# LOW-COST DETECTION AND TREATMENT OF FRESH COW URINE PATCHES

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**Abstract**
Leaching of nitrate-nitrogen ($NO_3$-N) from cow urine patches is the most serious threat facing the future viability – environmental and possibly economic – of grazed dairy farms in New Zealand. Proposed solutions to this problem have largely focussed on changing the fundamental basis of the NZ year-round grazing model to one extent or another, all requiring increased capital expenditure on and maintenance of housing or stand-off pads, and capital and running costs on collecting and distribution of manure.

Solutions that permit full-time grazing are largely focussed on means of better matching the energy and protein ratio of the feed to the cow's intake requirements, such as by different plant species, or mixes of crops and pasture. All these will require much research, and new skills to be learnt by the farmer.

Previous published attempts to reduce losses from the actual urine patch include (i) the Taurine® tail-activated N-inhibitor dispensing device (a work in progress), and (ii) sensing where urine patches are likely to be with chlorophyll level assessment in pasture. However, by the time significantly greater growth can be assessed, most of the urine-N is already present as nitrate.

This paper describes the development – to the farm-tested working prototype stage – of relatively inexpensive and easily manufactured vehicle-towed equipment which uses the measurement of surface-soil electrical conductivity to detect fresh urine patches with very high accuracy (Spikey®, patent application 617342). The equipment simultaneously sprays the urine patch with ORUN®, a mix of the commonly used urease inhibitor NBPT and gibberellic acid (GA3), and where more dissolved organic carbon (DOC) is required, the dicarboxylate polymer AlpHa® as well (patent applied for). This mix is assessed as being is at least as effective in reducing nitrate leaching as DCD (now removed from the New Zealand market).

In the future, it is intended that a robotised vehicle (Mini-ME™) will tow the equipment, releasing farm labour.

In addition to substantial extra grass growth and N recovery of pasture, achievable at relatively low cost of implementation, initial results indicate potential reductions in both nitrate leaching and nitrous oxide volatilisation of at least 30%.

## Introduction

To substantially reduce nitrate leaching and emissions of ammonia and nitrous oxide from urine patches in a practical fashion, while maintaining a full grazing system required the authors to address three challenges:

(1) How to detect and localise the urine patches, and before significant transformation of the urine-urea had occurred;

(2) Selection of methods of moving the detection equipment over the area of interest.

(3) What to treat the fresh urine patches with, and how.

This paper presents the approach taken to address these challenges, and the outcomes.

### *Detection and localisation of the urine patches*

Early experiments into the detection of the urine patches investigated fluorescence, temperature variation and grass response but none of these techniques yielded a practical system that could be applied soon after deposition of the urine but did not require immediate application. The most easily identifiable traces of urine deposition were found to be a changes in soil moisture and conductivity. It was realised that significant gains were to be made if the development lead to a system that could be implemented in conjunction with follow on application of urea, particularly the wetted prilled urea-based technology ONE*system*® (Quin *et al.* 2015).

The urine detection and treatment system specification developed was for a system capable of searching a typical paddock immediately after grazing, in the typical rotational grazing system used in pastoral dairy farming. Paddock searching could be achieved in conjunction with fertiliser application (where part or all of the paddock is covered). The ideal system was envisaged as being used daily on the area grazed that day would be once a day (that is, a requirement for detection up to 24 hours after urine deposition). However it was considered that even a maximum detection period of only 10 hours after deposition would allow the system to be deployed after every milking on the most common twice a day milking dairy system.

Early investigation showed surface conductivity measurement worked best in moist soil conditions and was severely limited in drier soils. In dry conditions, poor electrical contact restricted the current flow measurements to levels close the minimum resolution of the system, leading to erroneous measurements. Further experimentation lead to a method where both the contact resistance and the soil conductivity influence the measurement. The results presented here are based on this technique.

The prototype used for the data collected (Fig. 1) had a total of 7 measurement cells. This number is not limiting, and future longer iterations (modules) and compound iterations (multiple modules) are planned. Development is currently underway of a 6-metre arrangement consisting of three 2-metre modules that are designed to be towed behind a farm vehicle. The outside modules would fold upwards for passing through gateways. A single 2-metre module would be suitable for towing behind a small robotic vehicle, as discussed later.

**Figure 1.** Spikey®, named after the appearance of the contact disks.

The experimental technique developed to evaluate the performance of Spikey® under varying soil and soil-moisture conditions involves topping and raking a section of pasture that has not been grazed for at least 20 days. The topping/raking is undertaken to remove excess pasture, as is the case after grazing. Urine collected from cows or occasionally synthetic urine (formula urea 273 g, glycine 67.5 g, $K_2CO_3$ 326.2 g, $K_2SO_4$ 32.2 g, KCl 127.2 g, made up to 20 L in water) was then deposited at a fixed spacing at various times during the test period and marked with stakes and paint. At the test time Spikey® is towed over the urine patches, typically at 8 to 12 km/h. Some testing was undertaken at 4 and 16 km/h. When Spikey® is being tested, a mark is inserted by the driver of the tow vehicle in an extra channel of the data to indicate the location of the urine patch, thereby assisting data analysis.

The following figures include the raw data from the 7 sensing cells and the urine patch indicators which are the blue marks with sub-zero values.

Fig. 2 shows the data for very dry soil with a damp surface; 2 mm of rainfall occurred during the testing, following more than a month without rain. Three urine samples were placed at 3 different times during the day. The three samples placed consisted of fresh cow urine (collected that morning), old urine (collected 2 weeks prior) and synthetic urine. It is noted that every urine patch except one can be clearly detected by visual analysis of the data; the one just after the 15 second mark was less obvious. Some other data spikes are present. These are due to localised high conductivity effects, most commonly dung pats.

Fig. 3 shows the same urine patches detected 24 hours later (32 hours after the first deposition). It can be seen that all the patches are still clearly defined. The non-urine patch sourced spikes (most as mentioned could be observed to be due to dung pats) tended to be physically much smaller than the urine patches, and could be isolated by their relative size. This is evident in Fig. 4, where the spike caused by a non-urine patch was only evident in one channel of data, whereas the urine patches caused 2 or more multiple channels to be activated. However, even with the differentiation possible through channel comparison, there is likely be a small percentage of false positive responses. This not considered to be important. If required, the choice could be provided to deliberately include detection and treatment of cow pats, which themselves are a source of N losses, albeit a less serious one than urine patches.

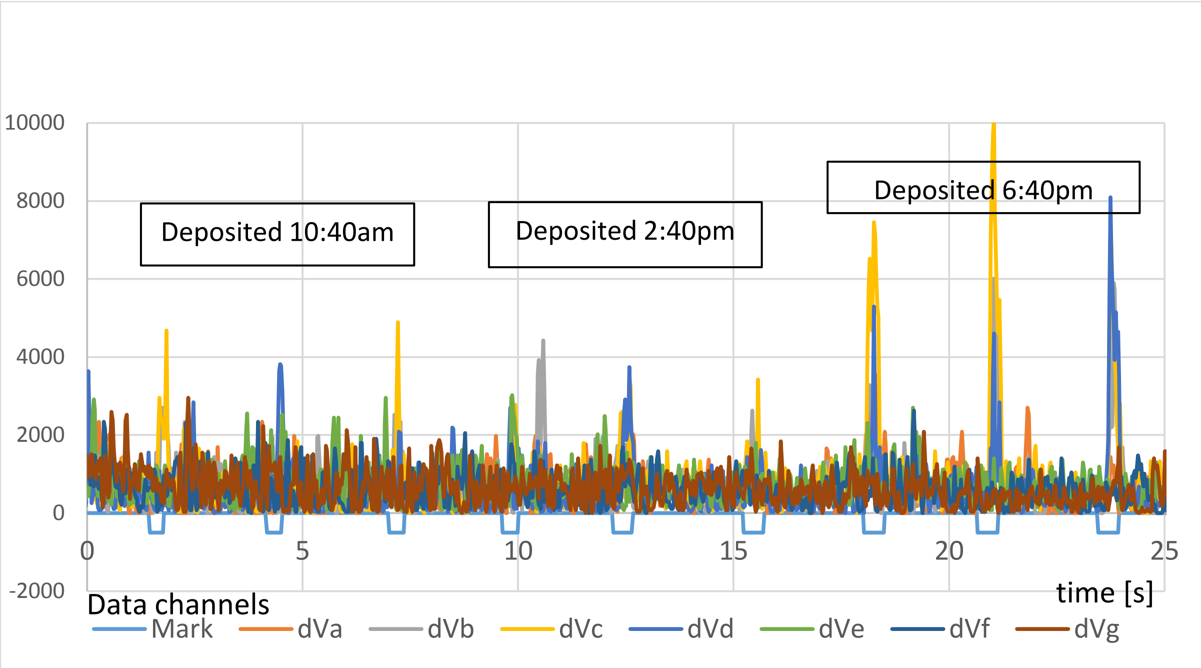


**Figure 2.** Detection of urine patches placed at various times during the day and detected at 7pm that day, dry soil, damp surface. Blue marks below zero indicate the placement of a urine patch.

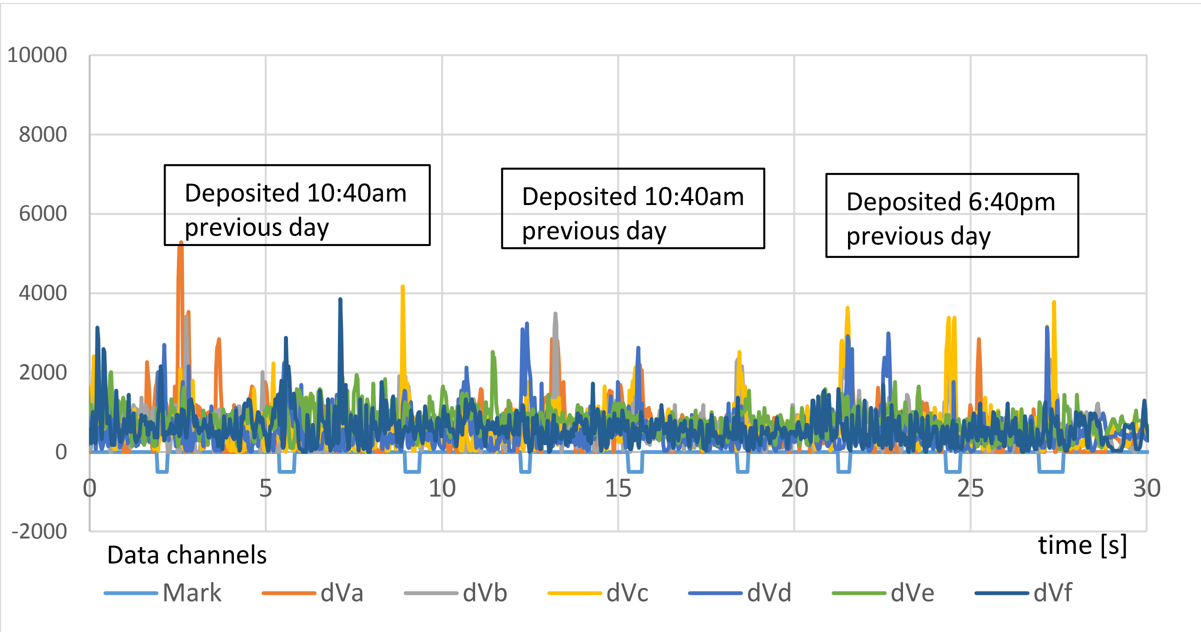


**Figure 3.** Detection of urine patches placed at various times during the preceding day (same patches as in Figure 2) and detected at 6:20pm, dry soil, damp surface.

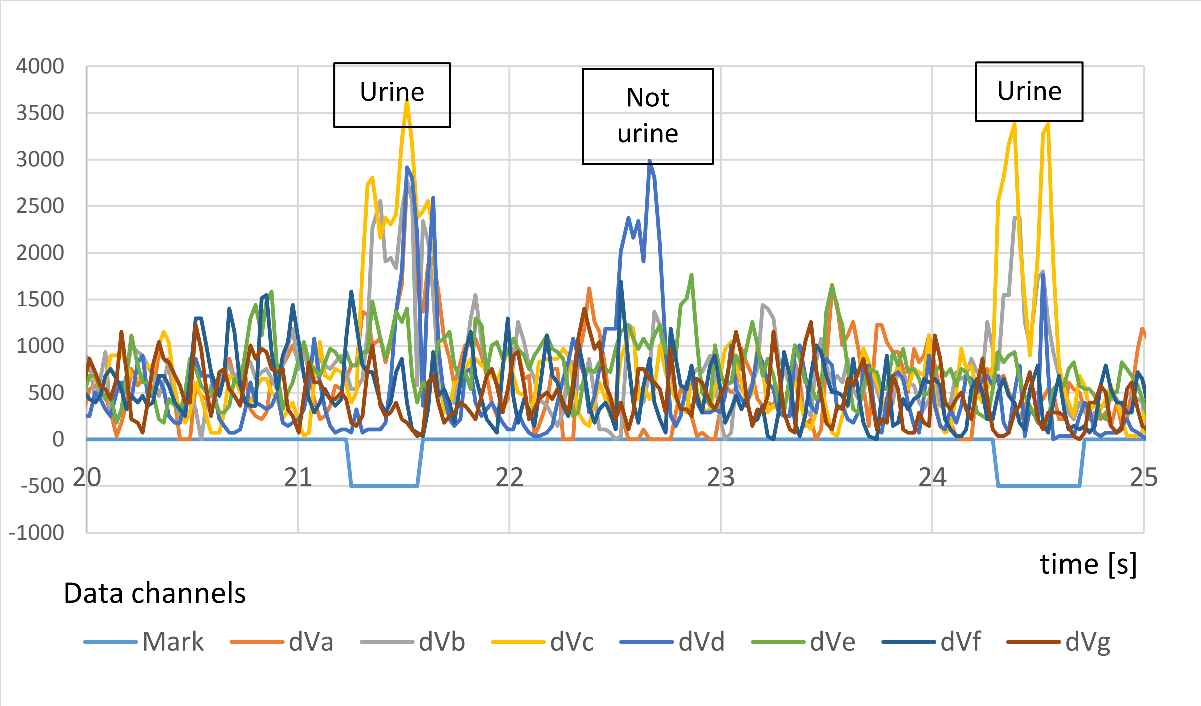


**Figure 4.** Comparison of response to urine and dung patches, dry soil, damp surface.
The signal amplitude is increased with moist soil, as can be seen in Fig. 5, where the data was collected in late spring before this summer's drought had started.

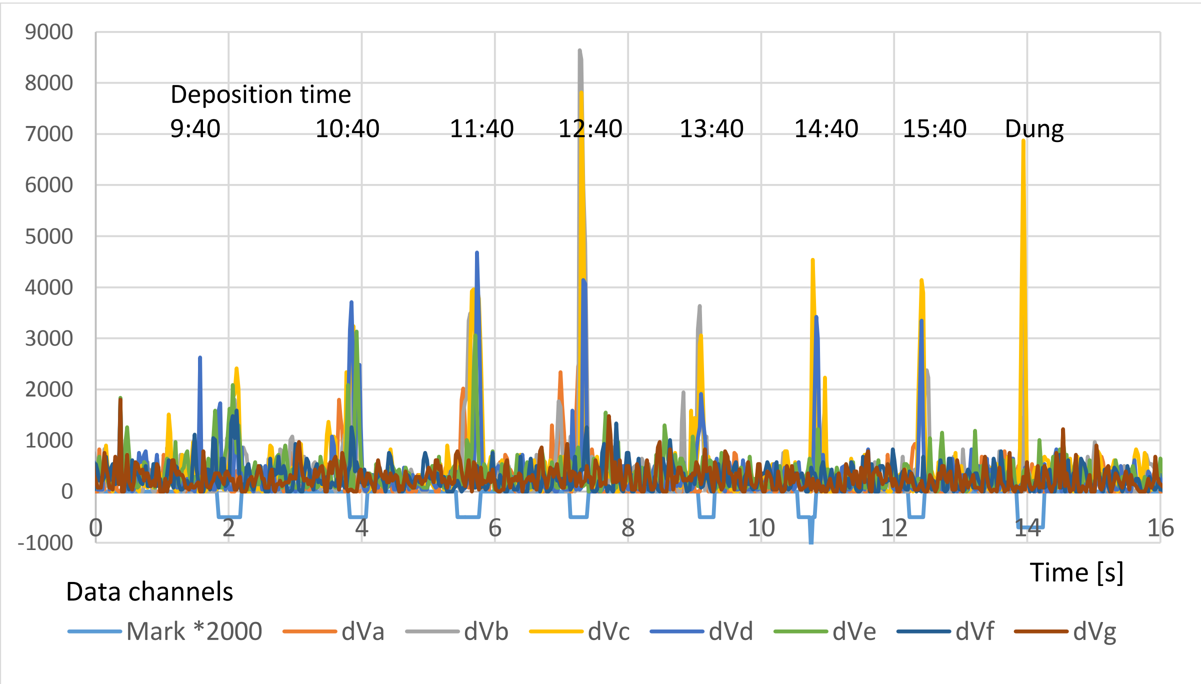


**Figure 5.** Urine patch detection in moist soil (South Auckland late November) with one dung patch placed at the end of testing. Data taken on the same day as deposition at 5 pm.

The converse of this is that the signal is much smaller in dry soil (Fig. 6). However, the background noise is also reduced, avoiding any reduction in urine-patch detectability.

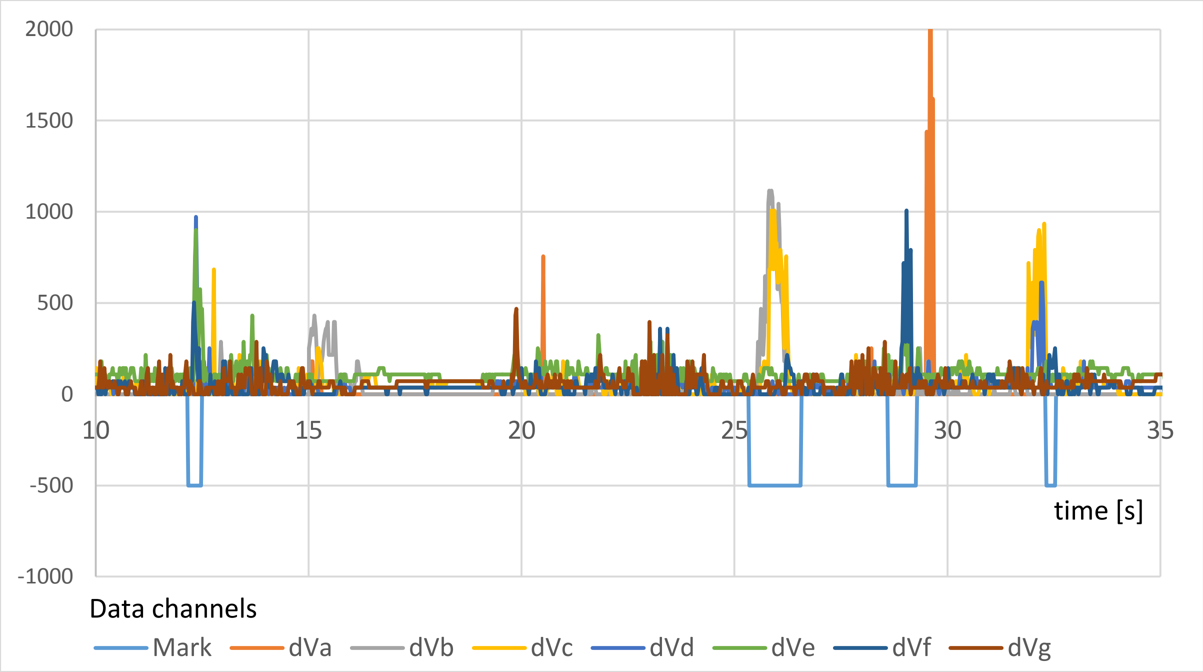


**Figure 6.** Urine patch detection in dry soil, data collected 2 hours after placement.

***Methods of moving the equipment to detect and treat the urine patches over the area of interest***

Two practical methods of moving the sensing system over the freshly grazed paddock have been implemented The first involves the use of a farm vehicle such as the quad bike, as shown in Fig. 7, similar to that used in the FLRC demonstration on Massey University No. 4 Dairy Research Farm. Tow behind configurations of Spikey® are now able to be supplied for research applications.

The second method, also demonstrated at the research farm, involves the use of a small autonomous farm vehicle or robot, as shown in Fig. 8. This robot, referred to as Mini-ME®, uses differential GPS to follow a pre-defined path in an accurate, repeatable and auditable manner.

**Figure 7.** Spikey® being towed behind a farm vehicle.


**Figure 8.** The Mini-ME® autonomous robot towing Spikey®.

***Treatment of urine patches with ORUN® - Optimised Recovery of Urine N***

The objective of reducing nitrate leaching and ammonia nitrous oxide emissions, if successfully attained, leads directly to increased plant N uptake. This in turn increases pasture growth and farm productivity.

However, in the aftermath of the DCD/Eco-N® fiasco, it was considered vital to achieve this outcome using only accepted, widely-used chemicals; ones which were considered to be of very low toxicity, and furthermore that decomposed sufficiently rapidly in the soil to avoid any potential milk residue problems.

Granular fertiliser urea treated with nbpt (typically 0.2-0.5%) has been widely used on grazed dairy pastures in NZ (SustaiN®) and other countries since 2002, primarily to reduce ammonia volatilisation. However, it has also been shown to reduce nitrate leaching and increase pasture response to fertiliser urea (Zaman *et al.* 2005, 2008, Blennerhassett *et al.* 2007). The global mega-analysis conducted by Abalos *et al.* (2014) demonstrated that nbpt was more effective than DCD in improving plant N uptake from urea on acid soils.

The growth promotant gibberellic acid ($GA_s$) has been used widely on dairy pastures since the 1990s, typically at rates of 20 gm/ha $GA_3$ per application. It is proven to produce substantial increase in growth through cell elongation, particularly in cooler weather (Matthew *et al.* 2009, Ghani *et al.* 2014).

Finally, it is possible that the growth of pasture affected by urine application can become limited by the availability if dissolved organic carbon (DOC) in the root zone. The potential growth is very high, given the non-limiting supply of available N and the further stimulus provided by $GA_3$. Where DOC is a possible limitation to N uptake therefore, it was considered useful to include a source of organic carbon that would be decomposed into plant-available form over the typical 'lifespan' of a urine patch (1-3 months). The fulvic acid polymer Alpha® was selected for this purpose.

In due course therefore, the treatment mix of choice, described as ORUN®, was made up of the following 3 products and their rates-

- Urease inhibitor N-(n-butyl) thiophosphoric triamide (nbpt), applied at a rate of 2 kg/ha of urine patch area (approx. 45 mg/urine patch)
- Gibberellic acid (GA3) at 30 mg/ha (0.75 microgram/patch)
- Where needed, Alpha®, a source of dissolved organic carbon (DOC) at 15 L/ha (0.4 ml/patch).

The 3 products were dissolved in water at a dilution sufficient to apply 300 L/ha.

***ORUN® trial results and discussion***

Field trials with cow urine were conducted on a Manawatu mottled fine sandy loam loam at Massey University between June 2014 and February 2015. In the first trial (winter to early summer 2014), dry matter production and N uptake from urine-affected areas, and the movement of mineral N through the soil profile were investigated. In the second trial (summer 2014/15), nitrous oxide emissions were measured over a 5-week period, using static cylinder technology.

1. The nbpt component keeps the urine-urea in the urea form urea for longer, thereby delaying its conversion to ammonium and then nitrate. This gives the pasture more opportunity to recover these forms of N.

2. This increased period before the urine-urea is transformed allows more time for the urea to move laterally in the soil solution, thereby increasing the effective area of the urine patch, typically by 30%.

3. The $GA_3$ in ORUN greatly stimulates the already high pasture growth on the urine-affected patch area (by increasing cell elongation), and also on the increased area resulting from lateral diffusion of urea. It can be used year-round for this purpose as there is little overlap of patches from one grazing to the next, GA3 can be applied in this manner after every grazing.

4. These factors combined to increase pasture dry matter and N uptake in the total urine affected area by percentages that are at least comparable in magnitude to the increases obtainable with DCD (Figs 9 and 10).

5. As a consequence of additional pasture N uptake with urine+ORUN®, there was a reduction in soil nitrate below the root zone in the 40 to 70cm zone on Sep 30, from 25 kg N/ha to 15 kg N/ha, indicating a minimum 40% reduction in nitrate-N leaching.

6. Measurement of nitrous oxide greenhouse gas emission from urine-patches (Trial 2, conducted Dec 2014- Jan 2015) showed a reduction of approximately 30% with ORUN® treatment, as shown in Figs 11 and 12.

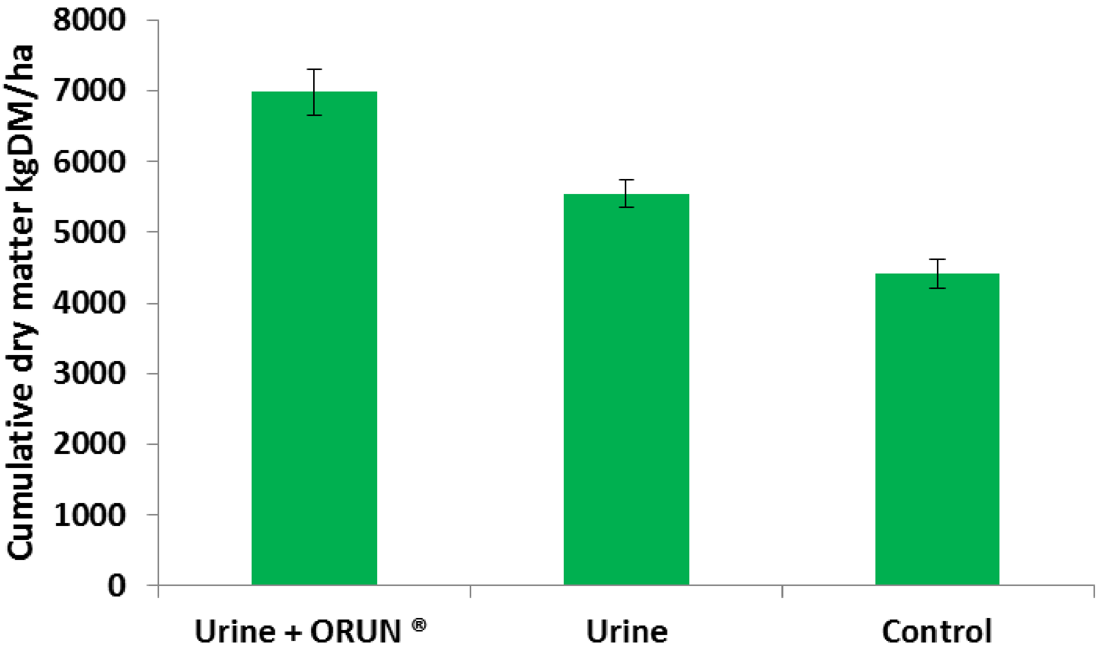


**Figure 9.** Cumulative dry matter comparison between non urine-treated pasture (control), urine-treated pasture, and urine+ORUN® - treated pasture.

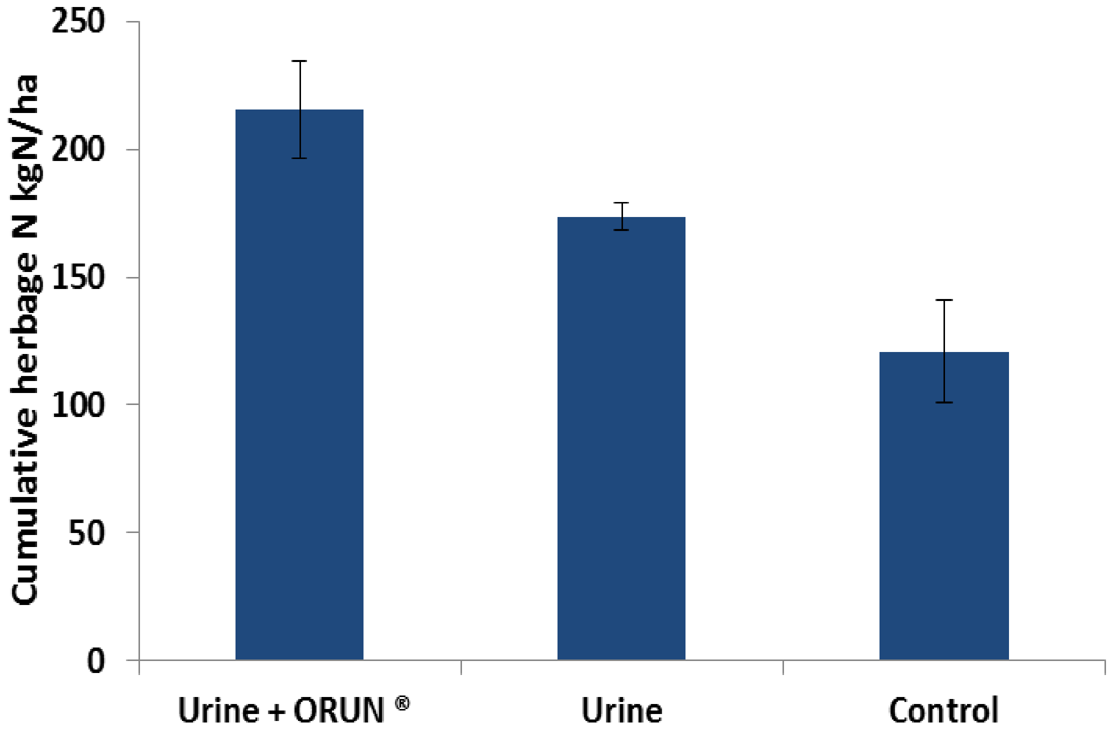


**Figure 10.** Cumulative herbage N uptake (kg N/ha) comparison between non urine-treated pasture (control), urine treated pasture, and urine+ORUN® treated pasture. Field trial conducted July – Dec 2014.

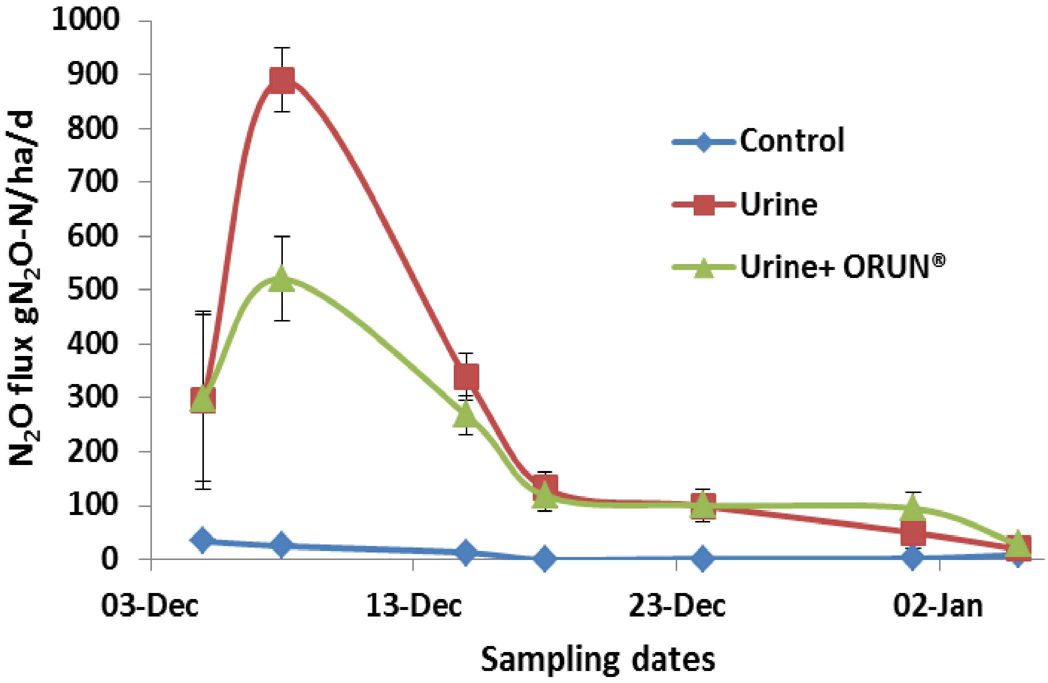


**Figure 11**. $N_2O$ flux comparison; control, urine and urine+ORUN®.

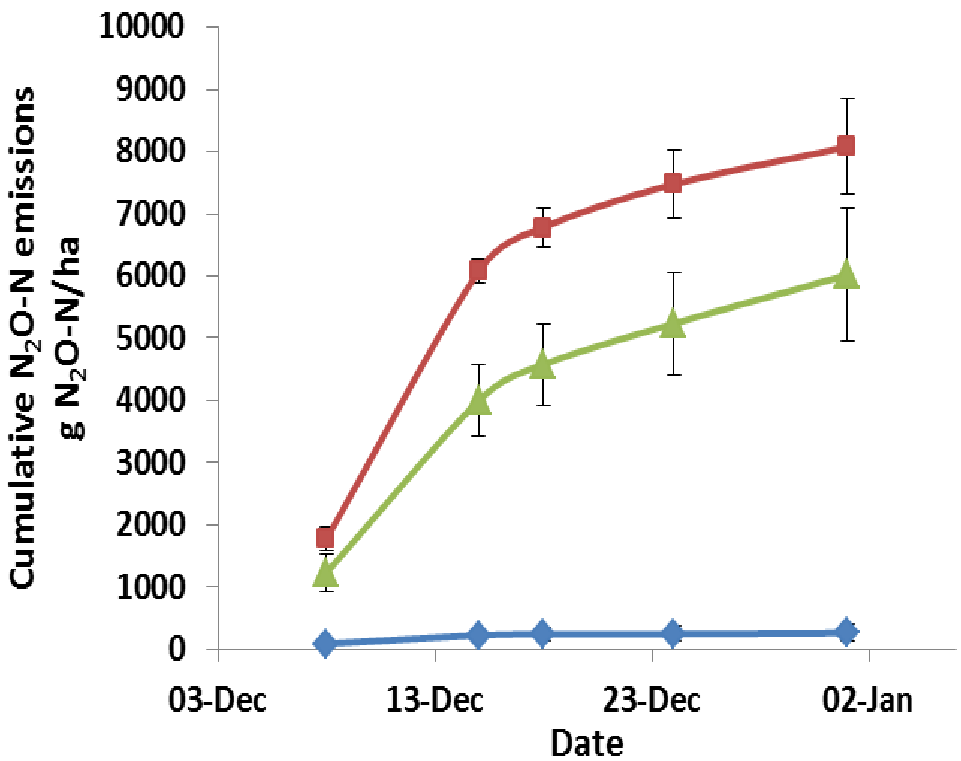


**Figure 12.** Cumulative $N_2O$ flux comparison between non urine treated pasture (control), urine treated pasture, and urine + ORUN treated pasture. Field trial conducted Dec 2014-Jan 2015.

## Conclusions

Treatment of urine-affected areas with ORUN® nbpt/$GA_3$/AlpHa® spray significantly increased urine-affected pasture response and N uptake; by 1.8 and 2.2 times the increases over the control attained by urine alone. The increased recovery of soil minera reducing both estimated nitrate leaching and measured nitrous oxide emission by at least 30% compared to non-treated urine patches. The authors are confident that refinements to the ratios and concentrations of the ingredients in ORUN® will bring about further reductions in N losses.

The methods of detection and treatment of urine patches developed in this research are practical to implement within existing farm systems and involve a relatively low investment of approximately $40,000 for a 3-module, 6 meter-wide Spikey® unit . It is estimated that this would require 45 minutes per day to tow the unit over the pasture grazed that day on a 150 ha dairy farm. The ORUN® cost of chemicals is estimated at less than $50/ha per year, allowing for 8 applications.

It is calculated that the increased utilisation of urine-N in extra DM produced would produce an additional 1.5% pasture growth per annum averaged over the entire farm. This would have an estimated positive contribution to farm earnings of approximately $8-10,000k per annum at a milksolids payout of $5/kgMS.

The one-off investment of $40,000 for Spikey ®, $7500 pa for ORUN®, and 200 hours labour per year ($4000 pa), less an $8-$10,000 pa increase in milksolids production, can be compared to an actual loss of annual earnings of $84k in 2013/2014 suffered by the 160 ha SIDDIC Dairy Research Farm at Lincoln as a result of reducing stocking rate sufficiently to achieve an Overseer® - calculated 10% reduction in nitrate leaching (Pellow 2015).

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***'Knowing is not enough; we must apply. Willing is not enough; we must do.'***

**Goethe**