Nitrification inhibitors: An effective mitigation technology for nitrous oxide emissions from grazed grassland

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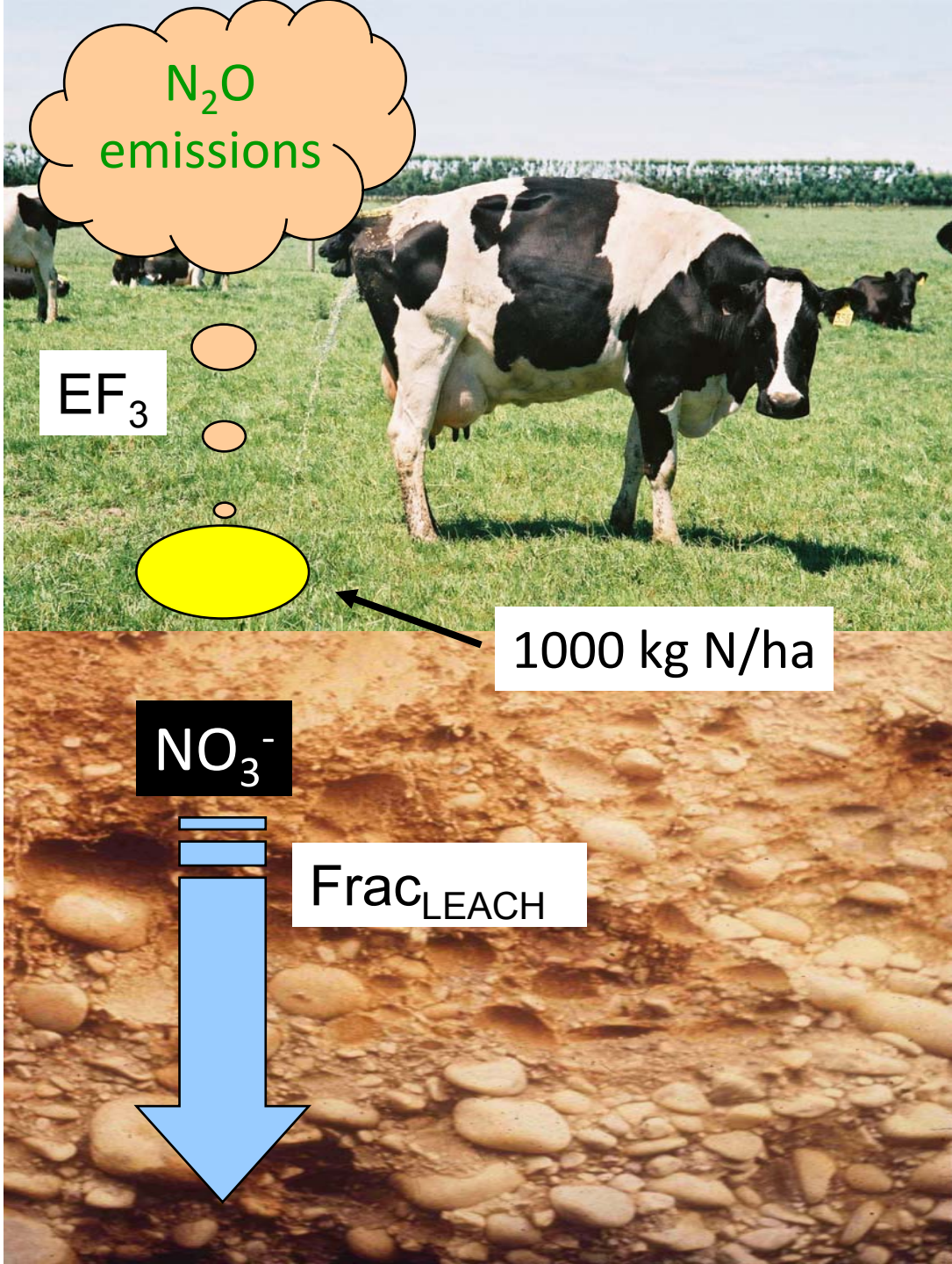
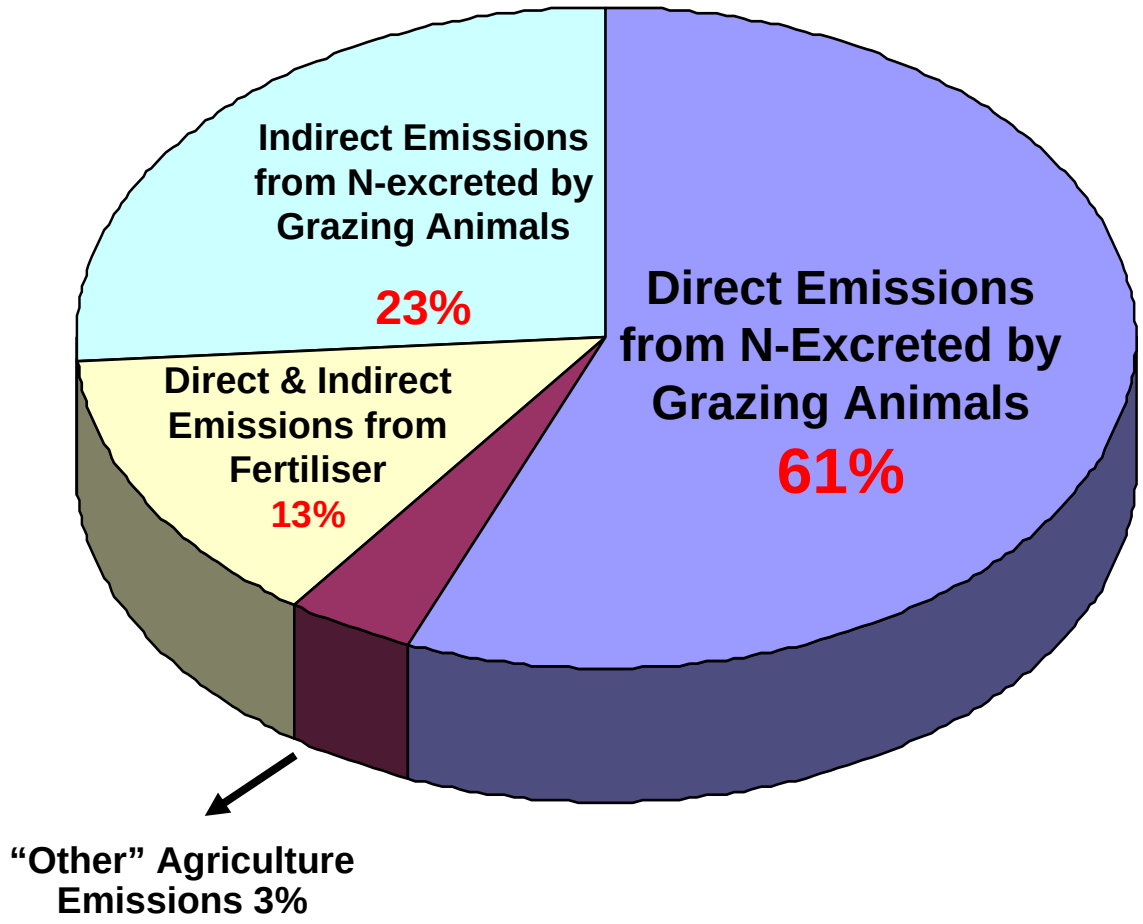
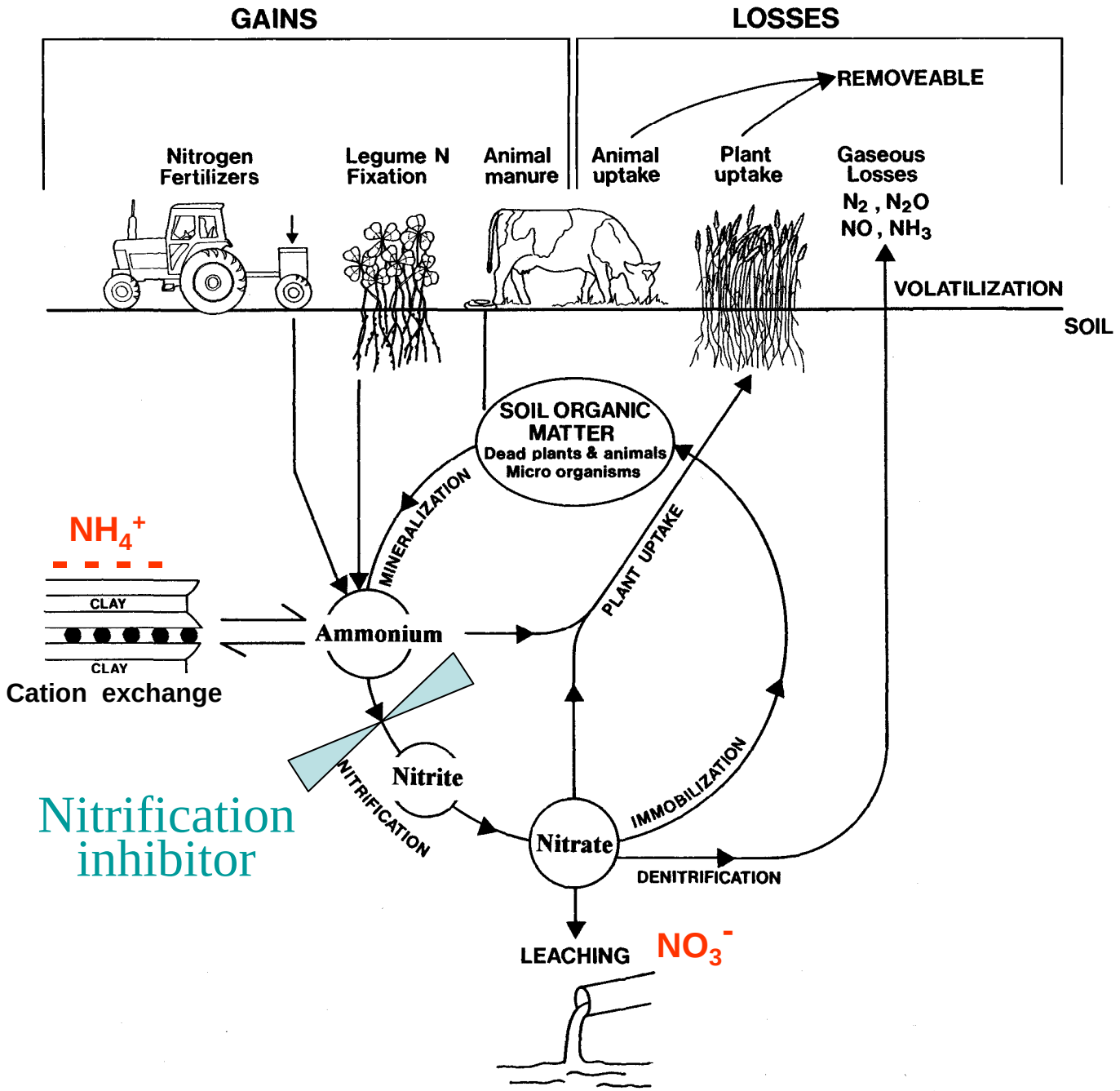
Sources of N_2O emissions and NO_3^- leaching (indirect emissions) in grazed pastures:

- Urine-N is the main source of both N_2O emissions and NO_3^- leaching.
- Direct losses from N fertilisers are relatively small.



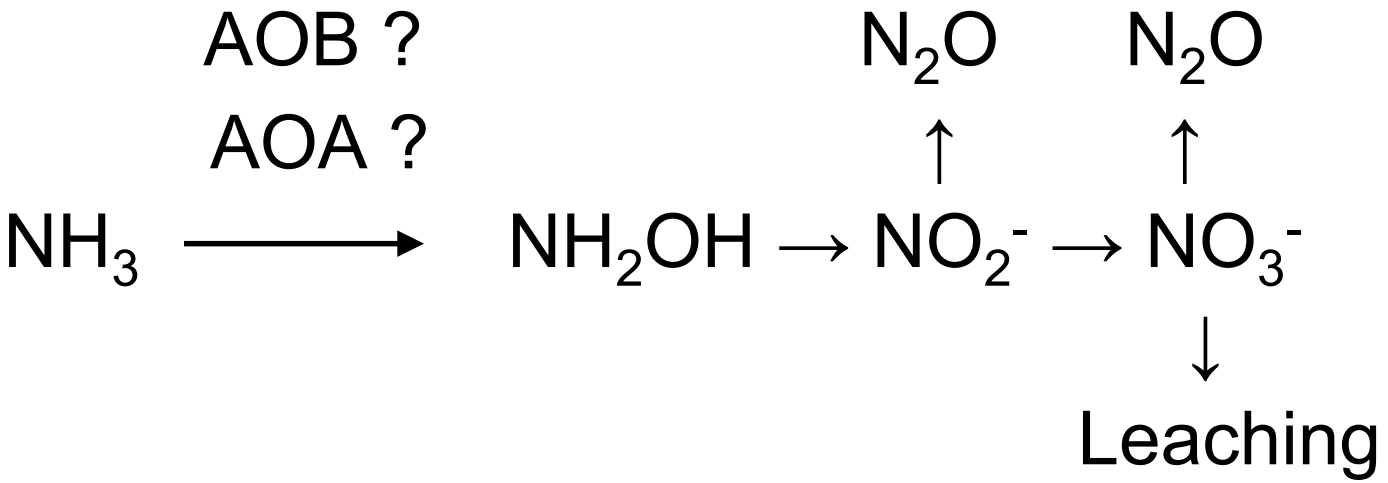
New Zealand's Agricultural N_2O Inventory 2007 (12,300 Gg CO_2-e)





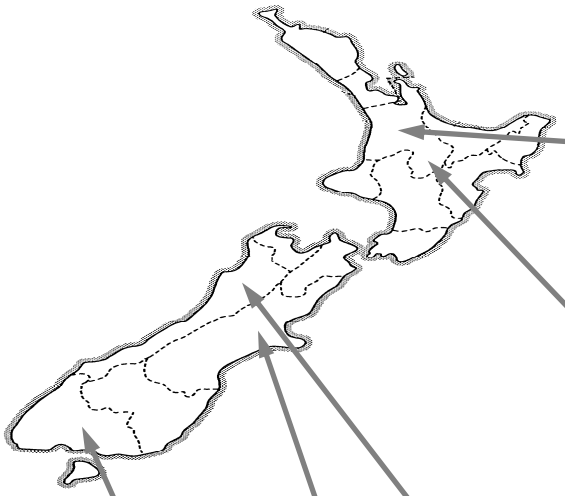
(McLaren and Cameron, 1996)

Ammonia oxidising bacteria (AOB) and archaea (AOA)



- Recent discovery of ammonia oxidizing archaea (AOA) in soils.
- Role of AOA and (AOB) in nitrification is unknown.
- Inhibition of AOB or AOA by nitrification inhibitor?

Research to determine the effectivenesss of DCD in different soils



Waikato: Horotiu soil

Canterbury, West Coast, Southland soils

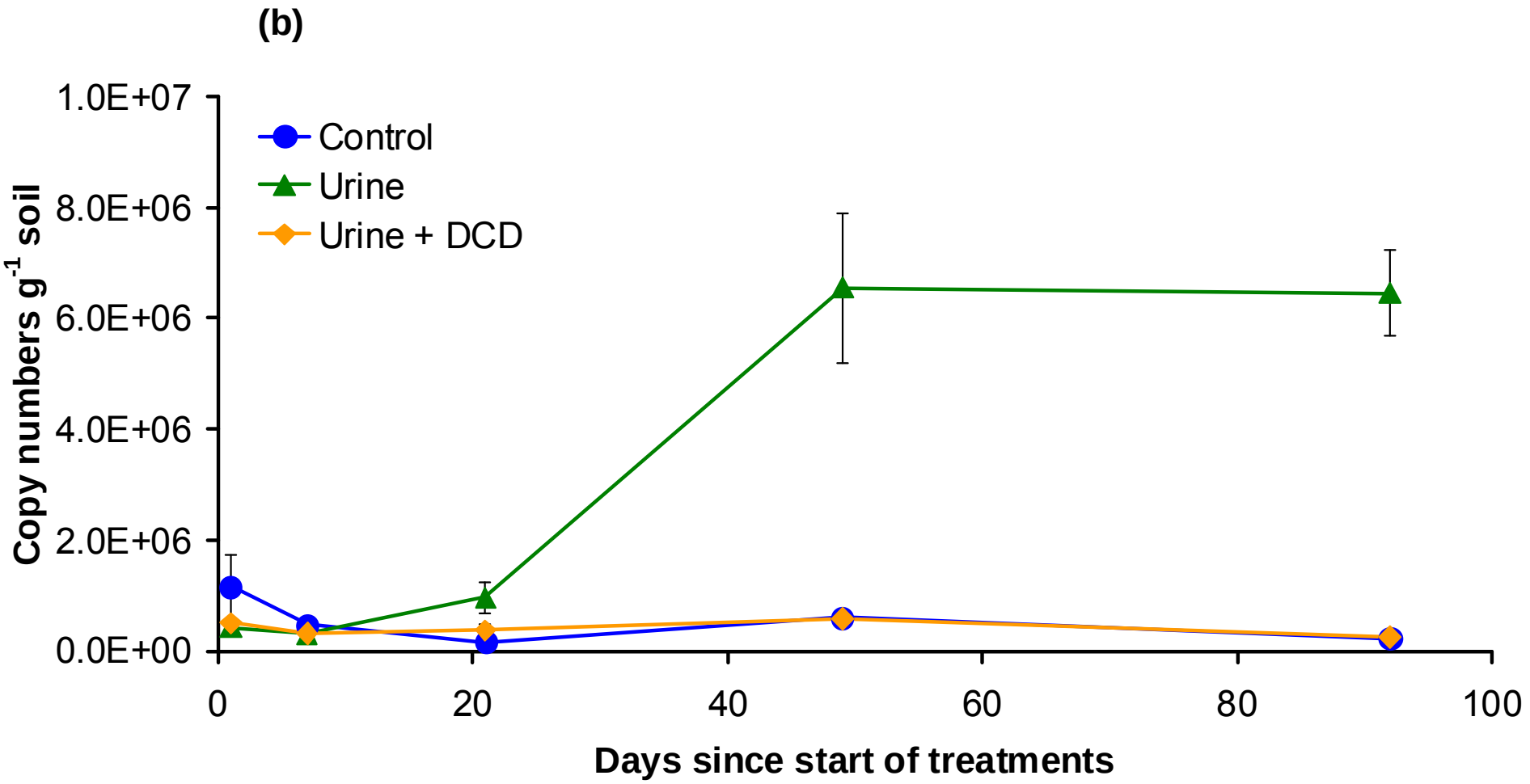
Taupo pumice soil

Molecular biology techniques used to determine the effect of DCD on ammonia oxidizers

- Real-time PCR
- DGGE
- DNA sequencing
- Phylogenetic analysis

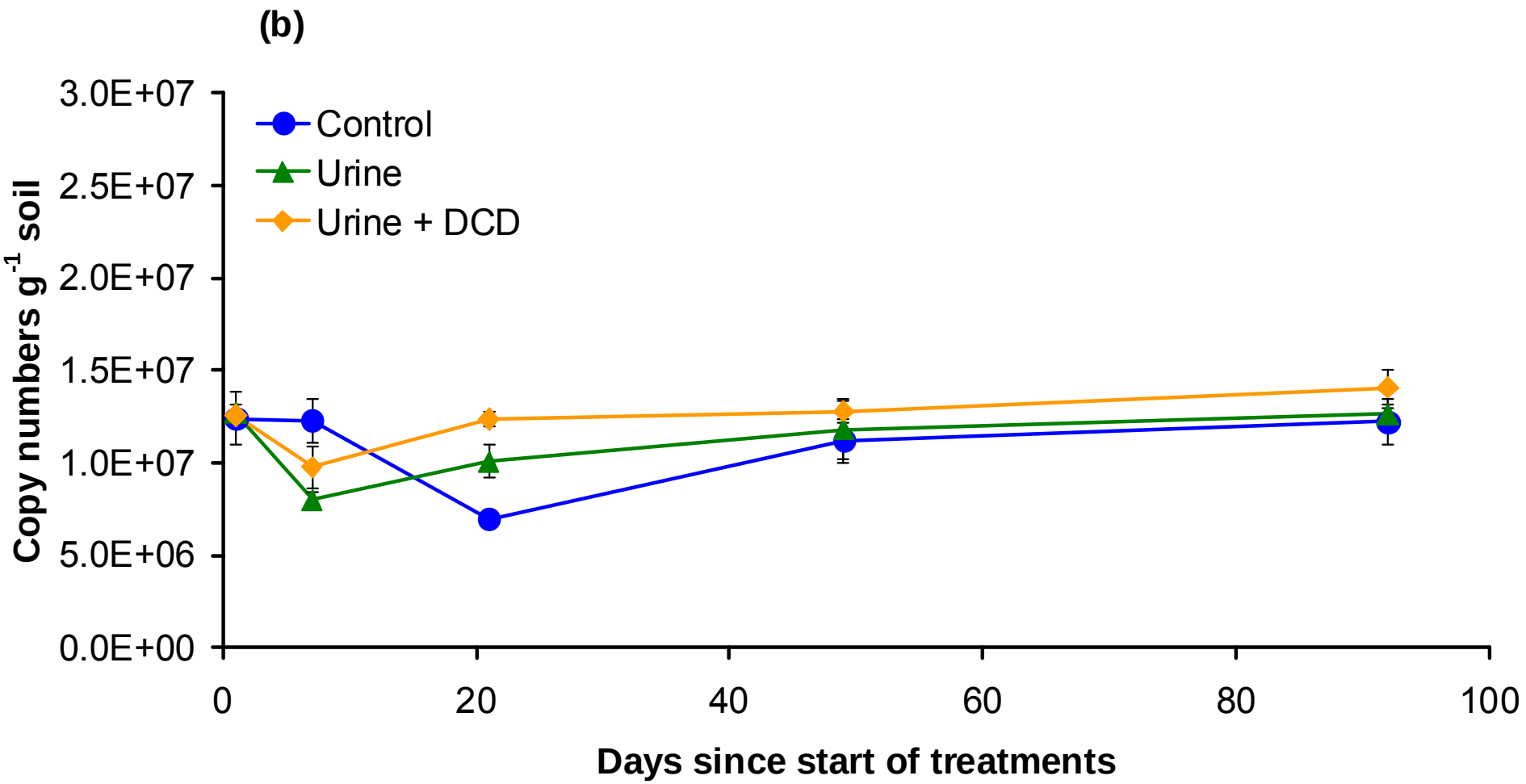
Rotor Gene™ 6000

Nitrification inhibitor restricted AOB population growth in Waikato soil (Di et al., 2009)

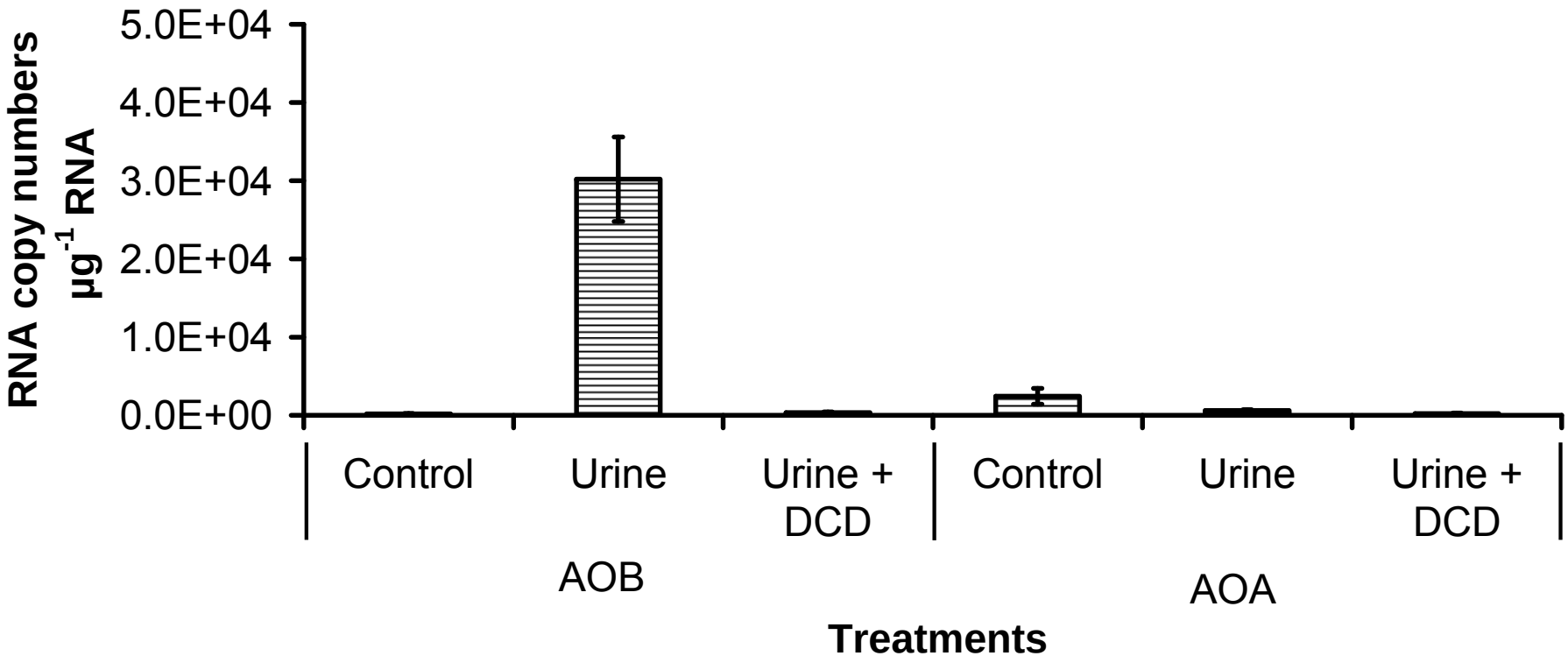


Nature Geoscience: 2: 621-624 (2009)

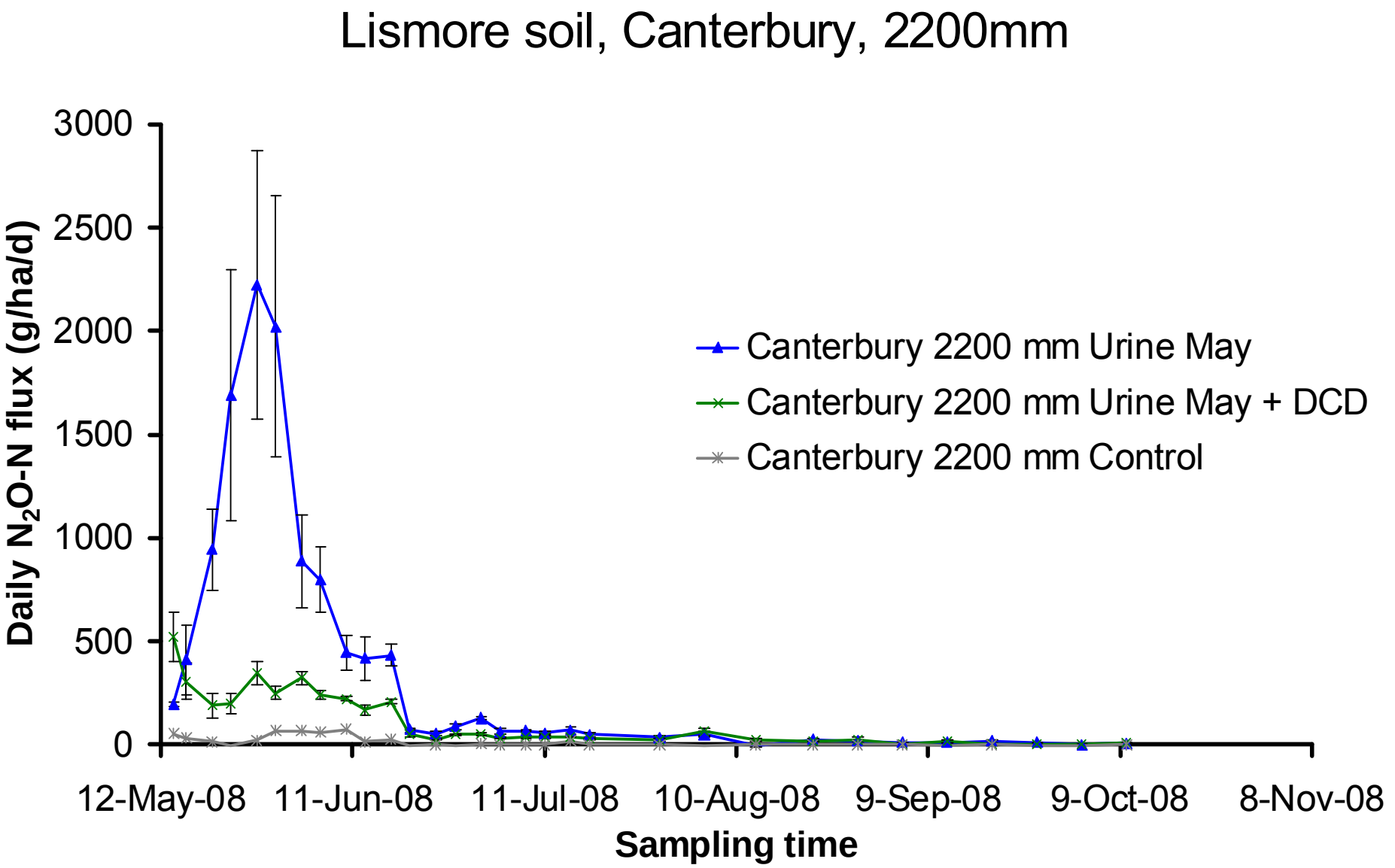
AOA in Waikato soil (Di et al., 2009)



AOB and AOA activity (Di et al., 2009)



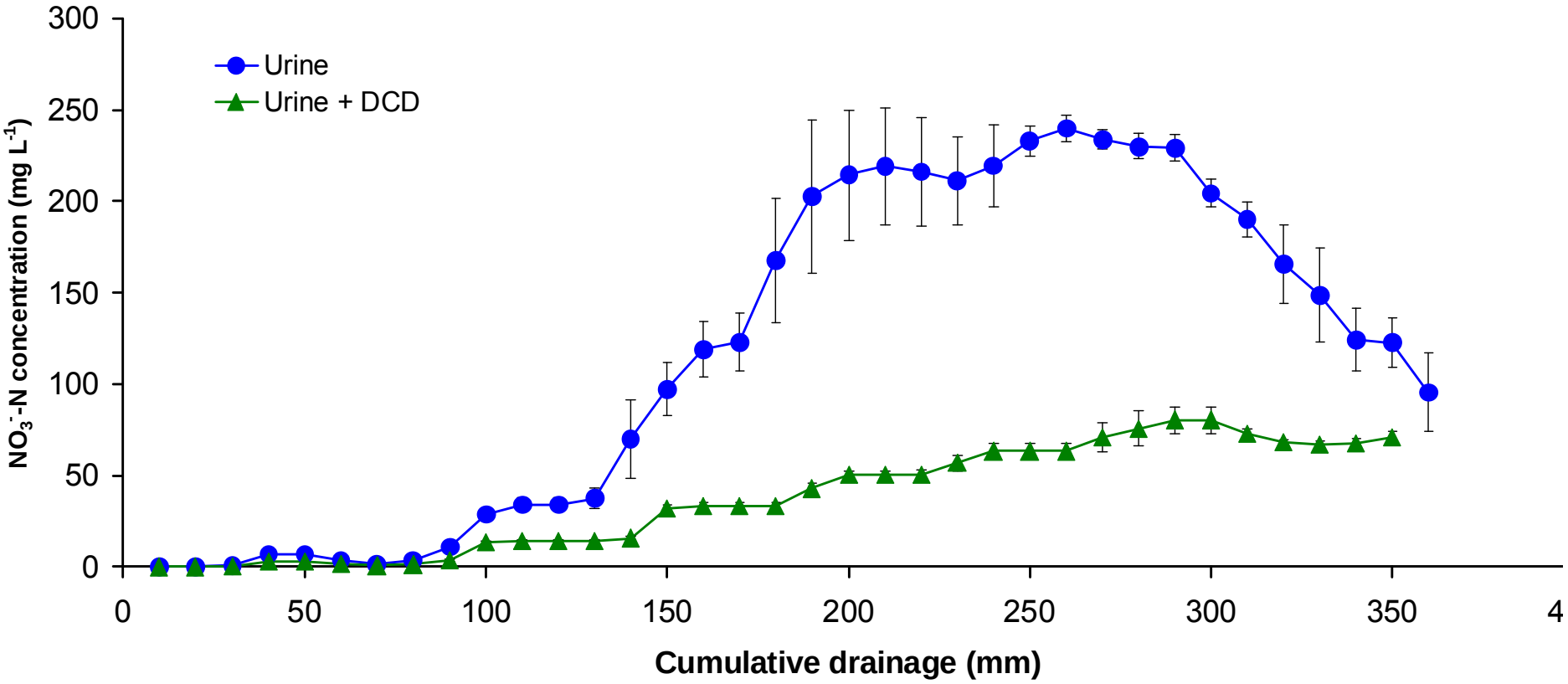
DCD reduced N_2O emissions by 74% in the Lismore soil (Di et al., 2009)



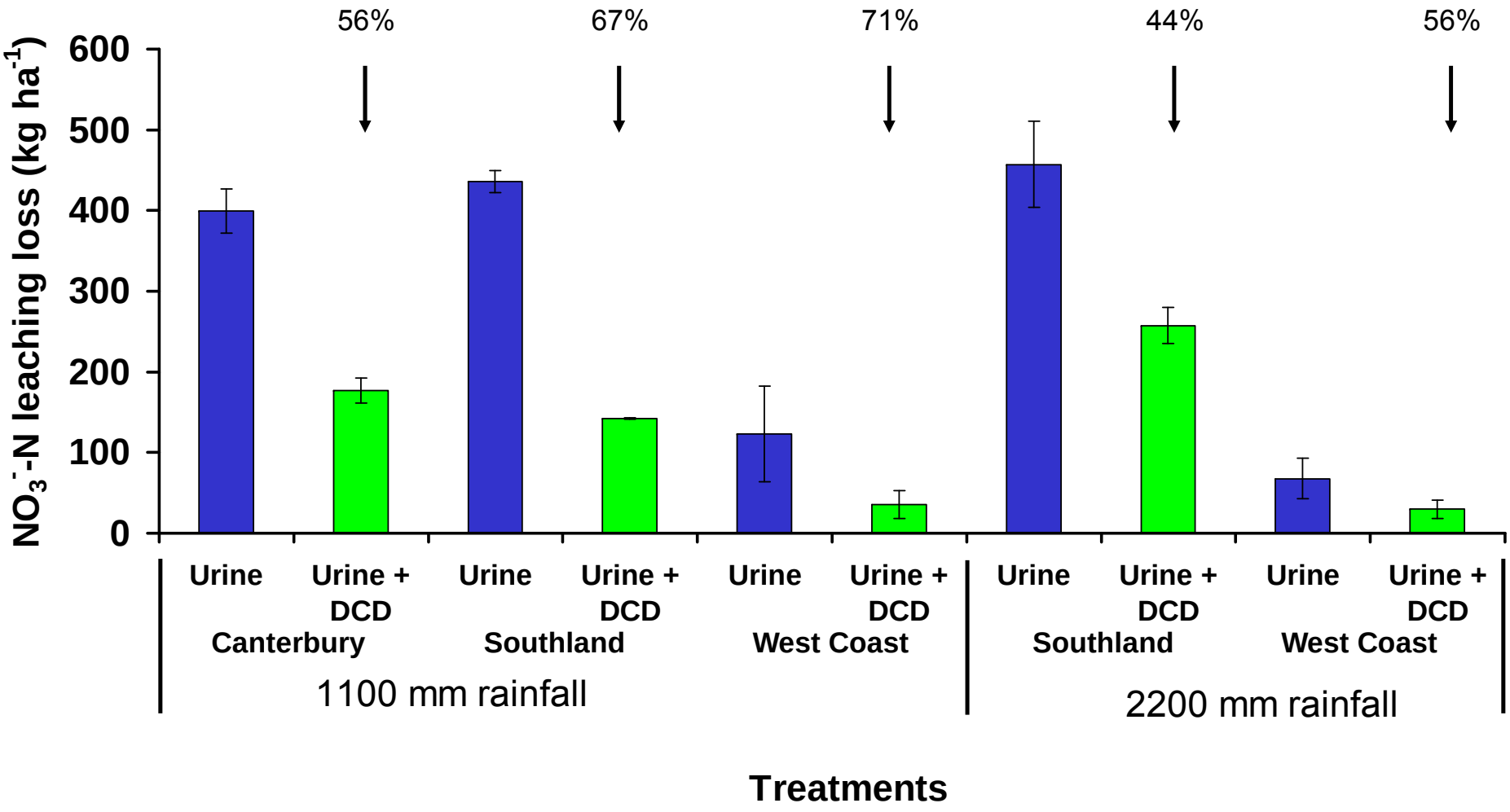
DCD reduced N_2O emissions in different soils under different rainfall (Di et al., 2009)

Regions and soil	Rainfall	EF3 (%)	EF3 (%)	% reduction
		Urine	Urine + DCD	
Canterbury, Lismore	1100 mm	3.0	1.4	53.3
Southland, Mataura	1100 mm	2.0	0.9	55.0
West Coast, Harihari	1100 mm	1.9	0.8	58.0
Canterbury, Lismore	2200 mm	3.9	1.0	74.0
Southland, Mataura	2200 mm	1.5	1.0	33.3
West Coast, Harihari	2200 mm	1.4	0.4	71.4
Average		2.3	0.9	64.0

DCD reduced nitrate leaching by 67% in the Southland Mataura soil (Di et al., 2009)



DCD reduced nitrate-N leaching losses in different soils under different rainfall (Di et al. 2009)



Compilation of published data in internationally peer reviewed science journals

1. Di HJ and Cameron KC (2002) *Soil Use and Management* **18**: 395-403.
2. Di HJ and Cameron KC (2003) *Soil Use and Management* **19**: 184-290.
3. Di HJ and Cameron KC (2004a) *Soil Use and Management* **20**: 2-7.
4. Di HJ and Cameron KC (2004b) *NZ Journal of Agricultural Research* **47**: 351-361.
5. Di HJ and Cameron KC (2004c) *Australian Journal of Soil Research* **42**: 927-932.
6. Di HJ and Cameron KC (2005) *Agriculture, Ecosystems and Environment* **109**: 202-212.
7. Di HJ and Cameron KC (2006) *Biology and Fertility of Soils* **42**: 472-480.
8. Di HJ, Cameron KC and Sherlock (2007) *Soil Use and Management* **23***: 1-9.*
9. Moir JM, Cameron KC and Di, HJ (2007) *Soil Use and Management* ***23:*** *111-120.*
10. Clough TJ, Di HJ, Cameron KC, Sherlock, RR, Metherell AK, Clark H and Rys, G (2007) *Nutrient Cycling in Agroecosystems* ***78:*** *1-14.*
11. Di HJ and Cameron KC (2007) *Nutrient cycling in Agroecosystems* **79**,281-290.
12. Cameron et al. (2007) *Proc. NZ Grassland Assoc.* 69: 131-135.
13. Di HJ and Cameron KC (2008) *Australian Journal of Soil Research* **42**: 927-932.
14. Di *et al.* (2009) *Nature Geoscience* **2:** 621-624.
15. Di et al. (2009) *Soil Use and Management*: doi: 10.1111/j.1475-2743.2009.00241.x

Nitrous oxide:

Number of data sets: 23

Rainfall range: 850-2200 mm

Average reduction of EF_3: 68%

SEM: 2.5

Reference	Season	Soil	Location of soil	Rainfall/ irrigation (mm/y)	DCD	EF3 (%)	Reduction in EF3 (%)
Di & Cameron (2002) *Soil Use & Management 18, 395-403.*	Spring	Lismore	Canterbury	1,360	No	3.8	-
	Spring	Lismore	Canterbury	1,360	Yes	0.7	82
Di & Cameron (2003) *Soil Use & Management 19, 284-290*	Autumn	Lismore	Canterbury	850	No	2.2	-
	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) *Biology & Fertility of Soils 42, 472-480.*	Autumn	Lismore	Canterbury	1,050	No	1.9	-
	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) *Soil Use & Management 23, 1-9.*	Winter	Templeton	Canterbury	1100	No	2	
	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)

Nitrate leaching:

Number of datasets: 14

Average reduction of leaching: 64%

SEM: 3.6

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) *Soil Use & Management 18, 395-403.*	Autumn	Lismore	Canterbury	1,360	1,000	No	516	-
	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) *NZ Journal Agricultural Research 47, 351-361*	Autumn	Templeton	Canterbury	1,600	1,000	No	85	-
	Autumn	Templeton	Canterbury	1,600	1,000	Yes	20	76
	Autumn	Templeton	Canterbury	1,600	1,000	Yes	22	74
Di & Cameron (2005) *Agriculture, Ecosystems and Environment 109, 202-212.*	Autumn	Templeton	Canterbury	1,200	1,000	No	134	-
	Autumn	Templeton	Canterbury	1,200	1,000	Yes	43	68
Di & Cameron (2007) *Nutrient Cycling in Agroecosystems 79, 281-290*	Autumn	Lismore	Canterbury	1,260	300	No	60	-
	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) *Soil Use and Management* (in press)	Autumn	Lismore	Canterbury	1100	1,000	No	400	-
	Autumn	Lismore	Canterbury	1100	1,000	Yes	177	56
	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)

Conclusions

- The nitrification inhibitor is highly effective in:
  - Reducing direct nitrous oxide emissions
  - Reducing nitrate leaching (indirect emissions)
- These benefits are achieved by inhibiting ammonia oxidising bacteria (AOB) rather than ammonia oxidising archaea (AOA) in soil.
- This technology is currently available for use by New Zealand farmers.
- It has been incorporated into New Zealand's 2007 GHG emissions inventory.

Acknowledgments

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  - New Zealand Foundation for Research Science and Technology (FRST)
  - Ravensdown Fertiliser Co-operative Ltd
  - NZ Pastoral Greenhouse Gas Research Consortium (PGGRC)
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  - Lincoln University