



Plantain Potency & Practice Programme

Providing confidence in a low cost,
high impact mitigation for
nitrate leaching.

October 2023



The SFFF Plantain programme is a seven-year Aotearoa New Zealand-wide collaborative research and development initiative. The aim is to substantially reduce nitrogen lost to freshwater and in greenhouse gases from the pasture-based food exporting sectors by using plantain (Ecotain®).

Funding partners

Ministry for Primary Industries
Manatū Ahu Matua



Delivery partners



Key results and messages

The biggest contributor to nitrate leaching from dairy farms is the urine patch. The concentration of nitrogen (N) in the urine patch is too high for a plant to utilise, so some of the urea in urine is converted to nitrate

through a process called nitrification, and is lost to ground water. There are four mechanisms explain how Ecotain plantain reduces nitrate leaching.

1. **Dilution effect:** Higher urination frequency and volume due to the lower DM% of plantain.
2. **Partitioning effect:** More of the N consumed (as protein) is partitioned to dung and milk instead of urine, meaning there is less N in the urine patch to be leached.
3. **Direct N retention effect:** There is evidence of Ecotain plantain reducing nitrate leaching in lysimeters, even when the urine used is from ryegrass. The Plantain programme is investigating the possible effects of plant secondary compounds driving this effect through slowing the rate of nitrification.
4. **Indirect N retention effect:** When animals consume the plant secondary compounds in plantain, they are then excreted in the urine. There is evidence of these compounds slowing nitrification in the urine patch.

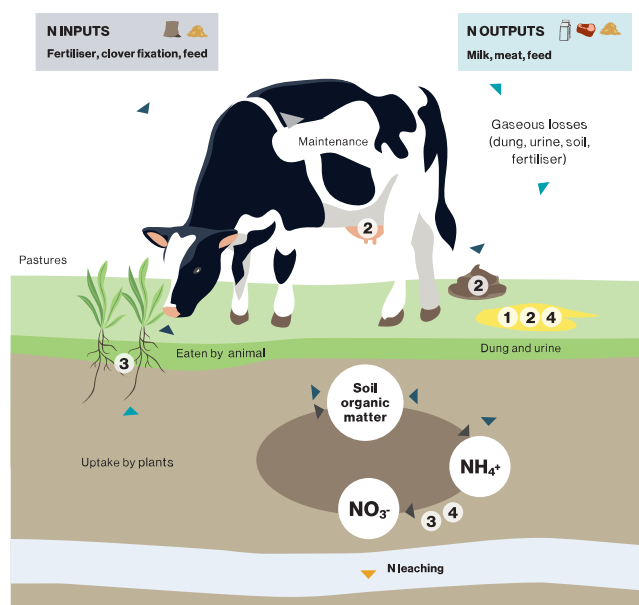


Figure 1. Diagram illustrating the mechanisms for reducing nitrate leaching of Ecotain plantain.

How plantain works

A big part of the Plantain Potency and Practice Programme is understanding how plantain works so that its full effect in different soils and climates can be modelled and cultivars can be tested for their effectiveness for reducing nitrate leaching.

Plant & Food Research are conducting hydroponic and pot experiments in glasshouses to understand the makeup of chemical compounds in different cultivars of plantain, how they influence nitrogen cycling, and how they behave in different soils. At AgResearch, the team is tracing nitrogen and carbon through lysimeters and measuring the leaching through the lysimeters under different proportions of plantain. Manaaki-Whenua Landcare Research are measuring nitrogen and carbon cycling under different proportions of plantain in field trial experiments in different climates and soils from Northland to Southland.

So far, it appears that the effect of plantain on retaining soil nitrogen varies with soil type. We are getting closer to explaining the mechanisms behind this effect.

Reductions in nitrate leaching at paddock scale

Nitrate leaching is being measured in farmlet studies at Massey and Lincoln Universities:

- The Massey University trial is on poor draining soils with a hard pan. Each replicate plot is hydrologically isolated with a mole-pipe drain system that allows the drainage water to be subsampled for total N and nitrate analysis.
- The Lincoln University trial site is on well-drained soil under irrigation. Nitrate leaching is measured through a network of suction cups at 600 mm depth (to measure nitrate concentration) and lysimeters (to measure amount of drainage).

Swards containing over 20% clover increased the risk of nitrate leaching (as seen in the 2022 graph in Figure 2). This is due to the high protein in the clover (increasing N concentration in the urine patch), and higher N fixation from the legume.

Three years of data from the Massey University farmlet trial has shown that nitrogen leaching can be reduced by 20-60% from swards containing 20-50% Ecotain plantain (equivalent to 15-30% in the diet; Figure 2).

- Year 1 of the trial had a low rainfall, meaning the overall leaching was low, however all plantain treatments (30-50% plantain) reduced N leaching by 53-73%.
- With 250 mm more rain in Year 2 compared to Year 1, more leaching occurred. Leaching was reduced by 21% when there was 32% plantain in the sward, and 46% when there was 47% plantain in the sward.
- In Year 3 the amount of plantain in the sward and diet decreased, but there was still a 20% reduction in nitrate leaching from the sward with 20% plantain.

Two years of data from Lincoln University has shown swards with 15-30% Ecotain plantain had approximately 20% lower total N leaching than ryegrass-white clover paddocks (P=0.048; Figure 3).

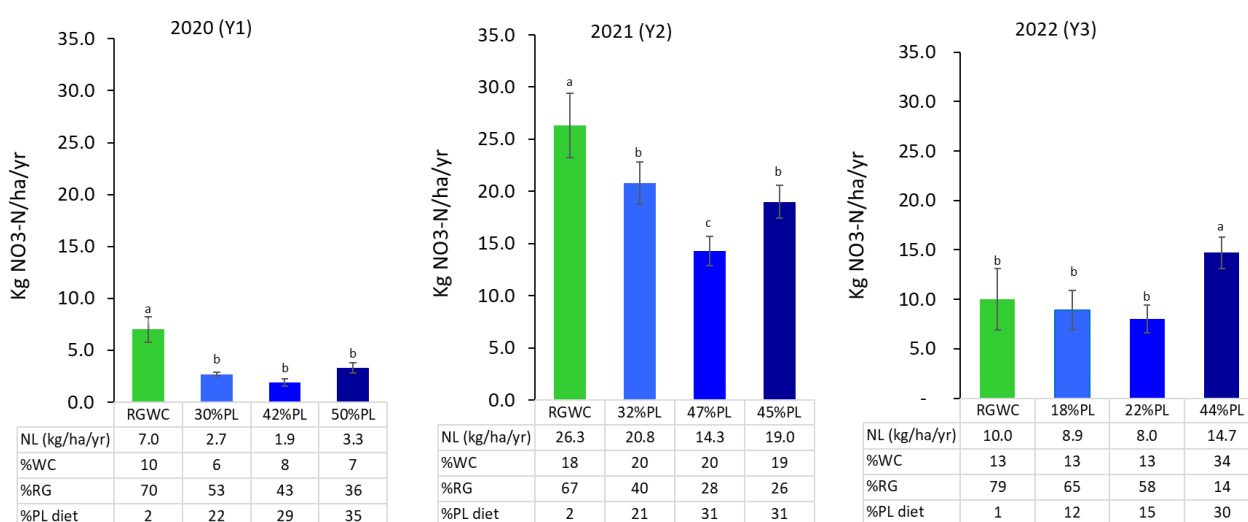


Figure 2. Cumulative nitrate leaching measured in the Massey University farm systems trial from ryegrass-white clover pastures (RGWC) and mixed swards containing three levels of plantain (%PL) during the 2020, 2021 and 2022 drainage seasons. The tables below each graph show nitrate leaching (NL; kg/ha/year), amount of white clover in the sward (%WC), amount of ryegrass in the sward (%RG) and amount of plantain in the diet (%PL diet). Error bars represent the SEM for nitrate leaching. Bars with different letters within the same year indicate a significant difference between treatments.

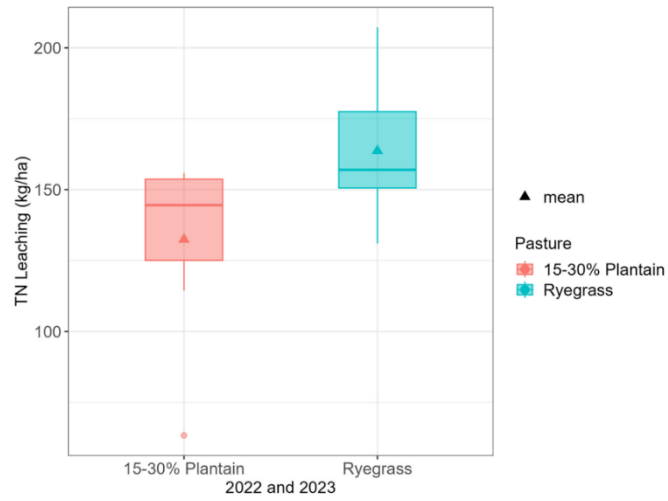


Figure 3. Total N Leaching (kg/ha) for the plantain and ryegrass pastures at Lincoln University research Dairy Farm. Data is cumulative total N leached per ha from Feb 2022 to April 2023.

Notes

Pasture & milk production

- Anecdotal evidence from programme partner farms suggests that summer dry environments generally have increased summer/autumn growth from plantain pastures.
- This is supported by data from Massey University, which indicates a higher growth rate of plantain pastures in December to February (Figure 4).
- There has been no change in feed quality by including plantain in grass-based pastures – measured across the partner farm network and in farmlet trials.
- A meta-analysis of studies conducted prior to the plantain programme showed a slight milk production advantage to plantain compared with perennial ryegrass.
- When grown in mixed swards at Massey and Lincoln University farmlet trials, plantain has not affected annual milk production.

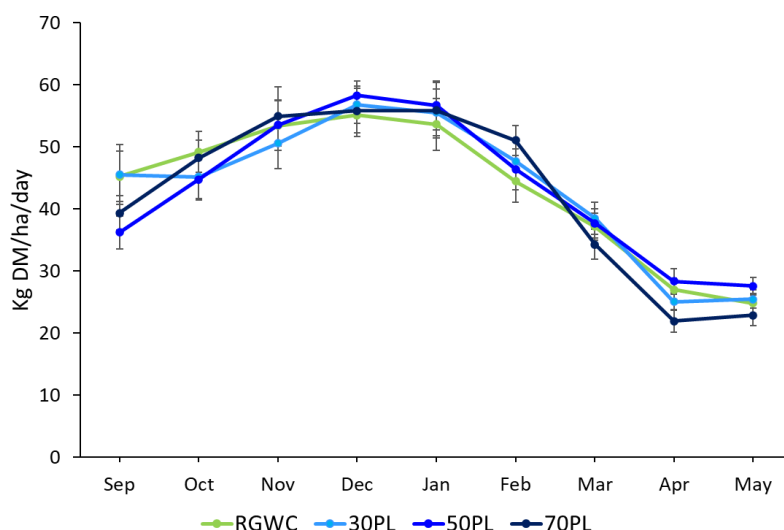


Figure 4. Average daily herbage accumulation rate for each month of pastures containing varying levels of plantain (ryegrass/white clover only, 30%, 50% and 70% plantain) measured at Massey University. Data are mean of four years.

A study at the Lincoln site conducted calibrations for rising plate meter (RPM) at 0%, around 30% and 45% plantain.

At plantain levels less than 30%, the same equation as ryegrass/white clover can be used. At higher proportions of plantain, a different regression is needed due to plantain having a lower DM% than ryegrass. More work is required to confirm what the equation should be.

Evidence is building that plantain also reduces nitrous oxide emissions

Data from AgResearch¹ (Figure 5) shows the soil mechanisms (#3 and #4) at work. Similar work from Massey University showed a 39% reduction in nitrous oxide emissions from pastures with 30% plantain.

The graph on the left from AgResearch shows reduced nitrous oxide emissions when urine

from cows grazing pure plantain was applied to pastures with varying levels of plantain. The graph on the right shows reduced nitrous oxide emissions when urine from cows grazing pure ryegrass was applied to pastures with varying levels of plantain. This shows both the diet effect and the effect of plantain interacting with soil

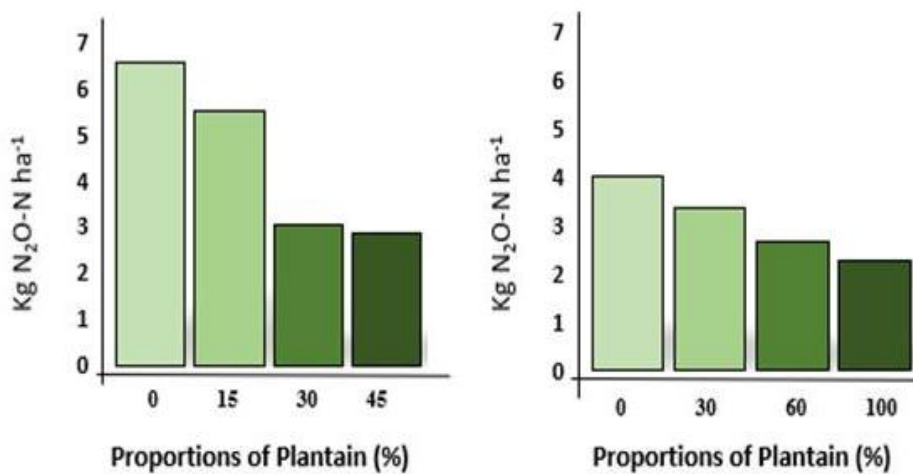


Figure 5. Nitrous oxide emissions from swards containing varying levels of plantain when urine from cows grazing plantain (left) or ryegrass (right) was applied between March and June¹.

¹ Simon, L.P., de Klein, C.A.M., Worth, W., Rutherford, A.J., & Dieckow, J. 2019. The efficacy of *Plantago lanceolata*

for mitigating nitrous oxide emissions from cattle urine patches. *Science of the Total Environment*, 691, 430-441.

Plantain in Overseer

There are 23 programme research and partner farms around New Zealand (Figure 6).

Data from 16 of these farms has been used in Overseer to model the urinary nitrogen mechanisms currently in the model (#1 and #2) and the expected reduction in nitrate leaching.

The soil mechanisms (#3 and #4) are not yet included in Overseer. We expect these to be included after 2027 when we have a fuller understanding of how they work in different soils and climates.

Modelling has shown an average 6% reduction (range 3-8%) in nitrate leaching for every 10% of plantain on the farm. The extent of reduction is largely dependent on the amount of pasture in the diet.

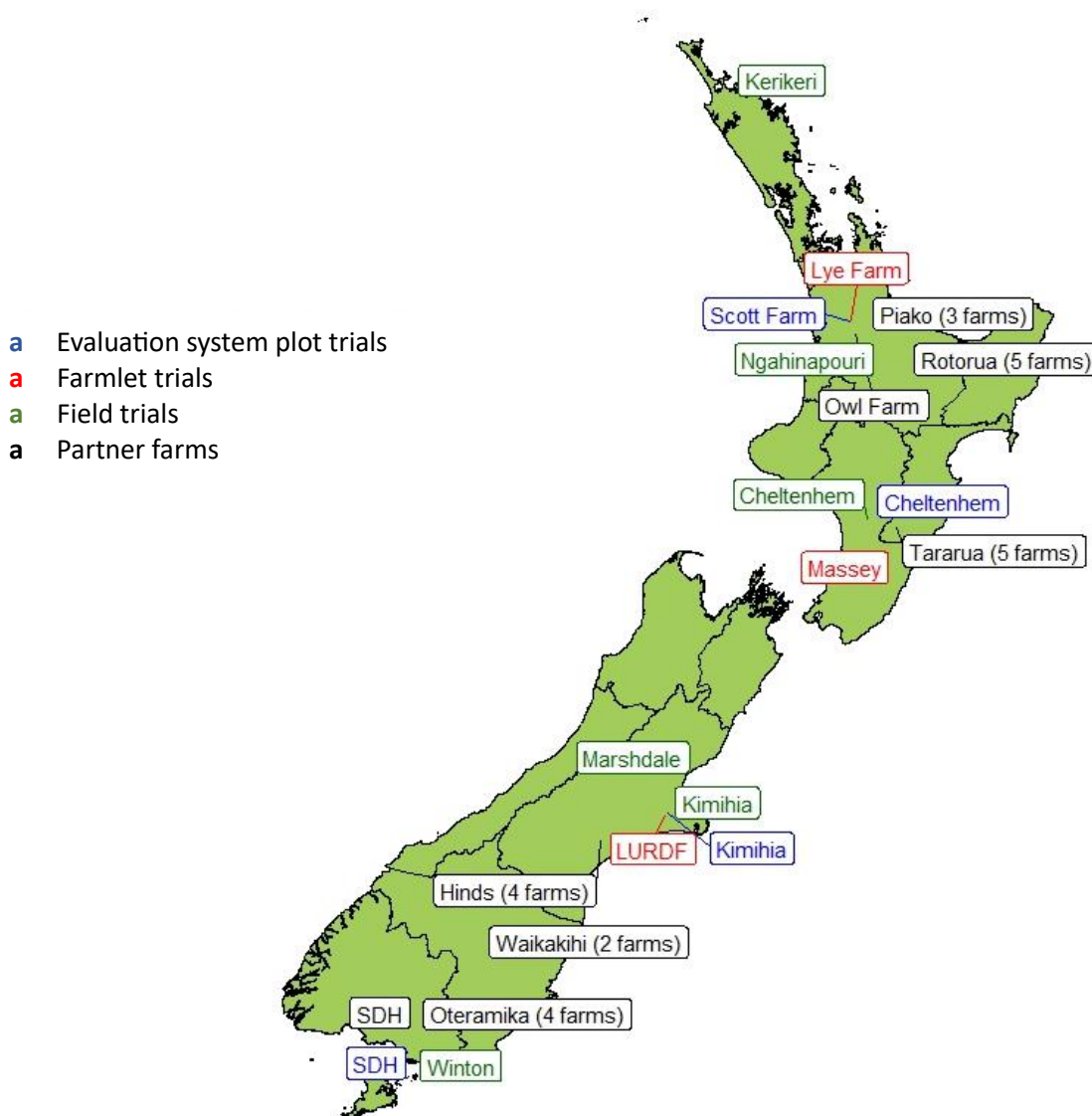


Figure 6. Location of programme research & partner farms

Economic case studies

Modelling using Farmax and Overseer shows that for 10 farms who use plantain, operating profit was reduced by average 2% (primarily due to sowing costs). Implementing the alternative mitigations mentioned in Table 1

resulted in a 1-37% reduction in operating profit to achieve the same level of N leaching reduction. Table 1 shows results for three of these farms.

Table 1. Economic case studies for three partner farms showing mitigation scenarios to reduce N leaching to the required levels.

Rotorua – 31% reduction in N leaching (59 kg N down to 41 kg N)				
	30% Plantain +	Fewer cows	Stand-off pad & 30 ha trees	Plantain broadcast at 2 kg/ha every year
Stocking rate	-7%	-31%	-5%	
Operating profit	-4%	-10%	-17%	
Southland – 20% reduction in N leaching (45 kg N down to 36 kg N)				
	30% Plantain +	Fewer cows	No crops	Plantain included in seed mix and broadcast at 4 kg/ha/year
Stocking rate	-	-24%	-	
Operating profit	-2%	-37%	-11%	
Mid Canterbury – 14% reduction in N leaching (57 kg N down to 48 kg N)				
	30% Plantain +	Fewer cows	No barley crop	Plantain included in seed mix at 3 kg/ha and broadcast at 3 kg/ha
Stocking rate	-	-20%	-	
Operating profit	-1%	-30%	-1%	

Plantain establishment & grazing management

A plantain cultivar evaluation system has been developed for evaluating effectiveness of plantain cultivars for reduced nitrate leaching.

The system currently assesses for animal effects (urinary nitrogen) and in future will

also assess for soil effects. Currently only Agritonic (marketed as Ecotain) has enough evidence to be classed as effective.

Clarification of other cultivars is expected within next 1-2 years.

Plantain ryegrass-based swards reach peak abundance at 12-18 months, before declining over the next 12-18 months (lasting approximately three years in total).

There are four methods for getting plantain established on farm:



New pasture: 3-4 kg/ha Ecotain with 8-20 kg/ha ryegrass + 5 kg/ha clover.



Pure crop: 12 kg/ha Ecotain (+ optional ~5 kg/ha clover).



Broadcast: 2-5 kg/ha with or without fertiliser. Prillcote for improved spreading (double sowing rate required).



Undersow: into existing pastures at 2-5 kg/ha.

A plantain visual assessment guide has been developed to determine the plantain levels on farm – visit dairynz.co.nz/plantain to find out more.

Manage grazing rotations the same as perennial ryegrass/white clover pastures.

- Low palatability can result from long rotations (>25 days), especially in autumn, but this can be corrected with topping.
- Avoid seedhead production to extend the life of the plant.

Pest & weed management

- Control weeds well prior to sowing as options are fewer post-establishment.
- Dictate (Bentazone) is now on-label for controlling seedling broadleaf weeds in plantain/grass/clover mixed swards.
- Pests include plantain moth and grass grub. They typically peak 2-3 years after sowing.
- Plantain moth mostly an issue in pure swards – can be sprayed with broad spectrum insecticide at larval stage from December to May.



Plantain safety

Plantain & animal health:

- Plantain pastures have lower facial eczema spores than ryegrass pastures.
- Potential risk of milk fever if plantain in diet varies around calving.
- Potential issues of mineral intake via dosatron due to less drinking.
- Potential risk of bloat on pastures high in plantain.

Milk from plantain fed cows shows:

- No risk to human health
- No impact on milk composition.
- No impact on processability of milk.
- Small increase in fat evaluation index.
- Higher Omega-3.

For more information on the plantain research programme visit dairynz.co.nz/plantain