

Clean and green with 'eco-n'

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Introduction

Lincoln University and Ravensdown Fertiliser Co-operative have developed a new soil treatment technology, called 'eco-n' technology, that can reduce the environmental impacts of dairy farming and at the same time help farmers to grow more grass.

Research shows that *eco-n* can:

- reduce nitrate leaching by 60 per cent
- reduce potassium, calcium and magnesium leaching by more than 50 per cent
- reduce nitrous oxide emissions (a potent greenhouse gas) by 80 per cent, and
- increase pasture production by over 10 - 12 per cent per year.

This paper will cover the science behind the *eco-n* technology and the practical application and economics of using *eco-n* technology.

Science behind eco-n technology

Nitrate leaching from dairy farming is a major environmental concern because a high nitrate concentration in drinking water is potentially harmful to humans and livestock, and elevated nitrate concentrations in surface waters may cause pollution which in turn affects fishing etc. (Cameron et al. 2002; Di & Cameron 2002a). It is now proven that in a grazed pasture system direct leaching losses of nitrate from applied fertiliser nitrogen (N), or farm dairy effluent (FDE), are relatively small compared to the large leaching losses that occur from animal urine patches (Scholefield et al. 1993; Di et al. 1998, 2002a; Silva et al. 1999; Ledgard et al. 1999; Di & Cameron 2002b; Monaghan et al. 2002). Because of the random distribution and irregular timing of cow urine returns it is very difficult to reduce nitrate leaching from animal urine patch areas compared with that from the fertiliser per se.

However, Di and Cameron (2002c, 2003, 2004a,b) recently reported a series of trials showing the effectiveness of treating grazed pasture soils, including animal urine patches, with a nitrification inhibitor (*eco-n*) to reduce nitrate leaching from a free-draining shallow stony

Lismore soil and a deep sandy Templeton soil. This work involved making direct measurements of nitrate leaching from large soil lysimeters.

The nitrification inhibitor slows the first stage of nitrification and reduces the rate that ammonium is converted into nitrate in the soil (Figure 1). Ammonium (NH_4^+) is adsorbed onto the negatively charged cation exchange sites on soil clays and organic matter, thus protecting it from leaching and allowing it to be taken up by plants or be immobilised into soil organic matter. However, nitrate (NO_3^-) is easily leached from the soil because it has a negative charge and is not held by the negative charged sites on the clay and organic matter. Therefore reducing the rate of conversion from ammonium to nitrate can help to retain more nitrogen in the soil for plant use.

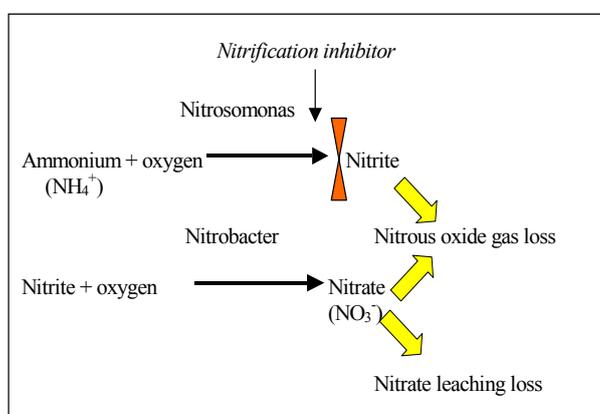


Figure 1. The nitrification inhibitor slows the rate of conversion of ammonium into nitrate in the soil and thus reduces the loss of nitrogen.

Nitrification inhibitors have been used in the past to increase the efficiency of N in fertilisers but until recently their potential to reduce nitrate leaching losses from grazed pasture systems had not been rigorously tested through direct measurements of leaching losses from lysimeters.

How many applications of *eco-n* are required?

Our initial research results showed that multiple applications of *eco-n* could reduce nitrate leaching by 60% (Di and Cameron, 2002c). Our more recent results show that reductions in nitrate leaching of 60% can be achieved with a single application of *eco-n* in the autumn (May) or two applications in the autumn plus spring (May plus August) (Figure 2).

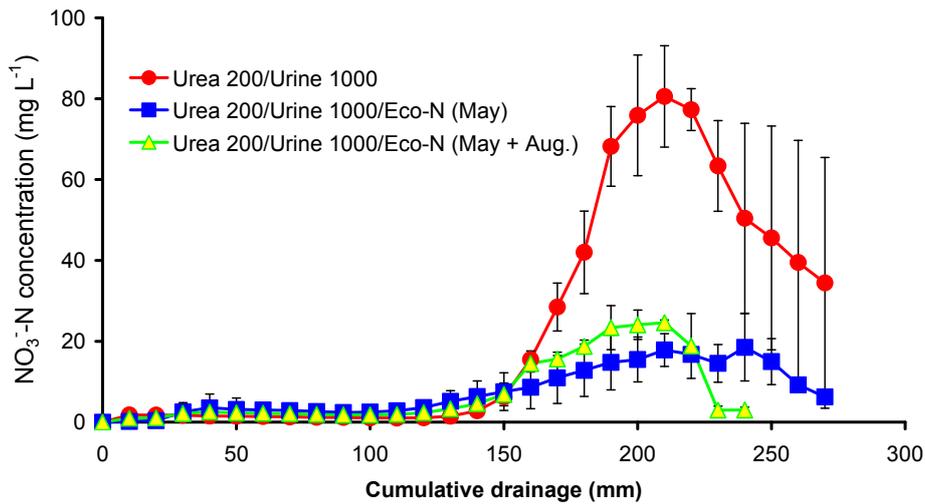


Figure 2. The effect of *eco-n* applied in May and May plus August on the nitrate concentration in drainage water from below cow urine patches applied in May (Templeton soil) (Di and Cameron, 2004b).

However under normal farming conditions we recommend two applications of *eco-n* to reduce nitrate leaching from both the winter and spring urine depositions. The effect of two applications of *eco-n*, one in May followed by one in August, on the amount of nitrate leached from a Templeton soil are shown in Figure 3. Both have significantly reduced the amount of nitrate leaching by over 60%.

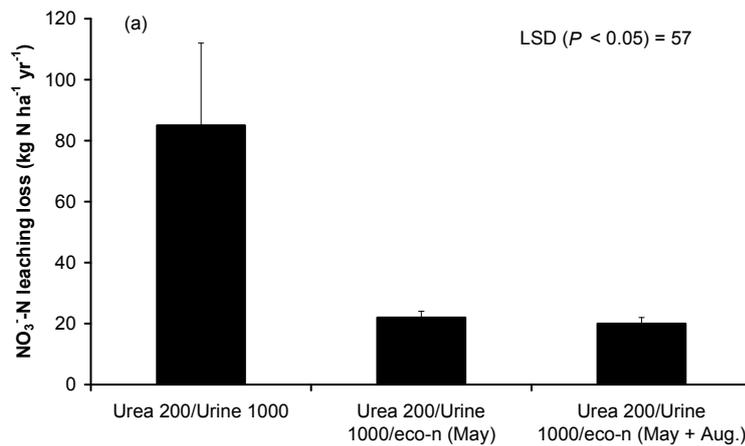


Figure 3. Total amount of nitrate leaching losses from large Templeton soil lysimeters following one application (May) and two applications (May and August) of *eco-n* (Di and Cameron, 2004b).

How long does *eco-n* last in the soil?

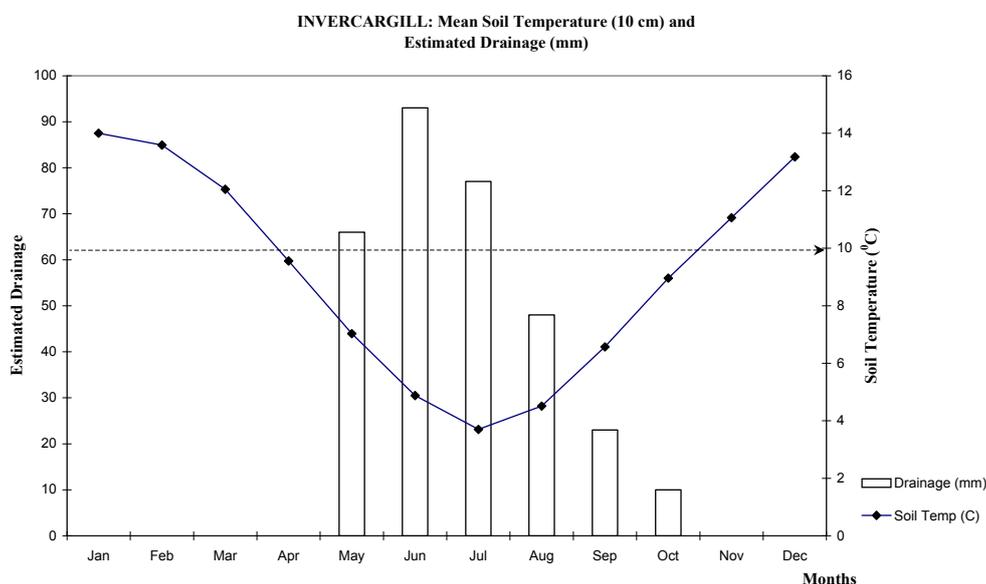
We have recently completed a detailed incubation experiment conducted under controlled temperature conditions to make direct measurements of how long *eco-n* will last in the soil (Di and Cameron, 2004c; Table 1).

Table 1. Half-life of *eco-n* in the soil at two soil temperatures

Treatments	Half-life (days)	% remaining after 25 days
Temperature of 8 °C	111	84 %
Temperature of 20 °C	25	50 %

The results in Table 1 show that at a soil temperature of 8°C the ‘half-life’ of *eco-n* was 111 days. (The ‘half-life’ of a substance is the time taken for the concentration of that substance to be reduced by half.) Thus a half-life of 111 days means that there will still be half the original concentration of *eco-n* remaining in the soil after this 3.5-month period. The rate that *eco-n* is decomposed in the soil is influenced by soil temperature and at a soil temperature of 20°C the half-life of *eco-n* was found to be 25 days. At 8°C the percentage of the applied *eco-n* remaining in the soil after 25 days is 84% and at 20°C the percentage remaining is 50%.

In Southland, coastal Otago and Canterbury, nitrate leaching mostly occurs during the main drainage period of the year (approximately June to September) when the soil temperatures are generally below 10°C (see Figure 4). During these winter months the *eco-n* is therefore likely to remain effective during this critical time of the year. The effectiveness of *eco-n* following a May application will be approximately 3 to 4 months (i.e. covering the critical drainage period from May to August). A subsequent application of *eco-n* in August will normally be effective for about another 2 months and will reduce leaching losses during the spring.



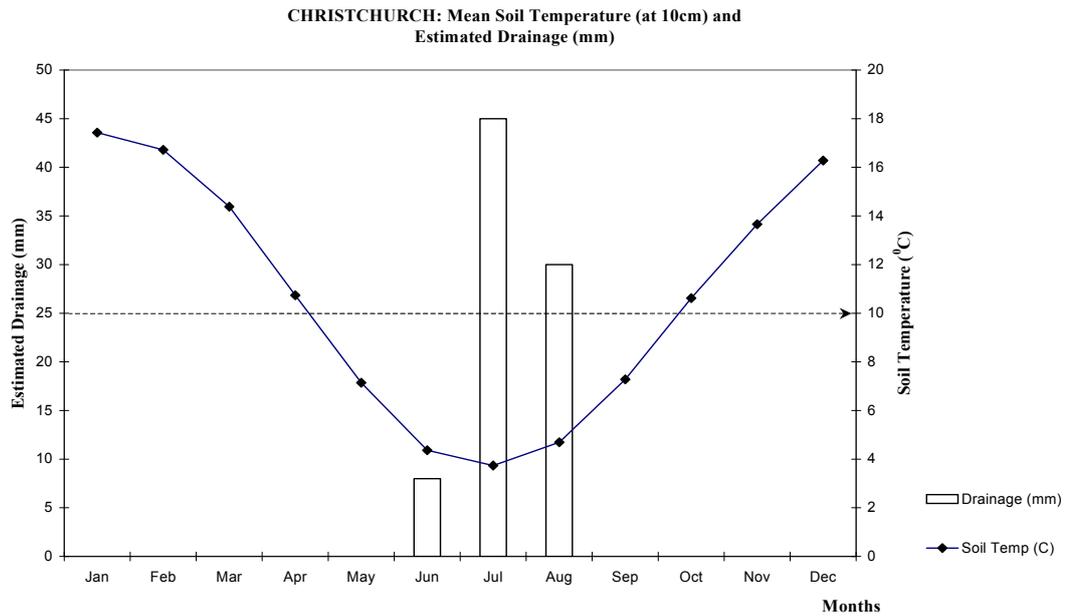


Figure 4. Long-term average mean monthly soil temperatures and estimated drainage in Southland and Canterbury (NB. actual drainage amounts will vary depending on soil type).

Measurements of the concentration of *eco-n* in field trial plots on the Lincoln University Dairy Farm have confirmed that 2 months after application in August the *eco-n* was still present at significant concentrations in the top 7.5 cm (Figure 5).

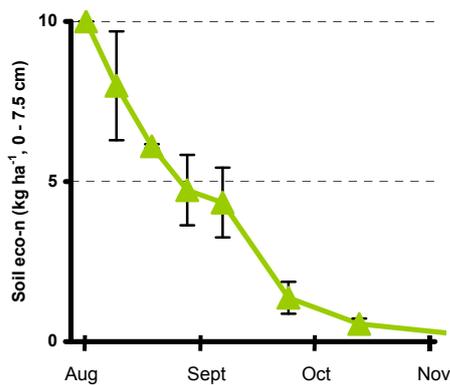


Figure 5. Soil *eco-n* concentrations following *eco-n* application in August.

How much time can elapse between *eco-n* application and urine deposition?

Our latest research results show that *eco-n* applied in May can still be effective in reducing nitrate leaching losses from urine deposited 2 months later in the month of July (Figure 6 and 7). This is possible because of the slow degradation rate of *eco-n* that occurs in soils during the winter (as discussed above) meaning that the deposition of urine at a later date can still be treated effectively by the *eco-n* remaining in the soil.

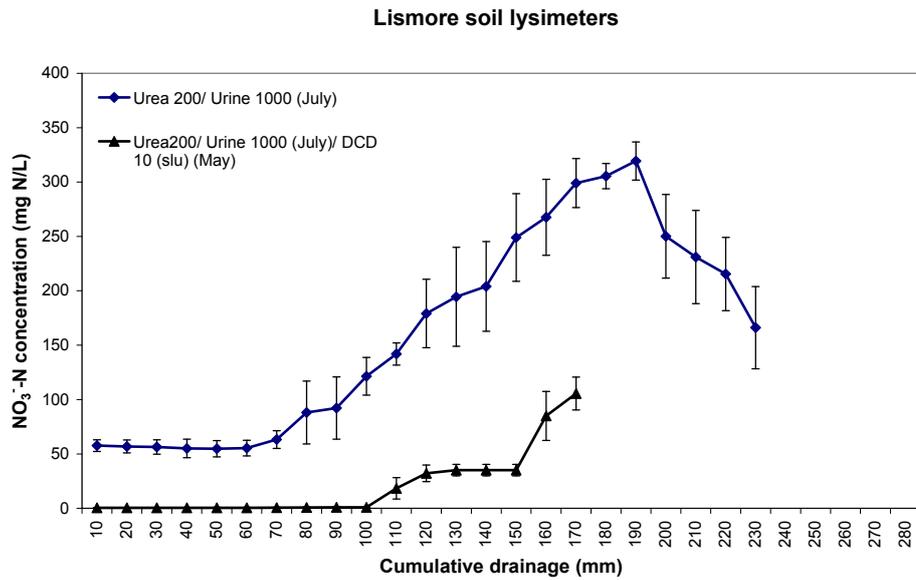


Figure 6. Effect on nitrate concentration of *eco-n* applied two months before urine application to Lismore soil lysimeters

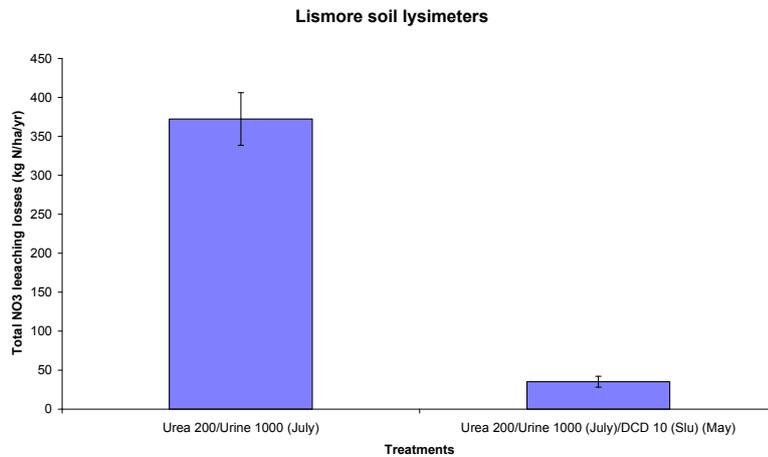


Figure 7. Effect of *eco-n* applied two months before urine on the total amount of nitrate leached from the Lismore soil lysimeters.

Can *eco-n* reduce leaching losses of potassium, calcium and magnesium?

Because nitrate leaching is usually accompanied by calcium, potassium and magnesium ions (i.e. ions with an opposite electrical charge), the leaching of these nutrients has also been found to have been reduced by applying *eco-n* (Di & Cameron 2004b: Figure 8)

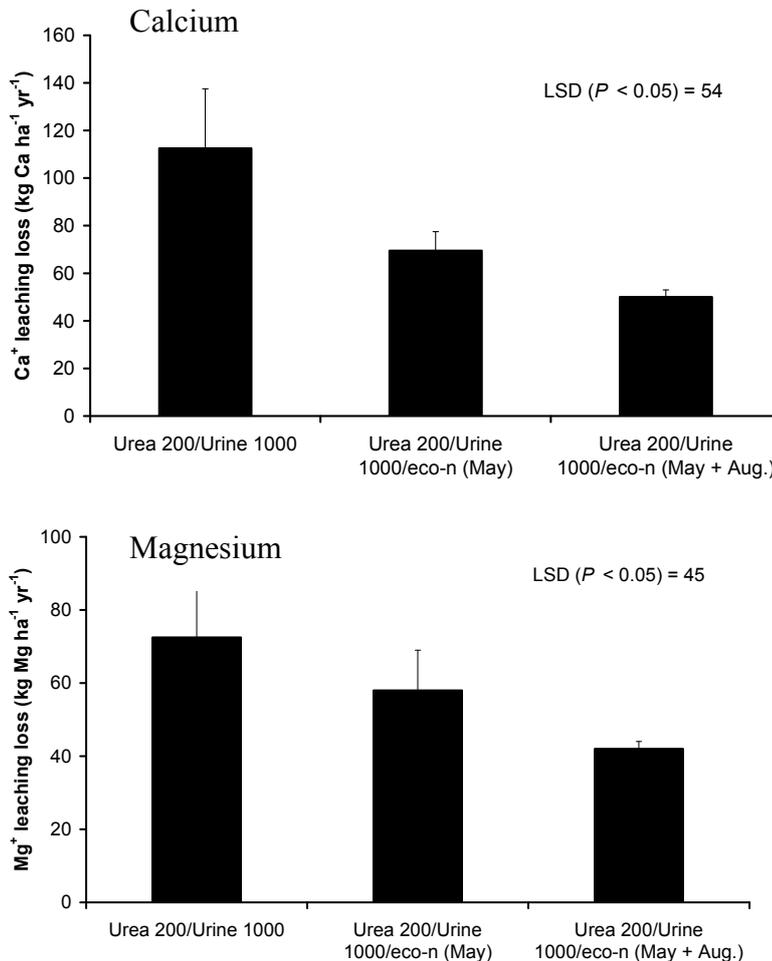


Figure 8. Effectiveness of *eco-n* application in reducing the leaching loss of calcium and magnesium from Templeton soil lysimeters (Di and Cameron, 2004b).

Does *eco-n* also reduce greenhouse gas emissions?

The use of *eco-n* has also been shown to reduce nitrous oxide (N₂O) emissions by 80% (Figure 9). This is important because nitrous oxide is a powerful greenhouse gas and its emission from grazed pasture soil represents about 33% of all greenhouse gases emitted from NZ agriculture. The availability of *eco-n* technology to reduce this greenhouse gas emission provides NZ farmers with a new tool to reduce NZ greenhouse gas emissions, as required by the

Kyoto protocol. This farmer-funded research breakthrough was of considerable significance during the recent debate about the scrapping of the so-called 'flatulence tax' and will continue to be of increasing importance in future years.

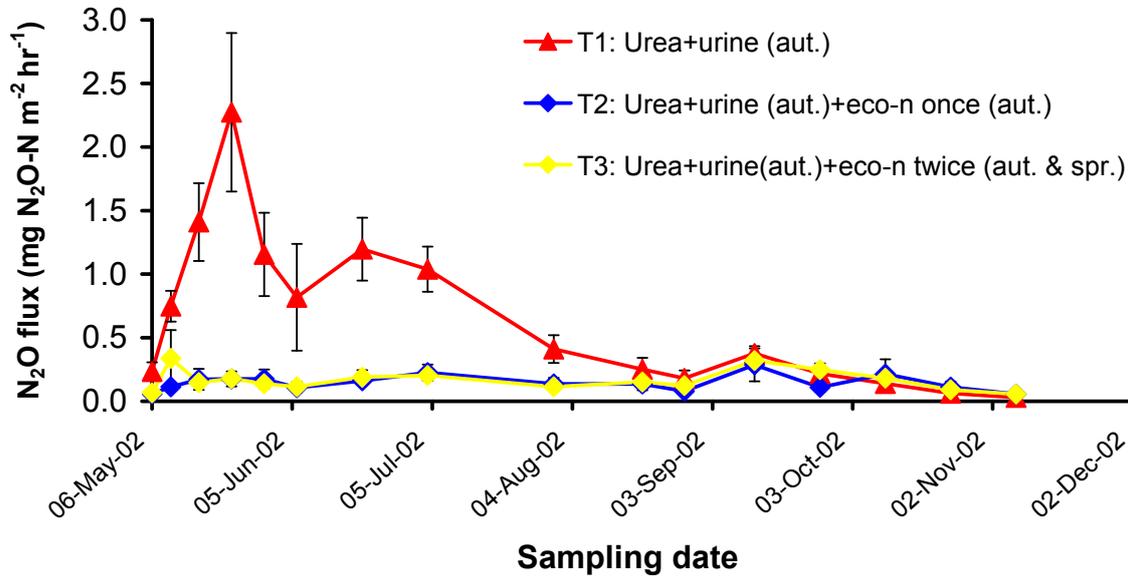


Figure 9. The effect of *eco-n* on nitrous oxide emissions from urine patches (Di and Cameron 2003).

How many applications are needed to get a significant pasture response?

Pasture yield increases occur because of the reduction in N losses meaning that more nitrogen remains in the soil for the plant to use. There is some variability in the pasture yield data, in a similar way to the variable responses to nitrogen fertilisers, but whole paddock measurements under dairy grazing e.g., on a poorly drained Temuka soil (Figure 10) suggest annual production lifts of 10% to 15% are likely to occur. Increased pasture production is being achieved between urine patches as well as from within the urine patches.

**Pasture Yield: Lincoln University Dairy Farm
May 2002 - May 2003**

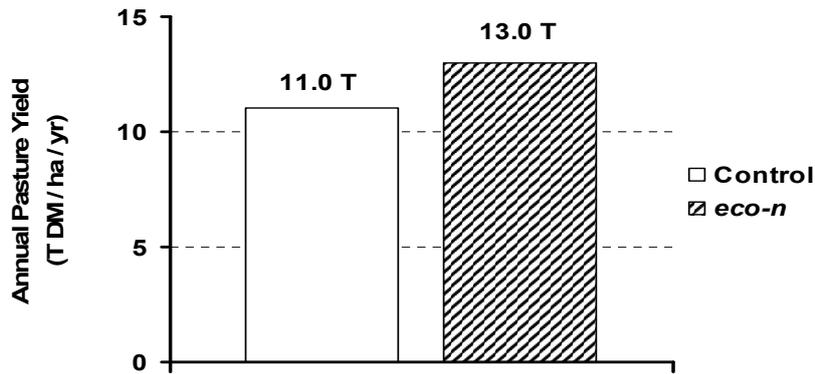


Figure 10. Increase in pasture production due to *eco-n* application under dairy grazing on a Temuka soil.

Our lysimeter research results have also shown that significant pasture yield increases can be achieved by two applications of *eco-n*, one in May followed by a second application in August (Di and Cameron 2004b ; Figure 11). Figure 11 shows that the total annual pasture yield with *eco-n* applied in May and again in August resulted in 21.1 t/ha/y compared with the yield on the control lysimeters of 15.9 t/ha/y. This represents a yield increase of over 30% under the carefully managed lysimeter conditions.

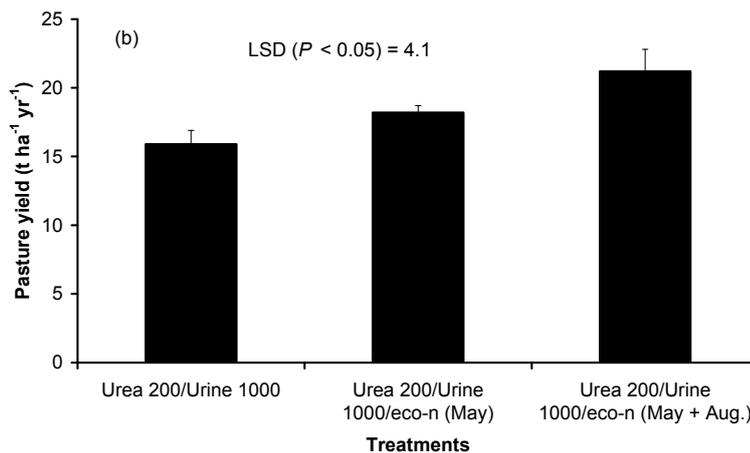


Figure 11. Total annual pasture yield on large Templeton lysimeters (Di and Cameron, 2004b).

How cost effective is *eco-n*?

The applied cost of *eco-n* will be \$63.00 per hectare. This is required twice a year as discussed, so the annual applied cost will be \$126.00/ha/year (GST exclusive). Valuing environmental gains is difficult but dairy farmers can more easily relate to the value of feed grown, as discussed by Christie (2004) and Christie and Roberts (2004).

The research work indicates increases in annual paddock pasture production from the use of *eco-n* of around 15%. Because of some inherent variability in measuring pasture production, a conservative figure of 10% may be safer to use. If we assume a base annual pasture production of 13,000 kg DM, 10% provides an additional 1,300 kg DM and 15% is 1,950 kg DM.

Extra feed grown in the paddock is the most economic to harvest and convert to milk. Alternatives to obtaining this extra feed include applying nitrogen fertilisers or purchasing feed. At normal N responses, urea costs are similar to purchasing feed at around 10 cents/kg DM. This provides us with one basis of comparison.

Another basis of comparison is the value of extra feed when converted to milksolids. This will vary between farms depending on what factors are limiting per cow production and the profile of variable costs. However, at 80% pasture utilisation and a conversion ratio of 15 kg DM to 1 kg MS, this equates to around 19 cents of additional value per kg DM.

Table 2 summarises the additional returns per hectare and the return on the *eco-n* investment based on 10% and 15% extra pasture growth scenarios.

Table 2. Net benefits and returns for using *eco-n* on dairy farms.

Return on <i>eco-n</i> expenditure				
No Cation Credit				
<i>Comparison Method</i>				
Assumes 13,000 kg DM/ha/yr before <i>eco-n</i>	Feed Value		Milk Value	
	\$0.10	/kg DM	\$3.50	/kg MS
Net benefit per hectare +15% grass	\$69.00		\$238.00	
Net benefit per hectare +10% grass	\$4.00		\$116.67	
Return on <i>eco-n</i> expenditure +15% grass	54.8%		188.9%	
Return on <i>eco-n</i> expenditure +10% grass	3.2%		92.6%	

The sensitivity to increased grass production achieved by *eco-n* (due to the better retention of nitrate-N) can be seen in the different financial outcome for 10% and 15% pasture production increases. At 13,000 kg DM base production, achieving a 10% lift is comparable

with using N fertiliser or purchasing feed at 10 cents per kg DM. If either the pre-treatment production is higher than 13,000 kg DM, or the extra yield is above 10%, then *eco-n* has significant advantages over purchasing extra feed. When the farm maximises the conversion of additional feed to milksolids, both the return per hectare and on the application investment are excellent, even with 10% extra grass growth.

In addition to the less financially quantifiable environmental benefits achieved when using *eco-n*, farmers should also consider the saving that will occur due to the reduced loss of cations. Potassium, calcium and magnesium losses will vary due to soil type, but on the lighter soils where potassium losses are high, additional gains of \$20/ha/yr or more can be expected over time from the reduced demand for the replacement of leached potassium, magnesium and calcium.

Dairy farmers who produce around 13,000–15,000 kg DM hectare a year and apply *eco-n* can expect increased pasture production. Higher N users (at around 200 kg/ha) and who produce very high pasture yields such as 18,000 kg DM hectare a year should be able to apply *eco-n*, reduce their N inputs, and still have similar levels of pasture production.

When should *eco-n* be applied?

Eco-n should be applied to recently grazed (short) pasture where it can more quickly get into the soil, and receive 10 mm of rainfall or irrigation soon after application to wash it into the soil. Treat in a similar manner to fertiliser by not applying while stock are in the paddock and allowing it to be washed in before regrazing. It is unlikely to have any effect on animals if grazed after application, but its effectiveness will be reduced if it does not reach the soil.

Application in spray form is necessary because it is vital to ensure even coverage of the whole grazed pasture soil area. A suspension is used as the most practical way to apply *eco-n*. Timing is very important. The April/May application covers the high-risk leaching period over winter, while the August/September dressing ensures coverage through spring. The product is not persistent over long periods and three to four months of protection per application is achieved. This is sufficient to obtain the benefits over a twelve-month period because the key soil drainage periods are addressed.

Ravensdown will closely manage the application of *eco-n* through the use of approved spray applicators that can provide proof of placement. This will mean that the product is sold on a per hectare applied cost basis. Taking this approach allows Ravensdown to ensure that the new product is applied appropriately (at the right rate and time) and on farm types where it will be economically effective. The accurate recording of where all product is applied also allows further studies on a regional and national basis in relation to the environmental benefits, particularly for greenhouse gas inventories.

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