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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment: Interim report on results from the Parekarangi Trust farm

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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment: Interim report on results from the Parekarangi Trust farm

Report prepared for: Bay of Plenty Regional Council, DairyNZ, Ballance Agri-nutrients, the Lake Rotorua Primary Producers Collective and the Ministry for Primary Industries

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Table of Contents

1. Summary

The aim of this research was to provide data on current nitrogen (N) leaching losses from dairy farms in the Lake Rotorua catchment and the effect of reducing N fertiliser input on pasture growth and N leaching. Two trials were established on the Parekarangi Trust dairy farm.

The first trial which started in spring 2011, was a paddock scale plot trial with three treatments: regular N fertiliser applied as per current farm practice (265 kg N/ha in year 1 and 176 kg N/ha in year 2), strategic N fertiliser applied in spring and autumn (76 kg N/ha in year 1 and 67 kg N/ha in year 2) and no N fertiliser applied. Averaged over two years, the pasture dry matter (DM) response to N was 15.0% and 4.3% on the regular N and strategic N treatments, respectively. This equated to 7.2 and 6.4 kg DM/kg fertiliser N applied to the respective treatments. Common grazing of the trial area would have resulted in even return of excreta across treatments, which may have reduced the magnitude of the differences in production between treatments.

The second trial started in autumn 2012 and was a farm-systems-scale experiment using 12 paddocks. Six paddocks received N fertiliser as per current farm practice (163 kg N/ha in year 1 and 142 kg N/ha in year 2), while the other six received no N fertiliser. The two sets of paddocks were grazed separately to avoid any fertility transfer. Averaged over two years, the pasture DM response to N fertiliser was 16.5%, equating to an additional 10.7 kg DM/kg fertiliser N applied. There was no significant change in the botanical composition of the pasture on either of the trials over the two years.

Each paddock in the farm system trial had 25 ceramic cup samplers (150 per treatment) to measure N leaching. In the first year when treatments had just commenced before winter, there was no significant difference in leaching losses between the N and nil-N paddocks (17 and 13 kg N/ha, respectively). However, in the second year 75 kg N/ha was leached from the N fertiliser paddocks versus 15 kg N/ha from the nil-N paddocks ($p<0.05$). This followed a summer/autumn drought, which would have introduced some uncertainty over how representative it was of a typical year. A further year of leaching measurements is now ongoing and will be presented in the final report in 2015.

2. Introduction

Dairy farming in the Lake Rotorua catchment is a significant contributor to nutrients entering the lake. The Bay of Plenty Regional Council (BOPRC), in its proposed Regional Policy Statement (RPS), has established nutrient reduction targets that require farmers to reduce inputs to Lake Rotorua by 270 tonnes of nitrogen (N) per year by 2032. Dairy farms have been estimated to contribute approximately half of the current nitrogen load from all farm sources. The Rotorua Dairy Collective's project, "Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment", aims to provide data on current nutrient losses and strategies to reduce these. As part of this study, AgResearch established a plot trial and a farm-paddock-scale trial on the Parekarangi Trust farm, approximately eight kilometres south of Rotorua. The study aims to examine the effects of N fertiliser use on pasture production and composition, and on N leaching.

The Parekarangi Trust dairy farm is 352 ha (effective area) carrying approximately 2.7 cows/ha and producing approximately 800 kg milksolids/ha/year (in 2009/2010). A feed-pad is used with some brought-in pasture silage and palm kernel expeller and one-third of the cows are grazed off for two months in winter. The farm is of rolling contour and the main soil series is a Haparangi soil from Taupo pumice. There is also a small area of Ngakuru soil from Taupo Tephra.

3. Trial setup

3.1 Plot trial

The plot trial was established following grazing in August 2011, with three N fertiliser treatments:

1. Standard – 265 kg N/ha in year 1 and 176 kg N/ha in year 2,
2. Strategic – 76 kg N/ha in year 1 and 67 kg N/ha in year 2 and
3. Nil – no N fertiliser applied.

These were replicated nine times, giving a total of 27 plots, each 275 m^2 in area. Grazing management followed standard farm practice and cows were able to move freely between plots. Rising plate meter readings (approximately 80 per plot) taken before and after grazing were used to estimate pasture growth. The standard plots received N fertiliser at the same time and rate as the rest of the farm for areas not receiving effluent and used for silage production. The strategic treatment plots received an application of N in spring and again in autumn. The amounts of N fertiliser applied are listed in Table 1. Pasture samples from all plots were collected for analysis of botanical composition in spring and autumn (except in autumn 2013 when the prevailing drought conditions caused short-term changes in species abundance).

Table 1. Timing and rates of N fertiliser application (kg N/ha) on the plot trial, corresponding to use on farm on the non-effluent area and areas used for pasture silage production.

	Treatment	
Date	Standard N	Strategic N
August 2011	46	46
September 2011	46	
October 2011	26	
December 2011	37	
February 2012	46	
March 2012	37	
April 2012	28	30
Year 1 total	265	76
August 2012	43	
September 2012	37	37
November 2012	21	
January 2013	35	
April 2013	40	30
Year 2 total	176	67

3.2 Farm system trial

The farm system trial commenced in April 2012. The trial consisted of six paired paddocks. One paddock in each pair received N fertiliser applications at the same time and rate as the rest of the farm (Plus-N), while the other received no N fertiliser (Nil-N). To prevent any fertility transfer from paddocks receiving N fertiliser to nil-N paddocks, the cows grazing the nil-N paddocks grazed a lead in paddock, which received no N fertiliser, before moving through to the nil-N treatment paddocks. The timing and rate of N fertiliser application is given in Table 2.

Table 2. N fertiliser application on farm system trial in year 1 and 2.

Year 1		Year 2	
Apr 2012-Mar 2013	kg N/ha	Apr 2013–Dec 2013	kg N/ha
April	30	April/May	40
August	43	August/September	40
September	37	November	25
November	21	December	37
January	35		
Annual total	166	Annual total	142

Rising plate meter readings taken before and after grazing were used to estimate pasture growth. Grazing management and N fertiliser application followed standard farm practice and both sets of nil-N and plus-N treatment paddocks were grazed as closely together as possible. In both years, pasture samples were collected and analysed for botanical composition in late winter/early spring and again in late summer. Sub-samples were analysed for N concentration.

In April 2012, 25 porous ceramic cup soil moisture collectors were installed in each treatment paddock at a depth of 60 cm. After an average of every 50 mm of drainage in 2012 and every 75 mm of drainage in 2013, a sample of soil moisture from 60 cm depth was collected using the ceramic cups and analysed for nitrate-N concentration. Drainage was estimated using a water balance model (Woodward et. al. 2001) set up for analysis using soil characteristics from the farm. Daily rainfall was measured on the farm and temperature and solar radiation data were obtained from the Rotorua airport meteorological station belonging to the National Institute of Water and Atmospheric Research (NIWA). The amount of nitrate-N leached below 60 cm depth was calculated by multiplying the nitrate-N concentration by its associated drainage.

4. Results

4.1 Plot trial

The standard N treatment produced significantly ($p<0.01$) more pasture production than the control nil-N treatment in both years of the trial (Table 3). The strategic N treatment produced significantly more growth immediately following fertiliser N application but on an annual basis it was not significantly different to the nil-N treatment.

Table 3: Plot trial pasture production from August 2011 to August 2013. LSD = Least Significant Difference at p<0.05.

Year 1	Nil-N	Strategic N	Standard N	LSD
Annual pasture production (t DM/ha)[1]	10.66	11.09	12.68	0.94
N response (%)		4.1	18.9	
Additional DM (kg/ha)		432	2015	
Annual fertiliser N applied (kg/ha)		76	265	
N response (kg DM/kg N)		5.7	7.6	

Year 2	Nil-N	Strategic N	Standard N	LSD
Annual pasture production (t DM/ha)[1]	10.56	11.03	11.73	0.68
N response (%)		4.5	11.1	
Additional DM (kg/ha)		476	1176	
Annual fertiliser N applied (kg/ha)		67	176	
N response (kg DM/kg N)		7.1	6.7	

[1] Pasture growth figures have not been adjusted to account for growth that occurred in the interval between the pre- and post-grazing plating measurements.

There was no significant difference between any of the treatments in pasture botanical composition when sampled in August 2011 and August 2013 (Table 4).

Table 4. Botanical composition of pasture (% dry matter): August 2011 and August 2013. LSD = Least Significant Difference at p<0.05.

	Ryegrass		Browntop		Other grass		Legume		Weed	
Treatments	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
Nil-N	85	82	<1	<1	6	3	5	8	4	6
Strategic N	86	84	<1	<1	6	3	4	6	3	7
Standard N	84	84	1	1	7	4	4	7	4	5
LSD	4.2	5.4	0.8	0.9	3.4	4.7	2.6	3.6	2.7	3.2

4.2 Farm system trial

4.2.1 Pasture N response

Nitrogen fertiliser increased pasture production by 16.3% in year one and by 16.6% in year two (Table 5), although only the year two increase was statistically significant ($p<0.01$). In year 1, pasture production was measured over a slightly shorter period than 12 months and additionally the values in Table 5 have not been adjusted to account for pasture growth between the periods of measurement of the pre- and post-grazing plating measurements. Adjustment for the latter would increase the estimated pasture production and N response by approximately 10%.

N concentration in the pasture followed a similar trend, with higher N concentrations in the plus-N pasture in both years but only the year two difference being statistically significant (Table 6).

The ryegrass content of the pasture in the nil-N paddocks fell slightly from late winter 2012 to late winter/early spring 2013 (Table 7) but this difference was not significant. There was no significant difference in browntop content between plus-N and nil-N paddocks over the course of the study. One paddock in the nil-N treatment had a relatively high % browntop from the start of the study, which gave an apparent higher overall level in the nil-N treatment, but this was unchanged over time.

Table 5. Pasture growth from autumn 2012 to autumn 2014. LSD = Least Significant Difference at p<0.05.

Year 1 (May 2012-April 2013)	Nil-N	Plus-N	LSD
Annual pasture production (t DM/ha)[1]	6.61	7.69	1.77
N response (%)		16.4	
Additional DM (kg/ha)		1081	
Annual fertiliser N applied (kg/ha)		163	
N response (kg DM/kg N)		6.6	

Year 2 (April 2013 - April 2014)	Nil-N	Plus-N	LSD
Annual pasture production (t DM/ha)[1]	12.64	14.74	1.35
N response (%)		16.6	
Additional DM (kg/ha)		2099	
Annual fertiliser N applied (kg/ha)		142	
N response (kg DM/kg N)		14.8	

[1] Pasture growth figures have not been adjusted to account for growth that occurred in the interval between the pre- and post-grazing plating measurements.

Table 6. Nitrogen concentration in mixed pasture samples (% dry weight). LSD = Least Significant Difference at p<0.05.

Treatments	August 2012	Aug/Sep 2013
nil-N	3.29	2.93
plus-N	3.52	3.50
LSD	0.25	0.56

Table 7. Botanical composition of pasture (% dry weight): August 2012 and Aug/Sep 2013. LSD = Least Significant Difference at p<0.05.

	Ryegrass		Browntop		Other grass		Legume		Weed	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
nil-N	73	61	10	9	10	11	5	10	2	9
plus-N	71	71	4	3	16	13	5	7	5	7
LSD	15.2	21.1	12.5	8	12.8	12.3	5.7	6.3	4.4	4.9

4.2.2 Nitrogen leaching

In the first year of the trial, there was no difference in nitrate-N concentrations in leachate between nil-N and plus-N treatments (Figure 1). However, in the second year the average nitrate-N concentrations in leachate from the plus-N treatment were significantly higher from the fourth through to the eighth samplings, with the difference rising to a maximum at the June sampling.

There was no significant difference between treatments in the amount of N leached in 2012, but in 2013 over four times as much nitrate-N was leached from the plus-N treatment as from the nil-N treatment (Table 8). In the first year of the trial, leachate sampling did not start until May and over 200 mm of the estimated 770 mm of drainage that occurred in 2012 took place before that sampling. Hence the data for N leached in 2012 reported in Table 8 underestimated annual leaching loss. In 2013, sampling began from the commencement of drainage and the total annual drainage was 760 mm.

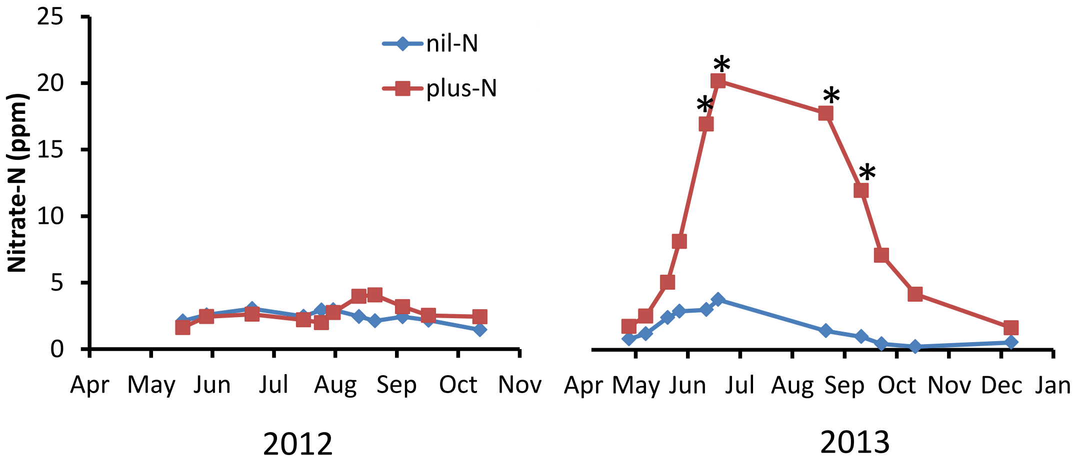

Figure 1. Nitrate-N concentrations in leachate during the 2012 and 2013 drainage seasons. Data was log transformed for statistical analysis and back transformed for presentation. Asterisks indicate differences significant at p<0.05.

Table 8. Amount of nitrate-N leached below 60 cm (kg N/ha). LSD = Least Significant Difference at p<0.05.

Treatments	2012 (May-Dec) *	2013 (Jan-Dec)
nil-N	13	17
plus-N	15	75
LSD	15.8	46.6

* Sampling did not include all drainage in 2012

5. Discussion

5.1 Pasture response to N fertiliser

Pasture responses to N fertiliser in the plot trial were 7-8 kg DM/kg N. Previous small plot studies with single applications of N fertiliser have been carried out in large national series trials throughout New Zealand in the 1970s. These studies showed pasture responses to urea on pumice soils in the Central Plateau region of approximately 6 kg DM/kg N (range 4-10) following April application and approximately 12 kg DM/kg N (range 6-20) following August application (During 1984; Ledgard 1984). These were of a similar magnitude to those for other regions across the North Island.

This plot trial included nine replicates of plots in a randomised block within a paddock which resulted in greater precision than if they had been spread across many paddocks around the farm. However, it also meant that the responses related to the N fertility of the soil in a single paddock and recent research has shown that paddocks can vary within a farm in their responsiveness to N fertiliser (Rajendram et al. 2009).

The plot trial was also communally grazed by cows, since it was not feasible to arrange for the small plots to be separately grazed. A consequence of this is that all plots are likely to have received the same return of N in excreta, even though the high N plots may have produced more pasture and with a higher N concentration compared to the nil-N treatment plots. Thus it is likely that the even return of excreta will have tended to reduce the magnitude of the differences in production between treatments over time compared to a situation where cows had previously grazed pasture from their specific treatment.

The farm system trial was managed in such a way that cows entering paddocks for grazing of the nil-N treatment had previously been grazing nil-N paddocks (including a nil-N lead-in paddock to avoid carry-over from plus-N paddocks). Similarly, the cows grazing the plus-N treatment had previously grazed pasture from this same treatment. In the first year of the farm system trial the pasture response to N fertiliser from the plus-N treatment compared to the nil-N treatment was relatively low at 7 kg DM/kg N. This coincided with a year of significant drought conditions in summer/autumn 2013, which would have reduced the magnitude of pasture response to N fertiliser (e.g. During 1984). In the second year of the farm system trial the pasture response to N fertiliser was much higher than that in the first year at 14.8 kg DM/kg N. This response was of a similar magnitude to that of the 10-year average from a farmlet grazing trial in Waikato comparing nil-N and 200 kg N/ha/year (Glassey et al. 2013).

5.2 Nitrogen leaching

In the first year of measurement of leachates in the farm system trial, the N fertiliser treatments only commmenced in autumn 2012 and there was insufficient time for treatment effects to develop over the first winter. The leachate samplers were located at 60 cm depth and therefore sufficient time is required for treatments to lead to differences in urine-N cycling and for urine and/or applied fertiliser N to be moved down through the soil with drainage water to reach the leachate sampler depth.

By the second year there were large differences between treatments with 75% less N leaching from the nil-N treatment compared to the plus-N treatment. This difference was statistically significant ($p<0.05$), although there was relatively high error associated with the calculated N leaching values due to the large spatial variability caused by urine patches (Cuttle 1992). However, large differences in N leaching associated with N fertiliser use have been measured in other farmlet trials in New Zealand. A five-year farmlet trial in the Waikato on ash soils where average annual rainfall was 1200 mm average showed N leaching of 30 and 65 kg N/ha/year for 0 and 200 kg fertiliser-N/ha/year treatments, respectively (i.e. 55% lower N leaching without N fertiliser use) (Ledgard 2001). Previous research has also shown that the amount of N leaching can vary markedly between years and, to be confident of the magnitude of difference in the Parekarangi Trust farm (on free-draining pumice soils under a moderate rainfall average of 1300 mm/year), it is important to obtain results for N leaching over a number of years.

6. Future research

Measurements of pasture production and composition will continue on the plot trial until spring 2014. Leachate measurements on the farm system trial will continue until the end of the 2014 drainage season under the Sustainable Farming Fund project (which has been extended to autumn 2015). Possible continuation of this study after that time is currently under consideration for funding by DairyNZ. All data to the end of 2014 will be statistically analysed and a final report will be produced on results from this Sustainable Farming Fund project.

7. Acknowledgements

We thank MPI, BOP Regional Council, DairyNZ and Ballance Agri-Nutrients for funding this research. We are also grateful to Parekarangi Trust for their generosity in allowing the farm to be used for this research and to the farm management team for assistance in conduct of the research.

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