The effectiveness of nitrification inhibitor technology to improve the sustainability of agriculture

Keith Cameron, Hong Di and Jim Moir

As reported widely in the general media and also in recent editions of *Primary Industry Management*, there is increasing recognition of the need to improve the sustainability of New Zealand agricultural systems. For example, Fonterra's Mark Leslie stated that the success of New Zealand's dairy industry depends on its continued sustainability.

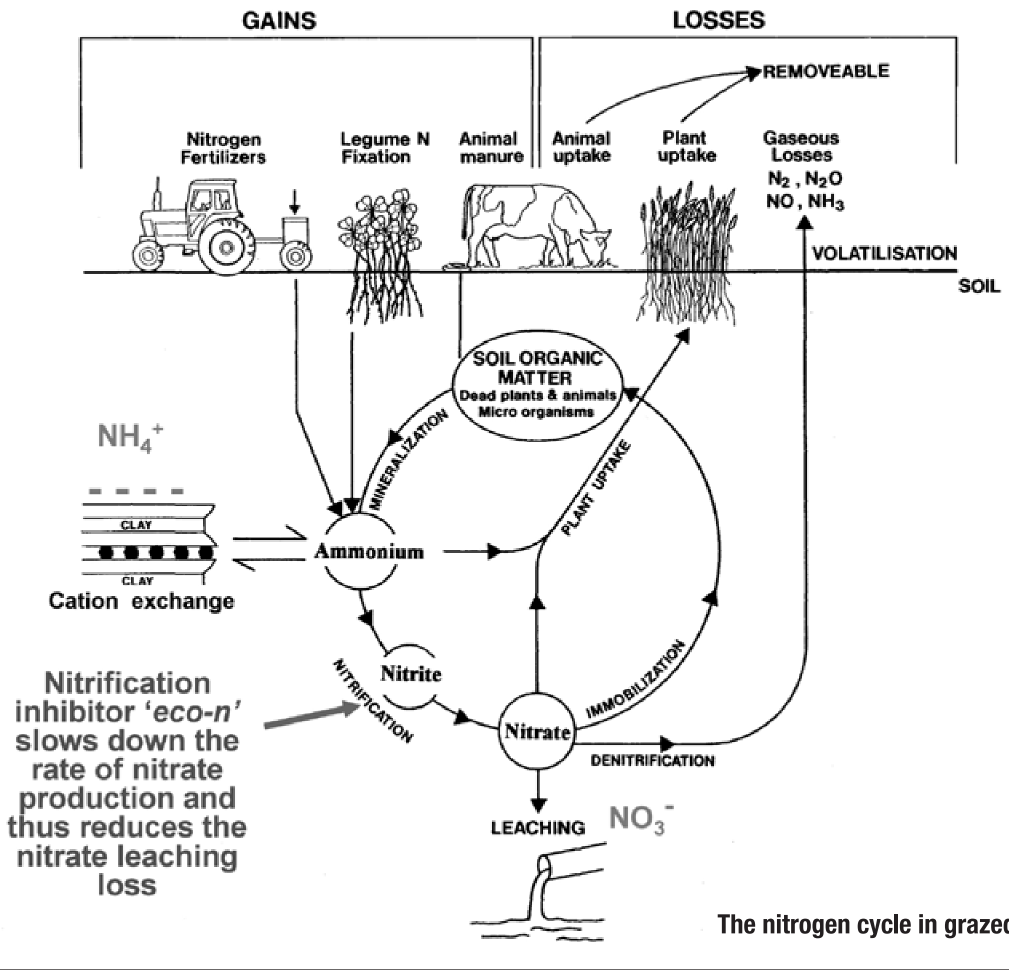
Sustainability issues around greenhouse gas emissions are front of mind for many. Mark Aspin, Manager of the Pastoral Greenhouse Gas Research Consortium recently said 'Global attitudes towards climate change have changed considerably. There is now much greater acceptance of the view that human activities are altering the composition of the atmosphere to such an extent that the planet's energy balance has been changed. The accumulation of greenhouse gases are causing the planet to retain more solar radiation, trapping more of the energy that previously would have been emitted back into space'. It is clear that international agreements between governments will result in a charge for greenhouse gas emissions and that New Zealand will either have to pay for excess emissions or reduce them.

A real risk

Tim Groser, Minister of Trade, has recently said that there was a need to deal with new environmental and climate change demands in traditional markets in Europe and North America and that the real risk is not about governments. It is that customers, or rather retailers that make the crucial decisions on sourcing, may walk away from New Zealand over environmental, climate change or other production processes and methods. It is a real risk that we must not treat lightly.

Sustainability issues relating to nitrate leaching into rivers, lakes and groundwater are already having an adverse effect on agricultural development. Major irrigation development projects are being delayed because of fears about the environmental effects that will be caused by the intensification of agriculture.

Progress to address those environmental concerns has been made through the development of the draft Canterbury Water Management Strategy released in August 2009. This strategy relies heavily on new technologies, such as nitrification inhibitors, to give the public confidence that threats of agricultural pollution can be reduced. The strategy states that 'Land use practice is changing and there are technologies available such as nitrogen



The nitrogen cycle in grazed pasture systems

Peer reviewed scientific papers showing the effectiveness of DCD in reducing nitrate leaching

Reference	Season	Soil	Location of soil	Rainfall/ irrigation (mm/y)	Urine rate (kg N/ha)	DCD	Nitrate-N loss (kg N/ha)	Reduction (%)
Di & Cameron (2002)	Autumn	Lismore	Canterbury	1,360	1,000	No	516	-
Soil Use & Management 18, 395-403.	Autumn	Lismore	Canterbury	1,360	1,000	Yes	128	75
	Autumn	Lismore	Canterbury	1,360	1,000	No	488	-
	Autumn	Lismore	Canterbury	1,360	1,000	Yes	112	77
	Spring	Lismore	Canterbury	1,360	1,000	No	397	-
	Spring	Lismore	Canterbury	1,360	1,000	Yes	230	42
Di & Cameron (2004)	Autumn	Templeton	Canterbury	1,600	1,000	No	85	-
NZ Journal Agricultural Research 47, 351-361	Autumn	Templeton	Canterbury	1,600	1,000	Yes	20	76
	Autumn	Templeton	Canterbury	1,600	1,000	Yes	22	74
Di & Cameron (2005)	Autumn	Templeton	Canterbury	1,200	1,000	No	134	-
Agriculture, Ecosystems and Environment 109, 202-212.	Autumn	Templeton	Canterbury	1,200	1,000	Yes	43	68
Di & Cameron (2007)	Autumn	Lismore	Canterbury	1,260	300	No	60	-
Nutrient Cycling in Agroecosystems 79, 281-290	Autumn	Lismore	Canterbury	1,260	300	Yes	10	83
	Autumn	Lismore	Canterbury	1,260	700	No	188	-
	Autumn	Lismore	Canterbury	1,260	700	Yes	75	60
	Autumn	Lismore	Canterbury	1,260	1,000	No	255	-
	Autumn	Lismore	Canterbury	1,260	1,000	Yes	139	46
Di et al. (2009)	Autumn	Lismore	Canterbury	1100	1,000	No	400	-
Soil Use and Management	Autumn	Lismore	Canterbury	1100	1,000	Yes	177	56
(in press)	Autumn	Mataura	Southland	1100	1,000	No	436	-
	Autumn	Mataura	Southland	1100	1,000	Yes	142	67
	Autumn	Harihari	West Coast	1100	1,000	No	123	-
	Autumn	Harihari	West Coast	1100	1,000	Yes	36	71
	Autumn	Mataura	Southland	2200	1,000	No	457	-
	Autumn	Mataura	Southland	2200	1,000	Yes	257	44
	Autumn	Harihari	West Coast	2200	1,000	No	68	-
	Autumn	Harihari	West Coast	2200	1,000	Yes	30	56
Average reduction								64% (s.e. =3.6)

Peer reviewed scientific papers showing the effect of DCD on the reduction of the nitrous oxide emission factor in New Zealand trials

Reference	Season	Soil	Location of soil	Rainfall/ irrigation (mm/y)	DCD	EF3 (%)	Reduction in EF3 (%)
Di & Cameron (2002)	Spring	Lismore	Canterbury	1,360	No	3.8	-
Soil Use & Management 18, 395-403.	Spring	Lismore	Canterbury	1,360	Yes	0.7	82
Di & Cameron (2003)	Autumn	Lismore	Canterbury	850	No	2.2	-
Soil Use & Management 19, 284-290	Autumn	Lismore	Canterbury	850	Yes	0.6	73
	Autumn	Lismore	Canterbury	850	Yes	0.6	73
	Autumn	Lismore	Canterbury	850	Yes	0.4	82
	Spring	Lismore	Canterbury	850	No	1.5	-
	Spring	Lismore	Canterbury	850	Yes	0.4	73
	Spring	Lismore	Canterbury	850	Yes	0.4	73
	Spring	Lismore	Canterbury	850	Yes	0.2	87
Di & Cameron (2006)	Autumn	Lismore	Canterbury	1,050	No	1.9	-
Biology & Fertility of Soils 42, 472-480.	Autumn	Lismore	Canterbury	1,050	Yes	0.7	65
	Autumn	Lismore	Canterbury	1,050	Yes	0.6	70
	Autumn	Lismore	Canterbury	1,050	Yes	0.5	73
	Spring	Lismore	Canterbury	1,050	No	2.6	-
	Spring	Lismore	Canterbury	1,050	Yes	0.7	73
	Autumn	Templeton	Canterbury	1,050	No	3.1	-
	Autumn	Templeton	Canterbury	1,050	Yes	1.2	61
	Autumn	Templeton	Canterbury	1,050	Yes	1.4	56
Di et al. (2007)	Winter	Templeton	Canterbury	1100	No	2	
Soil Use & Management 23, 1-9.	Winter	Templeton	Canterbury	1100	Yes	0.5	73
	Autumn	Lismore	Canterbury	1100	No	0.8	
	Autumn	Lismore	Canterbury	1100	Yes	0.3	63
	Autumn	Horotiu	Waikato	1100	No	0.6	
	Autumn	Horotiu	Waikato	1100	Yes	0.2	67
	Spring	Taupo	Taupo	1100	No	0.1	
	Spring	Taupo	Taupo	1100	Yes	0.02	80
Di et al. (2009) *in press*	Autumn	Lismore	Canterbury	1100	No	3	
	Autumn	Lismore	Canterbury	1100	Yes	1.4	54
	Autumn	Mataura	Southland	1100	No	2	
	Autumn	Mataura	Southland	1100	Yes	0.9	55
	Autumn	Harihari	West Coast	1100	No	1.9	
	Autumn	Harihari	West Coast	1100	Yes	0.8	58
	Autumn	Lismore	Canterbury	2200	No	3.9	
	Autumn	Lismore	Canterbury	2200	Yes	1	74
	Autumn	Mataura	Southland	2200	No	1.5	
	Autumn	Mataura	Southland	2200	Yes	1	33
	Autumn	Harihari	West Coast	2200	No	1.4	
	Autumn	Harihari	West Coast	2200	Yes	0.4	71
Average EF3 reduction (%) for all trials							68% (s.e. = 2.5)

inhibitors that have the potential to reduce nitrogen inputs into water. Modelling suggests that it will be possible to substantially increase agriculture output while maintaining groundwater quality within acceptable limits as long as technologies that reduce nitrogen are applied across the region'.

There is a lot at stake and we need to provide the public with confidence that future agricultural practices will reduce environmental effects. Therefore it is timely to review the effectiveness of using eco-n nitrification inhibitor technology to reduce nitrate leaching losses and mitigate nitrous oxide emissions. The technology also grows more grass which is an extra financial benefit today. In the long run it is the environmental benefits of this technology that will be of greatest value to the future growth of New Zealand agriculture.

The science behind nitrification inhibitor technology

The nitrogen cycle in grazed pasture systems is known to be leaky. Excessive amounts of nitrogen are deposited in animal urine patches causing leaching losses of nitrate and also emissions of nitrous oxide, a greenhouse gas

The eco-n nitrification inhibitor technology slows down the nitrification process and reduces the rate that ammonium is converted into nitrite or nitrate in the soil. Ammonium is adsorbed on to the negatively charged cation exchange sites on soil clays and organic matter, protecting it from leaching and allowing it to be taken up by plants, or be immobilised into soil organic matter. In contrast, nitrate is easily leached from the soil because it has a negative charge and is repelled by the negatively charged sites on the clay and organic matter. Reducing the rate of conversion of nitrogen from ammonium to nitrate can help to retain more nitrogen in the soil for plant use.

It is well known that in a grazed pasture system the direct leaching losses of nitrate or nitrous oxide emissions from applied nitrogen fertiliser are relatively small compared to the large losses that occur from animal urine patches. A typical cow urine patch may contain the equivalent of 1,000 kg nitrogen per hectare while a typical application of urea may only apply around 25 to 30 kg nitrogen per hectare for each application.

In order to reduce nitrate leaching and reduce nitrous oxide emissions from grazed pasture systems, such as dairy farms, it is essential that the losses from the urine patch areas are reduced. The development of eco-n nitrification inhibitor technology provides a significant opportunity to increase the sustainability of New Zealand agriculture by reducing the nitrate leaching losses and nitrous oxide gas emissions especially from urine patch areas.

Pasture yield increases measure in scientific trials and in on-farm and paddock pasture plate measurement comparisons

Site (& reference)	Time period	Trial type	Measurement method	DCD	Pasture production (t DM/ha)	Increase (%)
Full year Trails						
Lincoln (Temuka soil)	2002-2006: 4 year average	100 m^2 plots	Pasture cuts & modelling	No	10.6	
				Yes	12.8	21
(Moir et al. 2007 Soil Use & Management 23,111-120)						
Lincoln (Templeton soil)	2005-09: 4 year average	100 m^2 plots	Pasture cuts & modelling	No	11.8	
				Yes	14.7	25
Southland	2005: Aug to Dec	½ x ½ paddock	Pasture cuts	No	7.3	
				Yes	8.9	22
Temuka	2008/09: May-May	100m^2 plots	Plate meter	No	10.5	
				Yes	12.7	21
Average increase for full year trials						**22%**
						(se = 1.0)
Spring Trials						
Oxford	2006: Aug to Dec	½ x ½ paddock	Plate meter	No	3.6	
				Yes	4.3	19
Rangiora	2006: Aug to Dec	½ x ½ paddock	Plate meter	No	4.4	
				Yes	5.6	27
Ashburton	2006: Aug to Dec	½ x ½ paddock	Plate meter	No	5.1	
				Yes	6.7	31
Clydevale	2008: May to Nov	½ x ½ paddock	Plate meter	No	4.1	
				Yes	5.2	27
Otago	2008: Sept to Nov	½ x ½ paddock	Plate meter	No	3.5	
				Yes	4.9	40
Otago(Taieri)	2008: May to Nov	½ x ½ paddock	Plate meter	No	3.4	
				Yes	4.8	41
Average increase for part year trials						**31%**
						(se = 3.5)

There has been extensive research work conducted to develop this nitrification inhibitor technology for New Zealand farmers. The results of this research have been submitted to, and accepted for, publication in internationally peer reviewed science journals. The process of international peer review is very rigorous and is widely recognised as the primary quality assurance process for science. We can examine the results that have been accepted for publication on the effectiveness of nitrification inhibitor technology to improve the sustainability of New Zealand agriculture.

Consistent information

The previous pages have detailed tables of scientific papers. We have published 14 sets of data in internationally peer reviewed journals which show that DCD based nitrification inhibitor technology reduced nitrate leaching from urine patch areas by an average of 64 per cent, with a standard error of plus or minus 3.6 per cent. The small standard error indicates that there is a high level of consistency in the effectiveness of the inhibitor technology in reducing nitrate leaching losses.

We have also published 23 sets of data in internationally peer reviewed journals which show that the nitrification inhibitor technology reduced nitrous oxide emissions from urine patch areas by an average of 68 per cent, also with a small standard error. This indicates that there is a high level of consistency in the effectiveness of the inhibitor technology in reducing nitrous oxide emissions.

Pasture production

Pasture yield increases occur because of the reduction in nitrogen losses from the soil and significantly more plant-available nitrogen remains available for plant growth. There is understandably some variability in the pasture yield data, similar to the variable responses to nitrogen fertilisers, but whole paddock measurements under dairy grazing show significant annual production increases on-farm. The data are particularly consistent in the South Island.

Consistency and variability

The data in the tables shows that when used according to the specifications the eco-n nitrification inhibitor technology can produce significant environmental and pasture benefits. It is important to emphasise that the technology must be used according to specification.

From talking with farmers and consultants, it is our experience that the most common reason for variability in on-farm performance of the inhibitor is that the inhibitor has not been used correctly. The following are examples of where we have heard of pasture response variability and when we followed this up we have found one or more of the following reasons –

- Only a single application of the inhibitor was made in the autumn and not two applications in autumn and spring
- The inhibitor was applied too late in the spring such as October rather than August
- The inhibitor was not applied within seven days of grazing.

Other reasons for a perception of variability in the effectiveness of the inhibitor are that –

- The pasture growth response was only assessed by eye rather than by direct measurement using a rising plate meter, it is not possible to see a pasture growth response of less than 20 per cent by eye
- The pasture was grazed more frequently than usual but this was not included in the assessment of effectiveness
- More stock were used to graze the inhibitor area and this was not included
- More silage was taken from the inhibitor area but this extra pasture was not accounted for in the assessment; and last but not least
- Pasture growth was limited by other factors, such as moisture for example, because of insufficient irrigation.

It is essential to use the extra pasture grown. This can best be achieved by grazing down to a low pasture residual of 1,480 kg dry matter per hectare, or about seven 'clicks' on the rising plate meter, and to graze farm paddocks according to a feed wedge.

The specifications for the correct use of eco-n nitrification inhibitor on milking platforms are –

- Apply within seven days of grazing. This requires the spray contractor to arrive at least once a week at the farm and to spray the paddocks that have been grazed within the last seven days. This is particularly important for the autumn application.
- Apply in late-autumn and again in early spring
- For paddocks that are not likely to be grazed until mid-September then the second application can be made in late-July because the inhibitor will be washed into the soil before grazing.

Conclusions

The peer reviewed international literature shows that nitrification inhibitor technology can be used to reduce nitrate leaching and nitrous oxide greenhouse gas emissions from New Zealand dairy farms and at the same time increase on-farm productivity. The consolidated data shows that the use of the nitrification inhibitor on grazed pasture soils can –

- Reduce nitrate leaching from urine patch areas by an average of 64 per cent
- Reduce nitrous oxide emissions, a potent greenhouse gas, from urine patch areas by an average of 68 per cent
- Increase on-farm pasture production by up to 20 per cent in the South Island.

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Keith Cameron is Professor of Soil Science and Head of the Centre for Soil and Environmental Research at Lincoln University, Hong Di is Professor of Soil and Environmental Science at Lincoln University and Jim Moir is Senior Lecturer in Soil Science at Lincoln University.