Sustainable Food & Fibre Futures

Plantain Potency and Practice

Report for the quarter ending 31 May 2024

Programme guiding principle:			
The high-level purpose of the Plantain Potency and Practice programme is to: **Maximise the contribution of bioactive plantain-based pasture in farm systems to minimise N leaching and enhance consumer value and public trust.**			
To achieve this purpose, the programme is organised into four delivery projects			
Project 1 Prove that Ecotain® substantially reduces nitrate leaching at the farm system scale	Project 2 Confirm Ecotain® efficacy across soils and climates; define pasture composition targets; develop soil and other assays	Project 3 Remove any risk to value chains and animal wellbeing; scope product value-add potential	Project 4 Develop management guidelines and tools; demonstrate and communicate; drive adoption; extend to catchment impacts
Guiding principle key words			
Maximise contribution in farm systems; minimize leaching	Maximise contribution through all plantain pathways; bioactives	Consumer value; public trust	Maximise contribution through adoption; N leaching; farm systems; public trust.

Funding partners

Ministry for Primary Industries Manatū Ahu Matua

DairyNZ

Fonterra Dairy for life

PGG Wrightson Seeds

Delivery partners

agresearch āta mātai, mātai whetū

AGRICOM Pastures for Profit

Massey University Te Kunenga ki Pūrehuroa University of New Zealand

Manaaki Whenua Landcare Research

Lincoln Agritech

Lincoln University Te Whare Wānaka o Aoraki

Plant & Food Research Rangahau Ahumāra Kai

1. PUBLIC STATEMENT

The Sustainable Food and Fibre Futures Plantain Potency and Practice Programme is a seven-year (2021-2028) Aotearoa New Zealand-wide collaborative research and development initiative. The aim is to substantially reduce nitrogen (N) lost to fresh water and greenhouse gases from the pasture-based food exporting sectors by using plantain (Ecotain®).

2. KEY MESSAGES TO DATE

The following key messages represent the state of knowledge relating to plantain. The Plantain Potency and Practice Team is continuing to update these messages as the programme progresses.

Efficacy for reducing nitrate leaching at paddock and farm scale.

- Over four years on heavy soils at Massey University, nitrate leaching was reduced on average by 26% from pastures with Ecotain plantain constituting 18-47% of the sward and 12-30% of the diet (both % of dry matter) compared with perennial ryegrass/clover.
- At Lincoln under irrigation, pastures containing 15-30% Ecotain® plantain showed on average 17% reduction in nitrate leaching (2 years data) compared with perennial ryegrass/clover.

Effect of plantain on nitrogen gas emissions

- Evidence is growing for the effect of Ecotain® plantain on nitrous oxide emissions. Research from AgResearch and the NZ Agricultural and Greenhouse Gas Research Centre has shown that emissions from the urine patch can be decreased by up to 60%. However, results have been inconsistent, with some trials having small reductions or even small increases in emissions. More data are required to quantify and upscale this effect in different soils and climates.
- Aligned preliminary research indicates that ammonia volatilisation can be reduced from pure plantain relative to ryegrass. Further research is required to confirm this finding.

Mechanisms – the Animal Effects (Figure 1)

- Nitrogen concentration in the urine is generally decreased via dilution (through increased daily urination volume) and partitioning a lower proportion of nitrogen to urine and higher proportions to faeces and milk.
- Dilution occurs due to a lower dry matter content (higher water content) in Ecotain® plantain compared with perennial ryegrass. There may be an additional diuretic effect driven by plant secondary compounds, but there is insufficient data to support this. Modelling (Molly cow model) indicates a linear reduction in N concentration in urine relative to the proportion of plantain in the diet. This linear response is supported by grazing trial studies at Massey and Lincoln Universities. The programme is continuing to collect more data to confirm and refine this relationship.
- Changes to partitioning occurs due to differences in N fractions (lower soluble N and rumen degradable protein (RDP) and higher rumen undegradable protein); and differences in the ratio of dietary-N to non-structural carbohydrates in Ecotain® compared with perennial ryegrass. Plant secondary compounds may have an additional effect by reducing ammonia production during rumen fermentation, which has been shown in-vitro. The recent met-stall trial aims to determine whether dilution and partitioning can be predicted from known nutrition principles, or if other factors such as plant secondary compounds play a role.

Mechanisms – the Soil Effects (Figure 1)

- Ecotain® plantain has been shown to reduce nitrate leaching and nitrous oxide emissions in lysimeters, also when the urine is from cows grazing a perennial ryegrass pasture. This soil

effect may be due to reduced drainage and a slowing of nitrification driven by plant secondary compounds in root exudates. Research is ongoing to confirm these mechanisms.

- Evidence is growing that the efficacy and magnitude of the soil mechanisms is soil and season dependent.
- There is also evidence of nitrification inhibition driven by secondary metabolites found in urine from animals fed Ecotain® plantain. The efficacy and magnitude of this effect in different soils is being investigated.

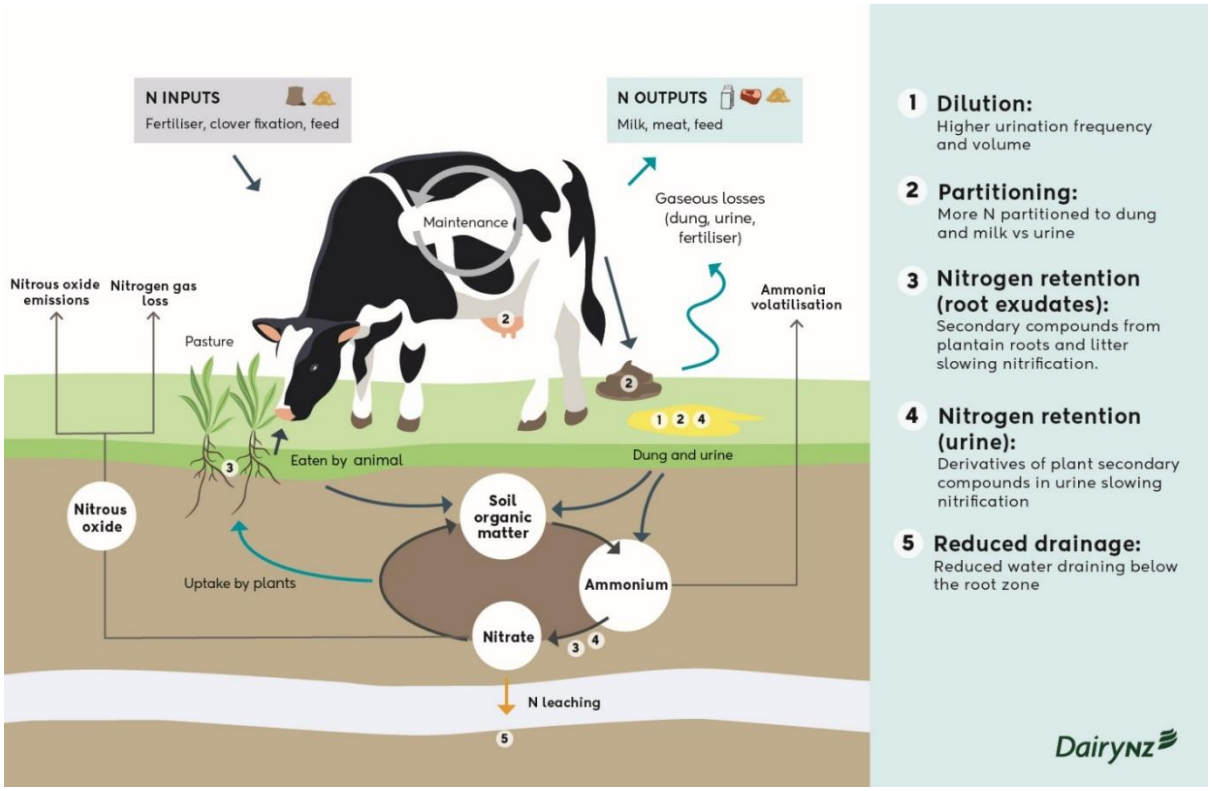


Figure 1. The nitrogen cycle and mechanisms of Ecotain plantain.

Modelling plantain in Overseer

- Nitrate leaching reduction via the animal effects can be modelled in OverseerFM. On average, for the programme's partner farms, OverseerFM indicated 6% (range 3-8%) reduction in nitrate leaching for every 10% of plantain in the pasture on average across the farm. Supplementary feeding, proportion of area in crop, soil type and rainfall affect the percent reduction at a farm level.
- OverseerFM accounts for the mitigating effect of plantain by adjusting urine patch N load and N partitioned to urine on a sliding scale from 5-60% plantain.
- Inclusion of the soil mechanisms in OverseerFM (resulting in further reductions in leaching from inclusion of plantain) may be possible with increased understanding from the science currently underway in the programme.

Effectiveness of different plantain cultivars

- There is evidence of variation in both the animal and soil effects of different plantain cultivars.

- Currently Agritonic (marketed as Ecotain®) is the only cultivar with enough evidence to be promoted as effective. Research is ongoing to develop plant-based protocols for evaluating the effectiveness of other cultivars.

Milk

- Milk from plantain-fed pastures poses no risk to human health. Presence of secondary metabolites found in milk from plantain pastures are linked to health benefits (anticancer, antidiabetic, antioxidant, antimicrobial, antiviral).
- Feeding Ecotain® plantain has little to no negative impact on milk yield, milk protein, lactose, solids, minerals or vitamins.
- Some level of milk fat depression has been observed in several studies at high levels of plantain intake. This is likely due to reduced dietary fibre in plantain, at times predisposing cows to subacute ruminal acidosis.
- There is no negative effect of Ecotain® plantain on the processability of milk into products such as skim milk, cream, cheese, yoghurt or butter.
- Levels of the beneficial Omega 3 fatty acid are elevated in milk from plantain pastures, when plantain levels in the diet are high. Another benefit is that plantain feeding potentially also reduces free fatty acid content of milk. The mechanism underpinning this is unclear.
- The Fat Evaluation Index (FEI) may increase slightly under plantain feeding (effect across trials has been variable). It is not known if any increase caused by plantain is additive to PKE feeding.
- Secondary metabolites found in milk can be correlated to the secondary compounds found in plantain pastures. However, the levels of secondary compounds in the plant varies, making it difficult to use the metabolites as a measure of plantain intake.

Meat

- Plantain (and other herbs) can take up minerals more efficiently than grass. This poses risk of higher presence of heavy metal in offal. The regulated maximum level of cadmium in offal for consumption is never exceeded in New Zealand, given that offal from animals older than 2 years cannot enter the food chain. However, the risk will be evaluated in our research.

Animal health

- Plantain pastures have lower facial eczema spore counts compared with perennial ryegrass pastures.
- Although we have not yet seen a consistent link between metabolic issues and plantain, farmers should be cautious with changing between pastures with and without plantain during calving due to differences in calcium, magnesium, potassium and sodium content.
- Animals will consume less trough water with an increase in plantain content in the pasture. This can reduce intake of minerals or other medication supplied via inline water dispensers.
- In the same soil, plantain takes up more copper than perennial ryegrass / white clover pastures. The copper in plantain may be more bioavailable to the animal, increasing liver copper stores. Farmers should monitor liver copper concentrations with their vet and adapt their supplementation strategy if needed.
- Cows grazing pastures with a high proportion of plantain can have an increased risk of bloat, particularly where white clover intake is high. Plantain appears to delay the onset of bloat; bloat on pastures containing plantain has been observed to occur later (2-5 hrs after fresh pasture allocation) than bloat seen on high clover pastures (typically 0.5-2 hrs after fresh allocation).

Production

- When added to a mixed sward with ryegrass and clover, plantain has maintained milk production, pasture growth and quality in most cases. Plantain mixed swards have higher herbage production in the summer/autumn period in summer dry environments. Some studies have also shown reduced winter production.

Plantain abundance and persistence

- Plantain is a short-lived perennial herb with a seasonal growth pattern that puts it in competition with spring-dominant grasses such as perennial ryegrass.
- Peak abundance in a perennial ryegrass-based sward generally occurs at around 6-12 months after sowing and tends to decline after two years. Abundance and persistence vary with soil, climate and companion species. Research continues to form specific recommendations and examples under a range of scenarios.
- Plantain can be established as a pure sward, as a new mixed sward with grass and/or clover, or under-sown or broadcasted into existing pastures. In a ryegrass-based sward, abundance is usually greatest when sown as a new pasture.
- Moderate plantain levels can be maintained by broadcasting or under-sowing into existing pastures. To get substantive amounts of plantain across the farm (>20%), most farmers use a combination of new pastures and broadcasting across the whole farm.
- Abundance and persistence of plantain is greater in more open swards and/or where the companion grass species is less competitive.
- There are limited herbicide options for weed control in plantain pastures. Farmers have had success with controlling broadleaf weeds on a 3-year cycle, and re-establishing plantain into mixed swards via broadcasting or undersowing.

KEY HIGHLIGHTS AND ACHIEVEMENTS FOR THE QUARTER

Plantain All-Team Conference

- 85 members (17 online) of the Plantain team including partner farmers and End User Advisory Group members met for the annual All Team Conference on the 18th-19th of June. The focus of the conference was to confirm key messages to date and priorities moving forward, and with an emphasis on development of plantain management strategies and the next phase of agronomy research. The group visited Owl Farm, AgResearch's Ruakura lysimeter facility, and DairyNZ's Lye Farm animal facilities as part of the conference.
- The conference confirmed the priority direction of the programme, which was to finish the farmlet scale research, continue work to understand and quantify soil mechanisms driving reduction in leaching and nitrous oxide emissions from plantain, and continue to work with partner farmers on methods for achieving target levels of plantain on farm.

Plantain team at the 2024 Annual All-Team Conference

Left to right: Owl Farm plantain crop, Jo Sheridan explaining Owl Farm, Nicole Hammond presenting her results in the met stalls.

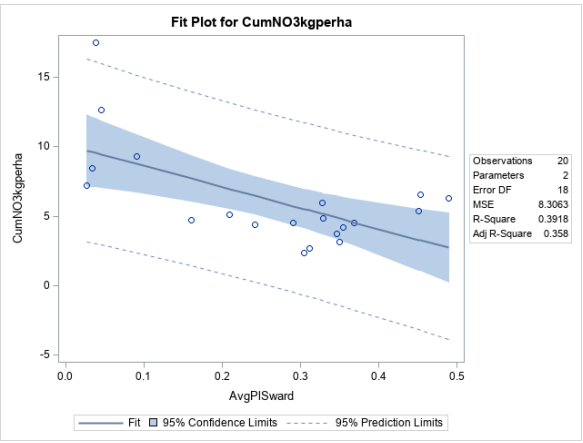
Left: Farmer panel. Right: Brendon Welten explains the lysimeter study at Ruakura.

Year 4 Massey leaching data reported

- The fourth year of leaching data from the Massey trial site was reported during the quarter and a preliminary analysis of all four years has been conducted.
- Analysis over four years showed nitrate leaching was reduced by on average 26% in plantain pastures compared to ryegrass/clover (Table 1). When assessed annually, statistically significant treatment differences were evident in Years 1 and 2. A significant negative linear correlation between plantain in the sward and nitrate leaching was also found in Years 1 and 2 (Figure 1).
- Figure 3 helps to explain in more detail what happened in each year. The high leaching in the PL70 treatment in Year 3 could be explained by very high clover content in that treatment. Lower treatment differences in the other treatments in that same year are likely a result of lower plantain levels.
- Year 4 was a very wet season and as such pasture utilisation and resulting N load was low. This is likely to have contributed to low overall nitrate leaching levels and differences between treatments were small. Also in that wet season, the ryegrass treatment yielded more than the plantain treatments (Table 2) which may have resulted in greater N uptake in that treatment. An N input/output analysis is now underway to further understand the results.

Table 1. *Nitrate leaching results per year from years 1 to 4 at Massey Farmlet trial. Superscripts a-c show significance difference (P<0.05) between herbage treatments (ryegrass and white clover (RGWC), 30PL (targeting 30% of plantain in sward), 50PL (targeting 50% of plantain in sward) and 70PL (targeting 70% of plantain in sward)).* ***Actual plantain % in each treatment can be found in Figure 2.***

	Herbage Treatments				
Drainage Season	**RGWC**	**PL30**	**PL50**	**PL70**	**P value**
2020 (Year 1)	11[a]	4.7[b]	3.7[b]	5.2[b]	0.0012
2021 (Year 2)	24.5[a]	19.2[b]	13.3[c]	18.0[b]	0.0010
2022 (Year 3)	10.0	8.9	8.0	14.7	0.0613
2023 (Year 4)	6.0	5.3	3.9	5.7	0.4277
Herbage Treatment Average	12.9[a]	9.5[b]	7.2[c]	10.9[b]	P<0.001



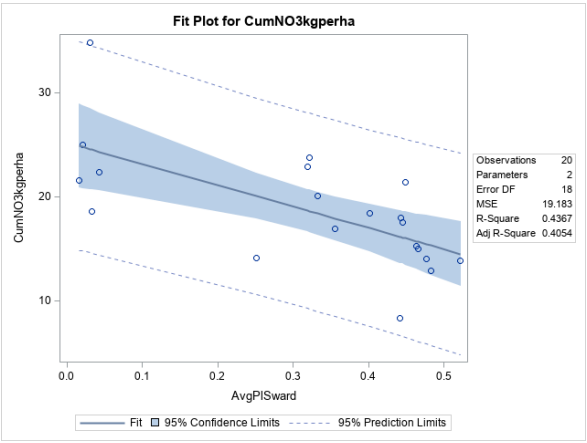
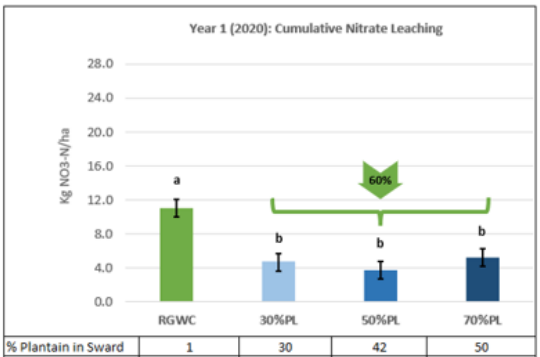
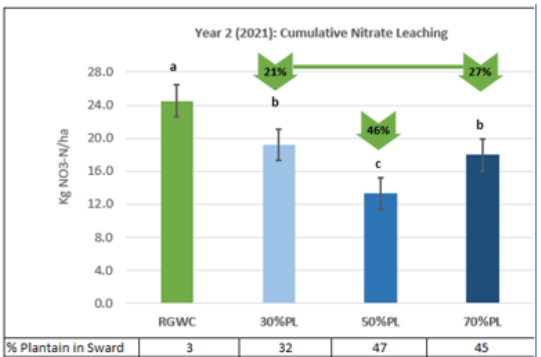


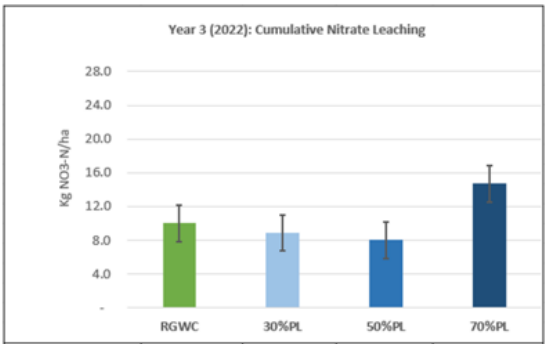
Figure 1. *Effect of average plantain % in sward on total nitrate leaching in years 1 (2020; left) and 2 (2021; right) at Massey Farmlet Trial.*



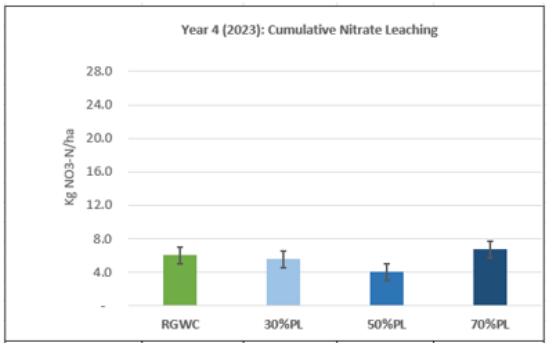
	RGWC	30%PL	50%PL	70%PL
% Plantain in Sward	1	30	42	50
% Plantain in Diet	2	22	29	35
% White Clover	10	6	8	7
% Ryegrass	70	53	43	36
Cum Nitrate Leaching	**11.0**	**4.7**	**3.7**	**5.2**



	RGWC	30%PL	50%PL	70%PL
% Plantain in Sward	3	32	47	45
% Plantain in Diet	2	21	31	31
% White Clover	18	20	20	19
% Ryegrass	67	40	28	26
Cum Nitrate Leaching	**24.5**	**19.2**	**13.3**	**18.0**



	RGWC	30%PL	50%PL	70%PL
% Plantain in Sward	1	18	22	44
% Plantain in Diet	1	12	15	30
% White Clover	13	13	13	34
% Ryegrass	79	65	58	14
Cum Nitrate Leaching	**10.0**	**8.9**	**8.0**	**14.7**



	RGWC	30%PL	50%PL	70%PL
% Plantain in Sward	3	24	27	32
% Plantain in Diet	3	16	18	22
% White Clover	17	18	12	22
% Ryegrass	72	51	53	41
Cum Nitrate Leaching	**6.0**	**5.5**	**4.0**	**6.7**

Figure 2. *Key nitrate leaching results per year from years 1 to 4 at Massey Farmlet Trial. Superscripts a-c show significance of differences (P<0.05) between herbage treatments (ryegrass and white clover (RGWC), 30PL (targeting 30% of plantain in sward), 50PL (targeting 50% of plantain in sward) and 70PL (targeting 70% of plantain in sward)). See table below each treatment for actual % plantain in the sward and diet, and the % white clover and ryegrass.*

Table 2*. Estimated herbage yield (t DM/ha/yr) for each herbage treatment at Massey farmlet trial: ryegrass and white clover sward (RGWC; targeting 0% of plantain in sward); 30PL, 50PL, 70PL (targeting 30, 50 and 70% of plantain in sward, respectively).* ***See Figure 2 for actual plantain achieved in each year.*** *Superscripts a-d show significance difference (P<0.05) between different herbage treatments.*

Production season	**Herbage treatment**				**P-value**
	RGWC	**30PL**	**50PL**	**70PL**	
2023/24 (Year 5)	16.6	15.7	15.6	15.9	n.s
2022/23 (Year 4)	14.3[a]	12.5[b]	12.9[b]	12.5[b]	<0.05
2021/22 (Year 3)	14.7	14.3	14.3	10.9**	n.s

2020/21 (Year 2)	15.8	16.9	17.3	16.6	n.s
2019/20 (Year 1) *	15.3	14.9	15.1	15.3	n.s

***** Data collection started in Sept 2019. Year 1 includes data for 9 months (Sept-May).

****** Due to PL70 being re-sown in autumn of 2021, no pasture yield data for PL70 were collected in the winter of 2021.

Partner farm autumn monitoring

Whole farm visual assessments of plantain were conducted during autumn, and more than 420 farmers and rural professionals also gathered at field days and other events during the quarter. The results of the partner farm monitoring will be available next quarter.

Rotorua partner farmers discuss the successful establishment of plantain from broadcasting with fertiliser.

Challenging plantain research

- A group of authors challenged the science behind the efficacy of plantain in a review published in the NZ Journal of Agricultural Research. The Plantain science team welcome feedback and scientific debate and as such have completed a considered review of the paper. The conclusion from the team is that this review is written from a certain perspective, it does not reflect the full scale of evidence highlighting plantain's efficacy, and in many cases has incorrectly interpreted research findings and incorrectly reported the way in which DairyNZ has recommended plantain use. The team has submitted a response to the NZ Journal of Agricultural Research.

NEXT QUARTER PLANS / STAKEHOLDER ENGAGEMENT

- The programme's mid-term review will be completed and reported.
- A response has been submitted to New Zealand Journal of Agricultural Research to provide evidence of the efficacy of plantain and help restoring confidence in the credibility of associated research conducted over the past 15 years.
- Results from autumn monitoring of partner farms will be reported.
- Year 3 leaching will be measured at Lincoln and Year 5 at Massey, and the final season of grazing will get underway with Massey finishing in November 2024 and Lincoln finishing in November 2025.
- Analysis of feed composition data from the recent cultivar evaluation metabolism stall experiment will complete the dataset determining differences in nitrogen excretion and methane emissions from the experiment.
- Leaching and gaseous emissions (from an aligned study) will be measured in the second soil lysimeter leaching experiment across two soil types and five levels of plantain (varying from 0 to 100% plantain contents).
- Results will be finalised from metabolomic analysis of plantain root exudates grown in different soils, and from a soil incubation study comparing carbon respiration and potential nitrification rate from soils treated with plantain and ryegrass urine.
- Results will be finalised from testing heavy metals, carcass characteristics and aspects of meat quality from cattle grazing plantain vs. ryegrass pastures.
- More case studies and associated recommendations for management of pastures with plantain will be developed and released on the DairyNZ website.
- A report will be finalised assessing the potential environmental and economic impact of plantain in the Rotorua Lake catchment; and on-farm data will be collected in Edendale, Southland, in preparation for modelling potential impact of plantain and stacking mitigations in that catchment.

INVESTMENT

Investment period	Co-investor contribution	MPI contribution	Total investment
During this Quarter	1,615,756	1,458,176	3,073,932
Programme to date	6,666,162	8,219,784	14,885,946