hours after application (equivalent to 8 hours after DCD application).

Figure 4 shows the simulated urine-N by depth 8 hours after the DCD application (32 hours after urine application). According to the simulations, 35% of urine-N in the well-drained soil and 26% in the poorly drained soil remained in the top 2cm soil layer. In this case, the poorly drained soil had higher air-filled pore space than the well-drained soil. This meant the urine patch did not spread so far laterally and travelled further down the soil profile relative to the well-drained soil.

The fact that only 26–35% of the urine-N remained in the top 2cm soil layer with an effective DCD concentration indicates that the effectiveness of the DCD is likely to be somewhat limited by the its inability to physically intercept the remaining 65–74% of the urine. We have also neglected the effect of NH_3 volatilisation, which is an additional source of N loss from the soil surface. However, this reduction in inhibitor effectiveness may not be directly proportional to the fraction of urine intercepted, as the N_2O produced in the deeper layers is more likely to be completely denitrified to N_2 before being emitted (Arah et al. 1991). In addition, this study has not yet examined the effects of rainfall on the movement of urine and DCD.

Conclusion

While the measurements showed some DCD below 2cm depth, the mean concentrations were <3 mg DCD/kg soil and therefore unlikely to be effective. The simulated urine-N remaining within 2cm of the soil surface after 32h was between 26 and 35%. This suggests there will be some limitation of inhibitor effectiveness due to physical separation. However, a better understanding of N_2O production and consumptions with depth is needed to quantify this.

Further research should look at expanding the range of soil types considered and examining interactions with rainfall.

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References

Arah J.R.M, Smith K.A., Crichton I.J., Li H.S. 1991. Nitrous oxide production and denitrification in Scottish arable soils. Journal of Soil Science 42:351-367

Bishop P.A. 2010. Polymer coated controlled release agrichemicals as mitigation tools in pastoral farming: a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Soil Science at Massey University, Palmerston North, New Zealand. Retrieved from http://hdl.handle.net/10179/2887

Giltrap D., Jolly B., Bishop P., Luo J., Bates G., Lindsey S., Berben P., Palmada T, Saggar S. 2020. Modelling 3D Urine Patch Spread in Grazed Pasture Soils to Determine Potential Inhibitor Effectiveness. Agriculture, Ecosystems and Environment 292:106809. DOI: 10.1016/j.agee.2019.106809

Portegys N., Saggar S., Hanly J., Giltrap D. 2020. Measuring spatial distribution of dicyandiamide movement in a well-drained and poorly-drained soil. In: Nutrient management in farmed landscapes. (Eds C.L Christensen, D.J.Horne and R.Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 33. Farmed Landscapes Research Centre, Massey University, Palmerston North, New Zealand.