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LOCATING AND TREATING FRESH COW URINE PATCHES WITH SPIKEY®;

THE PLATFORM FOR PRACTICAL AND COST-EFFECTIVE REDUCTION IN ENVIRONMENTAL N LOSSES

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Abstract

The Spikey® detection of fresh urine patches provides the platform for treating fresh cow urine patches to reduce losses of nitrogen (N) to the environment (Bates et al. 2015).

The technology platform provides the platform to amend the urine patch soil-pasture environment in a variety of ways. The first method developed is spraying with ORUN®, a mix of the urease inhibitor nbpt and the growth promotant gibberellic acid (GA3). GA3 will reduce N losses *provided* conditions are suitable for a pasture growth response to GA3.

DCD, if applied to urine patches only, and only shortly after grazing, is much less likely to result in DCD residues in milk. A combination of DCD plus nbpt has been shown to be very effective in reducing both nitrate and N_2O losses (Zaman et al. 2008, 2009).

These studies found that on some dairying soils, nitrate concentrations are markedly attenuated below as little as 22.5 cm, presumably through either denitrification or co-denitrification, particularly where a clay layer is present. The size of these reductions indicate that this denitrification may be equally important to denitrification in the vadose zone or in shallow groundwater, in the attenuation of nitrate-N levels.

While denitrification reduces nitrate leaching, it's overall benefit depends on whether it is going all the way through to N_2 production, or is leading to greater losses of N_2O. In situations where undesirably high losses of N_2O are occurring, Spikey® permits the targeted application of products to reduce this, such as sources of readily mineralisable carbon.

Recent studies have provided confirmation that the co-denitrification process, the reaction of NO species (produced from urea-sourced NH_4^+) with soil amides, is a major source of economic N loss as N_2 from urine patches (Selbie et al. 2015). These authors also reported that these losses can be reduced with DCD.

Regardless of the source of N losses, increased focus needs to be placed on increasing plant N recovery from urine. The Spikey® technology provides the platform to achieve this.

Introduction

- Dairy products produced under grazing are increasingly being preferred in developed markets.
- However, a practical, cost-effective solution to the urine patch 'problem' is essential
- Spikey® provides the means to *detect* the fresh patches, so that they can be treated *before* significant N losses occur.
- The most urgent objectives with urine patch treatment are (i) to reduce nitrate leaching and increase pasture production, as cost-effectively as possible, and (ii) to learn more about natural attenuation of nitrate under urine patches, and the processes driving this.

Part 1. Treatment of the fresh urine patch

The ORUN® approach

ORUN® was developed by Advanced Agricultural Additives Ltd, ORUN® combines nbpt and gibberellic acid. The nbpt, by being applied within 2 days of urine deposition, inhibits the conversion of urea in urine to ammonium-N for 5-7 days. This period is ample to allow lateral movement of the urea, significantly increasing the size, DM growth and N uptake of the urine patch (Bishop & Quin, 2010). The gibberellic acid component promotes growth and N uptake, but only in situations where plant energy supply is adequate.

Previous work (Bates et al. 2015) demonstrated that pasture growth and N uptake from spring-applied urine were increased by 70% with ORUN®, a mix of the urease inhibitor nbpt and growth promotant.

Results

This paper presents data from autumn trials including (a) 3 trials on commercial dairy farms (in which very recent urine patches were detected with Spikey®), and (b) a trial at Massey University in which cow urine and ORUN® were hand applied.

In the Spikey® trials, DM growth in $1m^2$ quadrates surrounding 12 matched pairs of actual fresh urine patches (<3m apart, with and without ORUN®) were measured on commercial dairy farms near Gore (Southland), Rakaia (mid-Canterbury), and Morrinsville (Waikato), over the period mid-late April until early June 2015. All 3 sites were ryegrass dominant. The DM growth over this period, *vs* nil-urine controls, are shown in this period (Table 1). Also shown are the 'likely consumable' quantities, calculated by deducting a residual DM of 1200 kgDM/ha.

The results (Table 1) show considerable increases in urine patch growth (kg DM/ha basis), with a 66% increase in 'consumable DM' (ie, above 1200 kg DM/ha residual). Analysis of %N content showed no significant differences between ORUN® and no-ORUN® at any site (data not presented). Fig. 1 compares the average of these results to that of spring-applied urine.

Table 1. Urine patch DM over 6 weeks from mid-autumn to early winter 2015

	Southland	Canterbury	Waikato	ave.	**Massey**
Control (no urine)	**1732**	**2025**	**2388**	**2048**	**1338**
DM above 1200 residual	*532*	*825*	*1188*	*848*	*118*
Urine only	**2111**	**2717**	**3332**	**2720**	**1535**
Increase over control	*379*	*692*	*944*	*672*	*197*
DM above 1200 residual	*911*	*1517*	*2132*	*1520*	*335*
Urine plus ORUN®	**2763**	**3160**	**3686**	**3203**	**1756**
Increase over control	*1031*	*1135*	*1298*	*1155*	*418*
DM above 1200 residual	*1563*	*1960*	*2486*	*2003*	*556*
Increase over Urine only	*652*	*443*	*354*	*483*	*221*
% incr over 'Urine only' incr	*(172)*	*(64)*	*(37)*	*(71)*	*(112)*
LSD (5%) kg DM/ha	169	301	247	210	-

The far right-hand column in Table 1 shows results from cow urine with and without ORUN® applied to a poor-species pasture set-stocked with sheep at Massey University. Although the low late-autumn N-responsiveness of the pasture at this site is evident, the increase in urine-patch DM with ORUN® (418kg DM/ha) was double that without (197 kg DM/ha). Soil nitrate-N in the 0-150 cm soil depth under urine patches at the end of the Massey trial was reduced 24% with ORUN®, from 83.6 to 64.1 kg N/ha, and the increase in plant N uptake was 50% more than the increase with urine alone. Fig. 1 compares N uptakes from spring (Bates et al 2015) and autumn (this study) urine patches, with and without ORUN®.

Separate studies demonstrated that the major effect of ORUN® was usually coming from the nbpt component (unpublished). The efficacy of GA3 on pasture has been shown by many to very dependent on a range of factors, particularly air temperature, minimum leaf mass, and plant energy levels. It can greatly stimulate pasture growth even in the presence of high soil mineral N in the right conditions, and for this reason and its low cost it is included in ORUN®. Our studies showed that the likelihood of a GA3 response was greatly diminished by application to freshly cut pasture with less than 1500 kg DM/ha present, as was likely to have been the case in the lysimeter studies reported by Woods et al. (2016). As GA3 acts only through leaf uptake, it is logical that there must be a certain critical DM mass present.

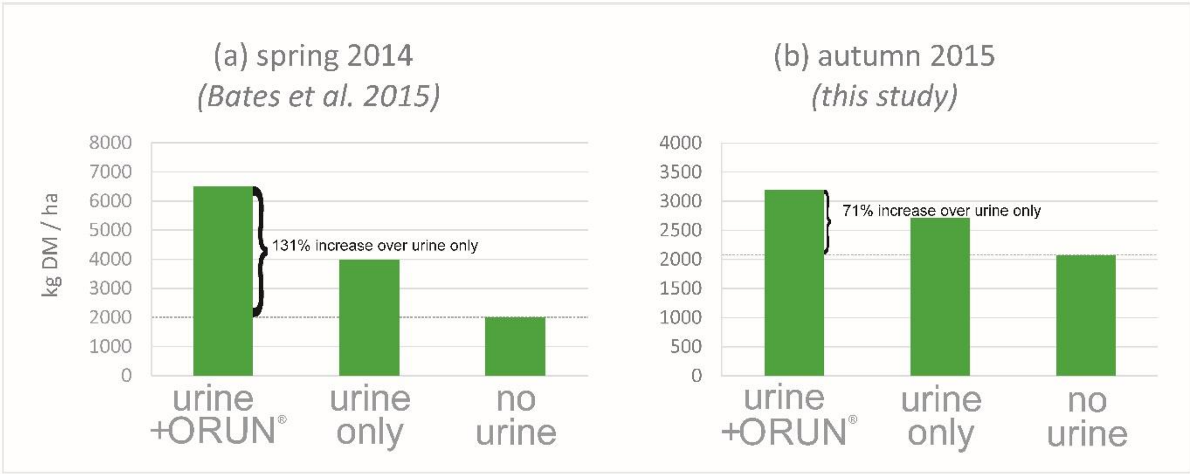


Fig 1. Comparison of pasture growth from urine deposition with and without ORUN®'.

Addition of a mineralisable source of polymeric organic carbon (AlpHa®) to ORUN® (ORUN® PLUS) in the Massey trial was required to produce a reduction in nitrous oxide emission in this autumn trial, in contrast to the summer trial (Bates et al. 2015). The presence of AlpHa® also reduced the amount of nitrate remaining in the soil profile. The fact that pasture growth and N uptake were not increased in the presence of AlpHa® however suggested that the reduction in nitrate must have been a result of either denitrification or co-denitrification.

Residue issues. There are no milk residue issues when nbpt is applied at low rates to fresh urine patches only, given the minimum 20-day grazing interval and extremely low rates of nbpt/ha. Nbpt has only ever been traced in milk, when it was physically mixed with feed immediately before consumption (even then at concentrations in the low ppb range). It has not been detected in milk in any grazed situation involving a 20-day grazing interval, even when applied to the entire pasture (report prepared for MPI by Global Sustainable Farming Ltd).

Economics. The entire equipment and running costs of Spikey® and ORUN® treatment are now calculated to be more than covered by the increase in pasture growth achieved and the savings in fertiliser N required (source: Pastoral Robotics Ltd, 2016).

The DCD option

DCD has been voluntarily withdrawn from the NZ dairy market until there is sufficient evidence regarding what levels of DCD in milk are safe for human consumption. The use of DCD is likely be far safer if applied only to fresh urine patches, given (i) the minimum 20-day interval before the next grazing, and (ii) the very low application rates per hectare required.

DCD plus nbpt

Work by Zaman, Nguyen, Sagger and others have demonstrated that the combination of the 2 inhibitors is more effective in reducing nitrate and nitrous oxide than either DCD or nbpt alone from urine patches, without increasing ammonia volatilisation as DCD alone does (Zaman et al. 2008, 2009). Their studies did not include a combination of nbpt plus GA3, nor did they assess the effect of nbpt in increasing the size of the urine patch.

Part 2. Some observations on the effects of clay and buried 'A' horizons on nitrate leaching

The above sites provided the opportunity to look at the effects of the presence of 3 differing soil physical aspects of relevance to attenuation of nitrate through denitrification and/or co-denitrification:

Site 1 (Southland) – continuous clay subsoil below 25-35 cm, medium water-holding capacity.

Site 2 (Canterbury) – shallow stoney free-draining soil, low water-holding capacity.

Site 3 (Waikato) – deep, high organic matter soil with non-continuous buried A horizon at 30-45 cm, high water holding capacity.

Results

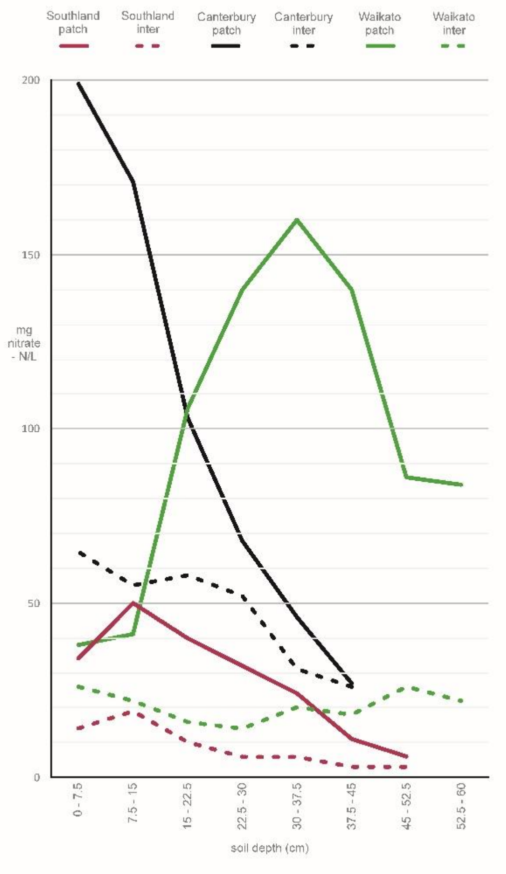
Although soil nitrate-N levels under individual urine patches were too variable to allow comparison of ORUN® and non-ORUN® treated urine patches, they did allow comparison of soil nitrate levels under urine patches deposited in mid-late Autumn with nitrate levels in areas of the pasture showing 'background' levels of pasture production, and therefore assumed to not have had recent urine deposition.

The 3 sites had all received at least 150 mm rainfall since the last urine deposition; all were at maximum water holding capacity. The nitrate remaining in these soil profiles could therefore be assumed to be at high risk of leaching unless denitrification took place prior to further leaching. In virtually all cases, soil ammonium-N levels (not reported here) were below 10 ppm (soil dryweight basis).

Fig. 2 shows the change in nitrate-N levels with depth, expressed as mg nitrate-N / L (ppm) in the soil water, for the 3 sites. Dotted lines are nitrate-N levels under recent (6 week) urine patches; dashed lines are those under pasture areas indicating no N response (and therefore unlikely to have received urine deposition in the last 3 months).

At Site 1, peak nitrate-N levels were lower than in the two other sites. They were highest in the 7.5-15 cm layer both under urine patches and in inter-urine areas (Fig.2), despite the site having received 200 mm rainfall in the 2 weeks prior to sampling. Nitrate levels were 2-3 times higher under urine patches than under inter-urine areas at any one depth. Average levels under both declined to 6ppm or less by the 45-52.5 cm depth. The relatively low nitrate levels under urine patches, and the rapid attenuation of nitrate to low concentrations below 37 cm is indicative of active denitrification and/or co-denitrification in this soil, probably due to the presence of the low oxygen-content clay.

Fig 2. Changes in nitrate in soil water with depth



At Site 2, nitrate-N peaked at a very high level off 199 ppm in the 0-7.5 cm layer under urine patches, and declined rapidly from there (Fig.2). The peak of 58 ppm in inter-urine areas occured in the 7.5-15 cm layer, then declined steadily. This situation, given the high rainfall in the trial period, suggests that nitrification of ammonium-N was slow on this soil, probably due to low soil organic matter levels combined with low soil temperatures (5^0C). Denitrification and/or co-denitrification may also be higher than assumed.

At Site 3, changes in nitrate-N levels were more complex. Under urine patches, levels steadily increased until a peak of 160 ppm in the 30-37.5 cm depth, then declined (Fig. 2). In inter-urine areas however, levels were relatively consistent with depth, except near the buried 'A' horizon, most typically at 22.5-30 cm, where slightly lower levels occurred. The data indicates relatively little denitrification overall in this well-aerated soil; the peak in nitrate levels under urine patches at 30-37 cm probably reflects drainage movement since the last grazing (to be modelled) using daily rainfall data).

Conclusions

In conclusion, the studies reported here indicate that the optimum method for reducing nitrate-N leaching losses in autumn, from urine patches in particular, is likely to vary between soil types.

In some soils, particularly those with restricted drainage and/or active denitrifier populations, denitrification of urine-derived nitrate in the soil itself may be more important that groundwater nitrate denitrification in attenuating nitrate deliveries to lakes.

It is known that losses of nitrate and nitrous oxide from cow urine patches need to be reduced, mainly because of the harm they bring to the environment. Co-denitrification of urine-N, while not environmentally harmful, can represent huge economic losses (Selbie et al. 2015). This is particularly true in low clover content, fertiliser-N dependent pastures. In these conditions, we believe that co-denitrification could be causing net reductions in total soil N over time.

The treatment of autumn-applied fresh urine patches with ORUN® has been shown to increase urine patch pasture growth and N uptake. Although the increases were less than those obtained in spring, they were nevertheless very worthwhile.

Initial work with the polymeric mineralisable carbon source AlpHa® added to ORUN® (ORUN®PLUS) indicate that it can considerably reduce autumn nitrate leaching and N_2O losses compared to ORUN® alone, although this may be at the expense of some growth response on some soil types, perhaps those with high urease activity levels.

Ideally, the primary objective should be to increase recovery of urine-N by the pasture, as this will automatically reduce nitrate leaching losses. Logically, the best way to do this is to maximise the area of pasture that can access urine-N by first locating *fresh* urine patches, then treating them with the optimum products for the soil type.

ORUN® is the first treatment available for this purpose. Others are bound to follow. The first commercially-sized pre-production Spikey (Spikey®2) has now been built and is being demonstrated on dairy farms (Fig. 3).

Fig.3. The first commercially-sized pre-production Spikey®2 (minus the foldable/removable side modules) being demonstrated on a Landcorp dairy farm near Wairakei.

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