Bishop, P. and Quin, B.F., 2018 Sodium thiosulphate as an alternative nitrification inhibitor TO DCD. In: *Farm environmental planning – Science, policy and practice*. (Eds L. D. Currie and C. L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 31. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 5 pages.

SODIUM THIOSULPHATE AS AN ALTERNATIVE NITRIFICATION INHIBITOR TO DCD

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Abstract:

Following the withdrawal of the nitrification inhibitor DCD by Ravensdown in 2012 there has been a significant gap in the mitigation toolbox for the reduction treatments of both the greenhouse gas N_2O and nitrate leaching from dairy urine patches. Current developments by Pastoral Robotics Limited (PRL) to produce a commercial system, Spikey®, for detecting and treating urine patch following urine dissipation has allowed the development of a range of spray treatments by Advanced Agricultural Additives Limited (AAA Ltd) under the brand ORUN®. The ORUN® range initially consisted of combinations of gibberellin, NBPT and AlpHa®Na designed to increase pasture N uptake by increasing pasture growth via gibberellin (ProGibb®). However, these effects are limited by available plant growth conditions prior to drainage and a nitrification inhibitor is required to broaden the ORUN® range.

Spikey® only treats the specific area of the urine patch making targeted applications of inhibitors, previously uneconomic for whole pasture application, are now possible. AAA ltd. in conjunction with PRL have identified and patented a range of thiosulphate compounds offering the equivalent effectiveness of DCD in soil incubation studies. Sodium thiosulphate (NaTS) solutions applied at rates from 62 to 185 mgS/kg in soil haves been shown to produce comparable nitrification inhibition rates as DCD, with 62 and 125mgS/kg of NaTS producing 50 and 80% of the inhibitor effect of 10mgDCD/kg soil incubated at 20 ^{o}C in the presence of 300mg Urea-N/kg. In Rhizosphere incubations of surface applied treatments there was no significant difference between the inhibitor effect of DCD applied at 10mgDCD/kg and NaTS applied at 62 mgS/kg soil in

Hypothesis:

Thiosulphate can be an alternate treatment replacing DCD for inhibiting nitrification in pastoral soils.

Introduction:

Limited but well documented evidence outlines the nitrification inhibiting properties of the anion thiosulphate ($S_2O_3^{-2}$) with the associated cations ammonium, calcium, potassium and sodium (Barbosa-Jefferson, Zhao, McGrath, & Magan, 1998; Ebelhar et al., 2007; Goos, 1985; Goos & Johnson, 1992; Janzen & Bettany, 1986), with nitrification being significantly inhibited with application rates of > 26mg S /kg soil. To determine the efficacy of thiosulphate

compared to DCD under New Zealand conditions, preliminary soil incubations have been conducted using a Lismore silt loam from Canterbury, New Zealand, with application rates of 62,125 and 185 mg S/kg soil compared to the standard rate of DCD at 10mgDCD/kg soil in the presence of urea added at a rate of 300mgN/kg soil, at 20 ^{o}C. Rhizosphere incubations were also conducted using Lismore silt loam and perennial ryegrass (Lolium perenne) in a controlled-environment growth chamber at 13 ^{o}C, with a 9 hr photoperiod.

Trial 1. Soil incubation

The soil incubations were carried out in 50 ml falcon centrifuge tubes containing 10g dry wt. (bulk density of 0.83 g/cc) of 4 mm sieved, field moist soil (12% Θ) that had been pre-incubated for 3months. Treatment mixtures were added to the soil in a total of 1 ml of liquid, which increased the water-filled pore space (Θ) to 20%:

- Control – 1 ml water
- Urea (300 mg N/kg): 1 ml (3000mg urea-N/l)
- Urea + DCD (10mg DCD/kg): 1 ml (3000mg urea-N/l, 100mg DCD/l)
- Urea + NaTS (62mg S/kg):1 ml (3000mg urea-N/l, 2500mg NaTS.5H_2O/l)
- Urea + NaTS (125mg S/kg): 1 ml (3000mg urea-N/l, 5000mg NaTS.5H_2O/l)
- Urea + NaTS (185mg S/kg): 1 ml (3000mg urea-N/l, 7500mg NaTS.5H_2O/l)

The incubation tubes were then stored open in trays inside large (ca. 50 l) plastic bags, with damp paper towels to reduce evaporation losses, in a 20^{o} C constant temperature room.

At 3, 10, 21 and 38 days following the applications of the treatments, three replicates were taken and extracted with 25 ml of 2M KCl and analysed for ammonium and nitrate-N.

Trial 2. Rhizosphere incubation

Following the soil incubation trial, leaching of the pre-incubated soil to remove mineralized nitrate N was undertaken. The soil was then then partially dried and sieved. 30 g of undried soil (25 g dry) was placed in 50 ml Falcon centrifuge tubes with half the tubes receiving 3 ryegrass seed. The ryegrass germinated in 7 days and was grown for 4 weeks prior to clipping and treatment applications.

Sequential treatment applications were undertaken to mimic a more natural situation of post urination spray application, with 3ml of urea solution added followed by 0.1 ml of inhibitor solution 1 hr later.

- Control – 3.1ml water
- Urea – 3ml (2498mgUrea-N/l) +0.1 ml water
- Urea+ DCD - 3ml (2498mgUrea-N/l) +0.1 ml (250mgDCD/L)
- Urea + NaTS (62mgS/kg)- 3ml (2498mgUrea-N/l) +0.1 ml (62,500mgNaTS.5H_2O/L)

The treatments were applied to the soil with and without grass to determine the rhizosphere effect of ryegrass.

The incubation tubes were then placed in a temperature controlled room at a constant 13°C with photo-synthetically active radiation supplied by fluorescent lighting at 90 µmol m^{-2} s^{-1} for a 9 hr photo- period. The water was maintained at between 15 to 25% Θ with watering every second day.

Results

Trial 1. Soil Incubation

The soil's treatment before incubation resulted in a significant mineralization of soil organic N, and increased the background soil nitrate levels to 90mg NO_3-N/kg soil. This may explain the observed zero order nitrification rate shown by ammonium oxidation and nitrate accumulation, as shown in Fig 1a and1b). The application of NaTS at the rate of 185 mgS/kg soil was equivalent (P=0.48) to DCD at the 10mg/kg rate, reducing the nitrification rate by 59%. The 2 higher rates of NaTS (62 and 125 mg S/kg) reduced nitrification by 25 and 41% respectively, both rates were less effective than DCD (P <0.01).

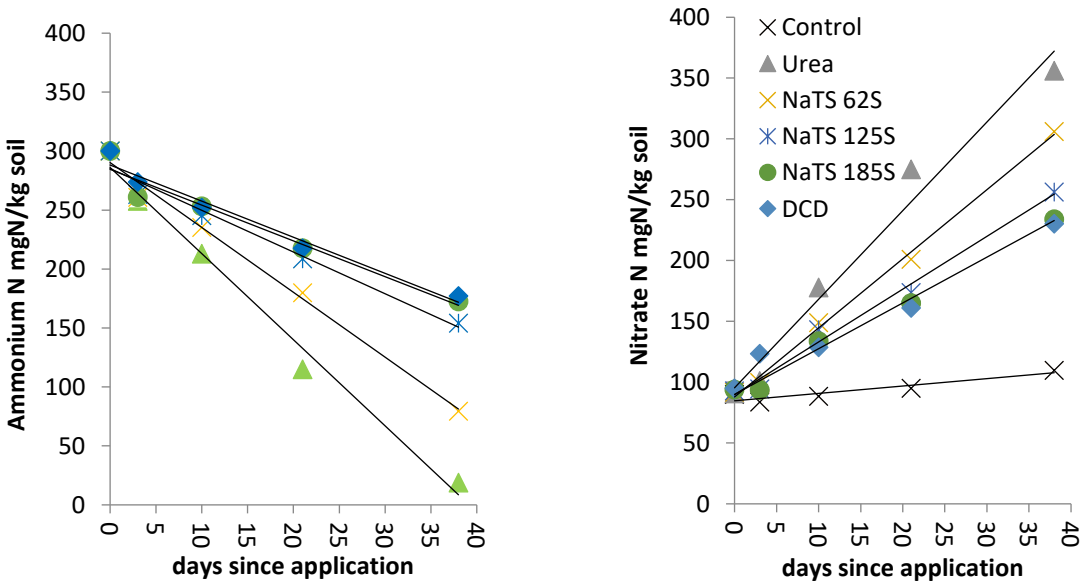

Figure 1 Effect of nitrification inhibitors DCD (10mgDCD/kg) and thiosulphate (NaTS, 62,125,185 mgS/kg) on soil ammonium- N and nitrate-N transformations of urea solution added to Lismore silt loam at a rate of 300mgN/kg and incubated at 20°C.

Trial 2. Rhizosphere incubation

Results from the rhizosphere incubations demonstrated the dominant effect of ryegrass on the system with the nitrification of the applied urea solution being 46% faster than both the soil only incubations in Trials 1 and 2 (P= 0.001). However, the change from a mixed solution (Trial 1) to surface application inhibitors significantly reduced the inhibition of nitrification by DCD, from 59% to 21%, while the effectiveness of the NaTS 62 was only reduced from 24% to 19% at day 18. The rate of nitrification in the incubations without ryegrass slowed further by day 40 with a DCD and NaTS 62 treatments producing reductions of 45% in nitrification.

With no significant differences observed between surface applied DCD (10mg DCD/kg soil) and NaTS at 62mg S/kg soil (Fig 2a, b).

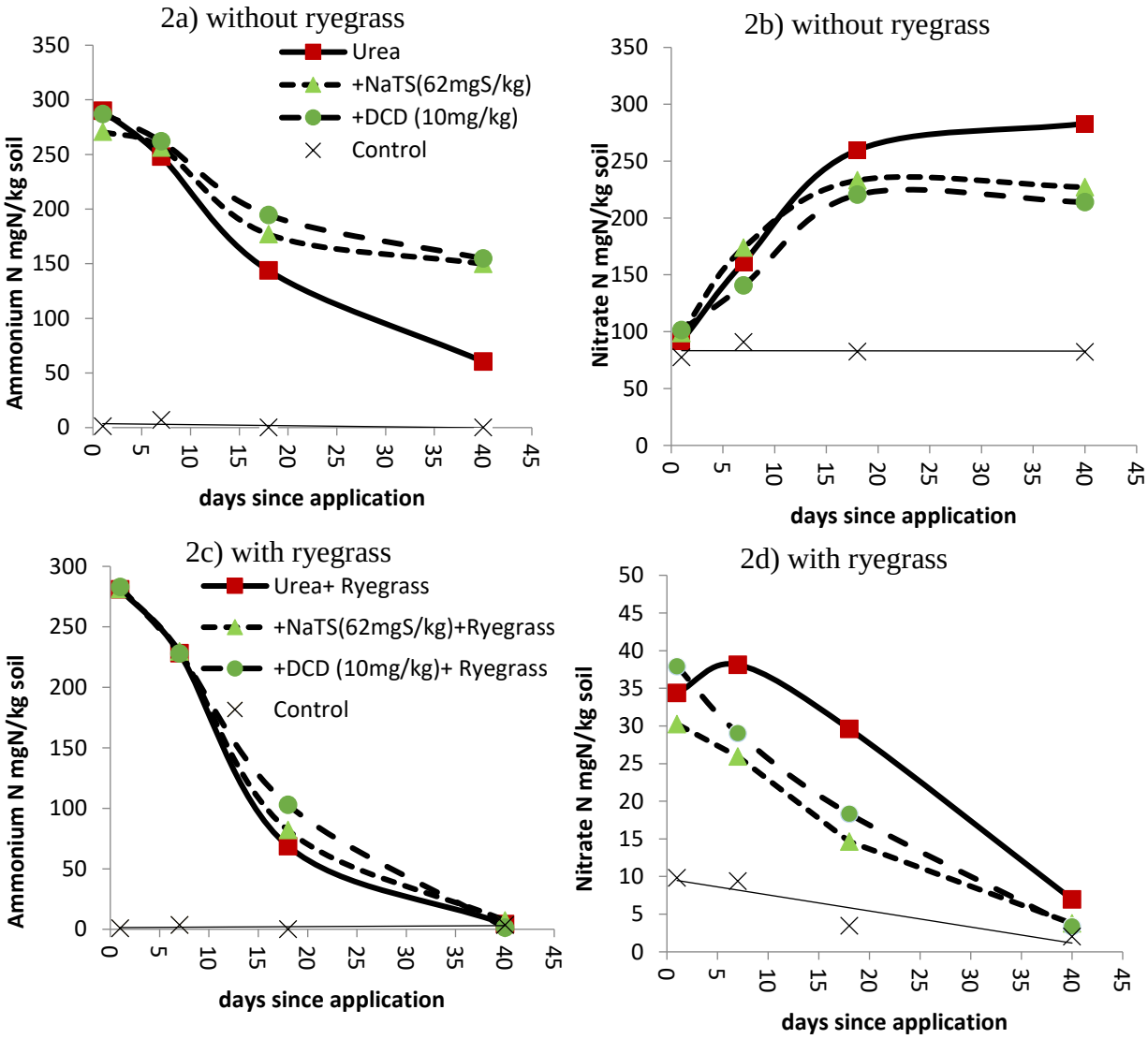

Figure 2 Effect of nitrification inhibitors DCD (10mgDCD/kg) and thiosulphate (NaTS 62 mgS/kg) on soil ammonium- N and nitrate-N transformations in rhizosphere incubations of urea solution added to Lismore silt loam at a rate of 300mgN/kg and incubated at 13°C with a 9 hr photoperiod at an intensity of 90 µmol $m^{-2}s^{-1}$, with and without ryegrass present.

The presence of the ryegrass in the rhizosphere incubations dominates the rates of decline of both ammonium and nitrate concentrations in the soil, resulting in no significant effect of the inhibitors on soil ammonium concentrations. However, the application of NaTS 62 showed a significant (P=0.1) reduction in soil nitrate N (Fig. 2d) compared to urea alone, from 29 to 14 mg NO_3-N /kg soil.

The major feature of the rhizosphere incubations is the removal of nitrate-N from the system by the ryegrass, amounting to 200mgNO_3-N /kg of soil in 18 days. This is consistent with autumn 2017 field trial results conducted at the site of soil collected for this study (not published), which showed a 50% uptake of applied urine N in 30 days.

Conclusion:

The rate of nitrification in soil is significantly reduced by the addition of NaTS at 62 mgS/kg soil (equivalent to 248 kg NaTS.$5H_2O$ /ha) and above. The high rate of application is likely to render whole pasture area treatments non-viable economically, but is within the application rates achievable with the Spikey® treatment system. The results from the rhizosphere incubations were greatly influenced by nitrate uptake, which increased apparent nitrification rates by 46%, and reduced accumulation of soil nitrate from 260 to 29 mg NO_3-N/kg soil in 18 days.

The surface application of NaTS at 62mg S/kg in rhizosphere incubations in the presence of ryegrass plants reduced soil nitrate levels by 50% compared to the untreated urea treatment at day 18 (P=0.1).

The surface application of NaTS at 62 mg S/kg in soil-only incubations was as effective as DCD at 10mg/kg, both reducing the nitrification rate by approximately 45%.

Trials 1 and 2 demonstrate the effectiveness of NaTS at appropriate application rates in incubation studies, both when mixed with the soil and under surface-application to rhizosphere soil in the presence of ryegrass plants.

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