Low N Systems

Low N Systems

Funding Partners

Delivery Partners

Lincoln University Research Dairy Farm (LURDF)

- Established in 2009 with 100 cows on 33 ha
- External lease expired taking farm up to 56 ha in 2011
- 66 ha effective since 2016
- Paparua sandy loam and Wakanui silt loam soils
- Cow numbers: 180 - 200 Holstein Friesian x Jersey dairy cows
- Centre pivot irrigation and half pivot, sprinklers in corners
- Advanced milking system with cow ID (Del Pro, Afi collar), herd management system, individual milk flow recording, automatic calf feeders pre-weaning
- 12 aside herring bone, separate milk lines, three vats
- Feed yards, feeding stall and animal handling facilities for small herds and indoor feeding individual cows
- Low stocking rate to allow for areas coming in and out of the farm for research

Plantain Potency and Practice Programme

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

Efficacy

- Benefit at scale
- *How* plantain works
- Range of soils/climates

Safety and Integrity

- Risk/benefits to milk, meat, animal health/welfare

Adoption and Impact

- Management for persistence
- Tools for regulation
- Partner farms, modelling
- Cultivar evaluation

Funding partners

Ministry for Primary Industries
Manatū Ahu Matua

DairyNZ

Fonterra
Dairy for life

PGG Wrightson Seeds

Delivery partners

agresearch
ātā mātai, mātai whetū

AGRICOM
Pastures for Profit

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

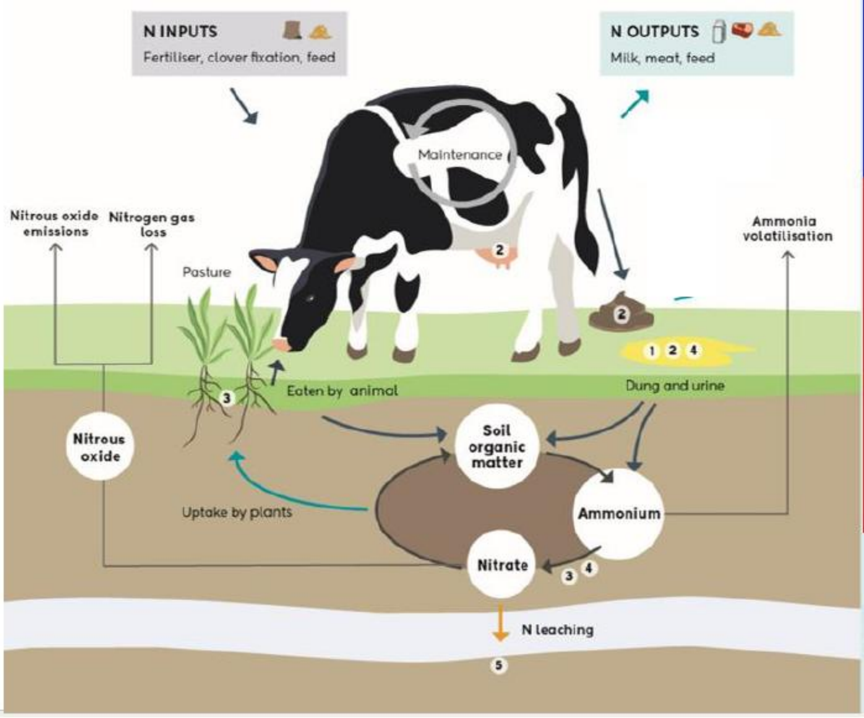
Manaaki Whenua
Landcare Research

LINCOLN AGRITECH

LINCOLN UNIVERSITY
TE WHARE WĀNAKA O AORAKI

Plant & Food Research
Rangahau Ahumāra Kai

Mechanisms for reduced N losses



Overseer – av. 6% reduction/10% plantain

1 **Dilution:**
Higher urination frequency and volume

2 **Partitioning:**
More N partitioned to dung and milk vs urine

3 **Nitrogen retention (root exudates):**
Secondary compounds from plantain roots and litter slowing nitrification.

4 **Nitrogen retention (urine):**
Derivatives of plant secondary compounds in urine slowing nitrification

5 **Reduced drainage:**
Reduced water draining below the root zone

Lysimeter trials (ryegrass urine): 1% plantain = 1mm reduced drainage & 0.57 kg N/ha reduced N leaching.

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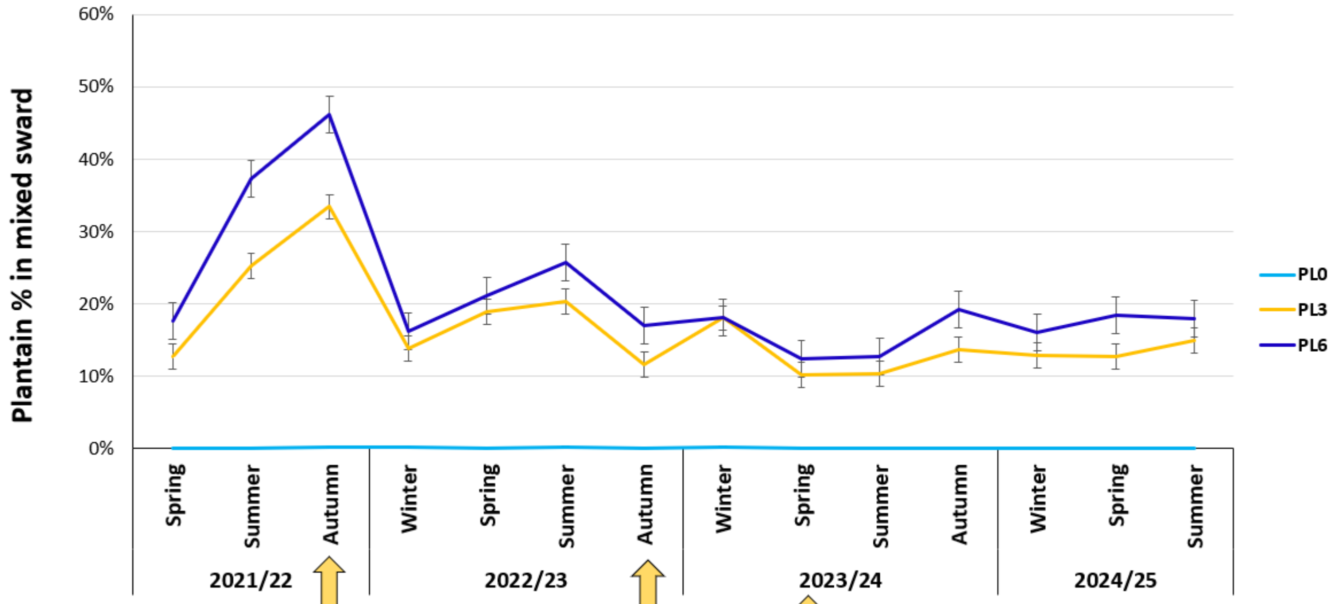
DairyNZ

Plantain % in the mixed sward- Botanical composition

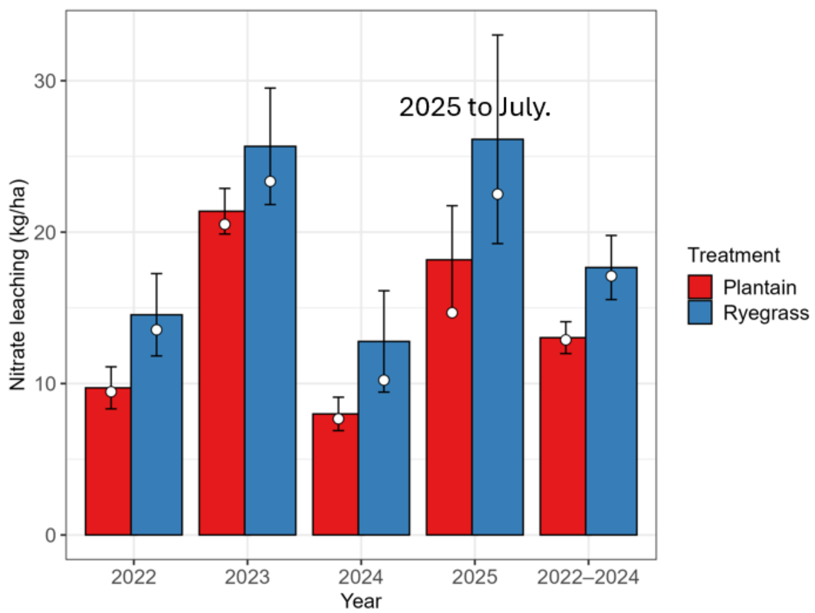


Over-sowing
36% of PL3 area
31% of PL5 area
Seed rate 5-7 kg/ha

Direct drilling
34% of PL3 area
31% of PL6 area
Seed rate 6 kg/ha

Over-sowing
100% of PL3 area at 5 kg/ ha (coated seed 10 kg/ha)
100% of PL6 area at 7 kg/ ha (coated seed 14 kg/ha)

26% reduction in leaching from 17% plantain at LURDF



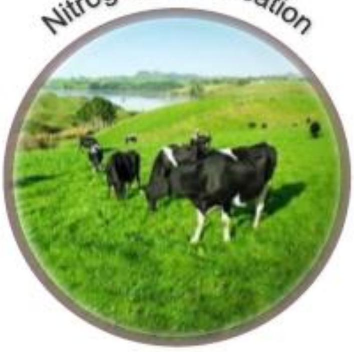
Plantain proportions:
2022: 24%
2023: 17%
2024: 12%
Average: 17%

2025: 13% plantain, 35% lower leaching so far

Low N Systems

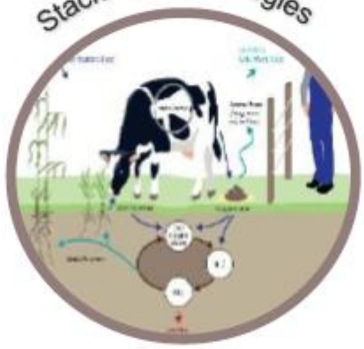
Stacking of nitrogen (N) mitigation options for transformational improvements to freshwater quality

Nitrogen Optimisation



Developing a real-time, milk-based indicator tool to monitor and manage excess N & reduce urinary N loss risk

Stacking Technologies



Modelling, measuring and demonstrating transformational N leaching reductions (>40-60%)

Stakeholder Engagement

Facilitating implementation of stacked Low N systems

Low N Farmlet Trial (Stacking Technologies) - LURDF

Study objectives

This study evaluates the impact and practicality of a ‘stacked’ set of complementary mitigations to reduce nitrogen (N) leaching on milk production and profitability in a Canterbury dairy farm system. Target N loss reductions are 40 to 60 percent across the whole farm system (milking platform and wintering & support land) compared with a typical farm system. The aim is to demonstrate a stacked low N farm system that achieves significant N leaching reductions whilst maintaining farm business viability.

Background

The Low N Farmlet Trial began in July 2023 at the Lincoln University Research Dairy Farm (LURDF) and will run for three seasons. The study compares a typical Canterbury dairy farm system (‘Control’ farmlet) with a ‘Stacked’ farmlet that incorporates:

- diverse pasture species (Italian or Hybrid ryegrass and Plantain),
- less than ½ Control farm N fertiliser,
- a 6% lower stocking rate, and
- modified wintering practices (diverse pasture and balage compared with kale and balage).

The research team will monitor how the farmlets perform from a productivity, economic and environmental perspective against modelled expectations.

Design

Each farmlet consists of a non-replicated ~12 ha milking platform, subdivided into 24 paddocks, and a 5-ha support block for wintering, youngstock and some balage production. The key features of the farmlets are summarised below. Tactical mitigations include monitoring bulk milk urea as an indicator of herd surplus dietary N, and options considered include feeding lower dietary N:ME supplements, extending rotation length, and offering fresh pasture allocations in the afternoon instead of the morning.

	Control	Stacked
Description	Canterbury Current	Stacked N mitigations (low N)
N fertiliser	190 kg N/ha/yr	80 kg N/ha/yr
Pasture species	Irrigated perennial ryegrass & white clover	Irrigated plantain (target 30%), Italian or Hybrid ryegrass, white & red clover
Annual Regrassing	10% full renovation	10% full renovation +15% undersowing
Number of cows	40	39
Stocking rate	3.4 cows/ha	3.2
Milking platform area	11.8 ha	12.2 ha
Support area	1.8 ha Wintering + 3.2 ha Youngstock & supplements	3.0 ha Wintering etc. + 2 ha Youngstock & supplements
Winter system	Kale crop & balage	Pasture & balage
Tactical mitigations	No	Yes

Low N Farmlet Trial layout

How are we measuring N cycling on the milking platform?

	Measurements
Suction cups	Leachate collection plus drainage model
Soil measurements	Deep soil cores at 3 depths
Pasture measurements	Mass, nutrient & botanical composition
Animal measurements	Liveweight, BCS, milk yield & composition, urine & faecal N, health, bulk milk urea from 2 separate vats
Climate data	Rainfall, temperature, PET, soil moisture probes
Modelling	Farmax near real time, Overseer end of season
N balance estimation	Calculations based upon collected data, N inputs and outputs etc.

Physical and environmental data – 2023-24 and 24-25 seasons

Table 1. Comparison of key physical & environmental measures for the Control and Stacked farmlets for the milking platform in each of the 2023-24 and 2024-25 seasons (as predicted by FARMAX and OverseerFM) using farmlet data. Financial data provided below are preliminary.

1 Milk production per cow and per hectare is total milk produced (including any milk retained for calves).

	2023/24		2024/25 (Preliminary)		Average Difference
Farmax-Overseer Results	Control	Stacked	Control	Stacked	
Milksolids per cow (kg MS/cow)[1]	450	445	468	461	-1%
Milksolids per ha (kg MS/ha)[1]	**1,536**	**1,419**	**1597**	**1470**	-7%
Nitrogen use total (kg N/ha)	190	80	173	78	-56%
Est pasture offered (tDM/ha)	15.1	14.1	15.5	14.1	-8%
Silage conserved (t DM/ha)	0.25	0.53	0.78	0.43	-7%
Supplements offered (t DM/ha)[2]	2.4	2.5	2.7	3	8%
Total feed offered (tDM/ha)	17.5	16.6	18.2	17.1	-6%
Est Farm profit[3] ($/ha)	5,800	5,300	7,400	6,500	-11%
Purchased N surplus[4] (kg N/ha)	**72**	**-24**	**39**	**-32**	**-150%**
Predicted N leach loss (kg N/ha)	**33**	**20**	**33**	**22**	**-36%**
Predicted total GHG (kg CO_2e/ha)	**14,020**	**12,350**	**14,690**	**12,980**	**-11%**

2 Includes estimated supplements fed to replacement heifer calves prior to grazing off (Farmax default).
3 2023/24 Profit (before tax) based on upon $8.11/kg MS and 2021-22 expenses; 2024-25 profit based on $10.14/kg MS and 2024/25 DairyNZ Econ Tracker expense estimates. Expenses assume same wintering cost ($/cow/week) for both farmlets. Analysis of the comparative costs of kale vs pasture-based wintering for Control and Stacked farmlets, respectively, will be available in due course.
4 Purchased N Surplus is the difference between N purchased in feed and fertiliser and N exported in milk and meat, and for this farm includes N removed from the farm as effluent.

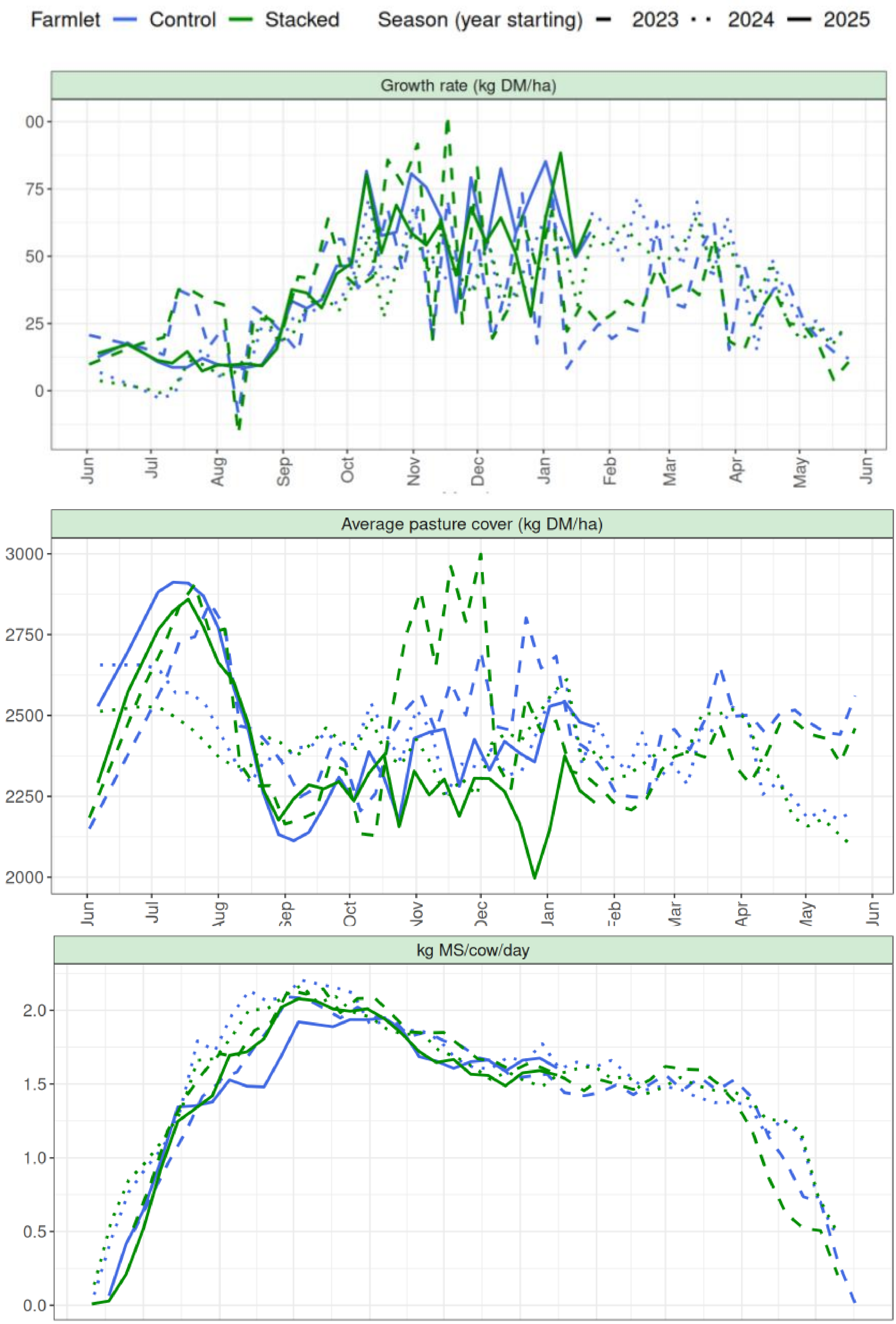
Summary of Key Results (Years 1 and 2):

- Milksolids per cow were similar, but production per hectare was 7% lower for the Stacked farmlet relative to the Control farmlet.
- Pasture production on the Stacked farmlet differed in seasonal growth patterns.
- Predicted N leaching (kg/ha) was, on average, 36% lower for the milking platform of the Stacked farmlet, while total greenhouse gas (GHG) emissions (kg CO_2e/ha) was 11% lower. Emissions intensity (kg CO_2e/kg MS) is estimated to be 6% lower from the Stacked farmlet.
- Operating profit per ha averaged over both years was 11% lower for the Stacked compared with the Control farmlet, with a larger difference in 2024-25, partially a result of the higher milk price in 2024-25. The key drivers were lower milk revenue and higher costs for pasture conservation (year 1 only), increased purchased silage (year 2 only) and additional re-grassing, but savings were made in lower N fertiliser use.
- Overall, Year 1 results were similar to those predicted from pre-trial modelling; year 2 shows a larger difference due to the higher milk price (as above).

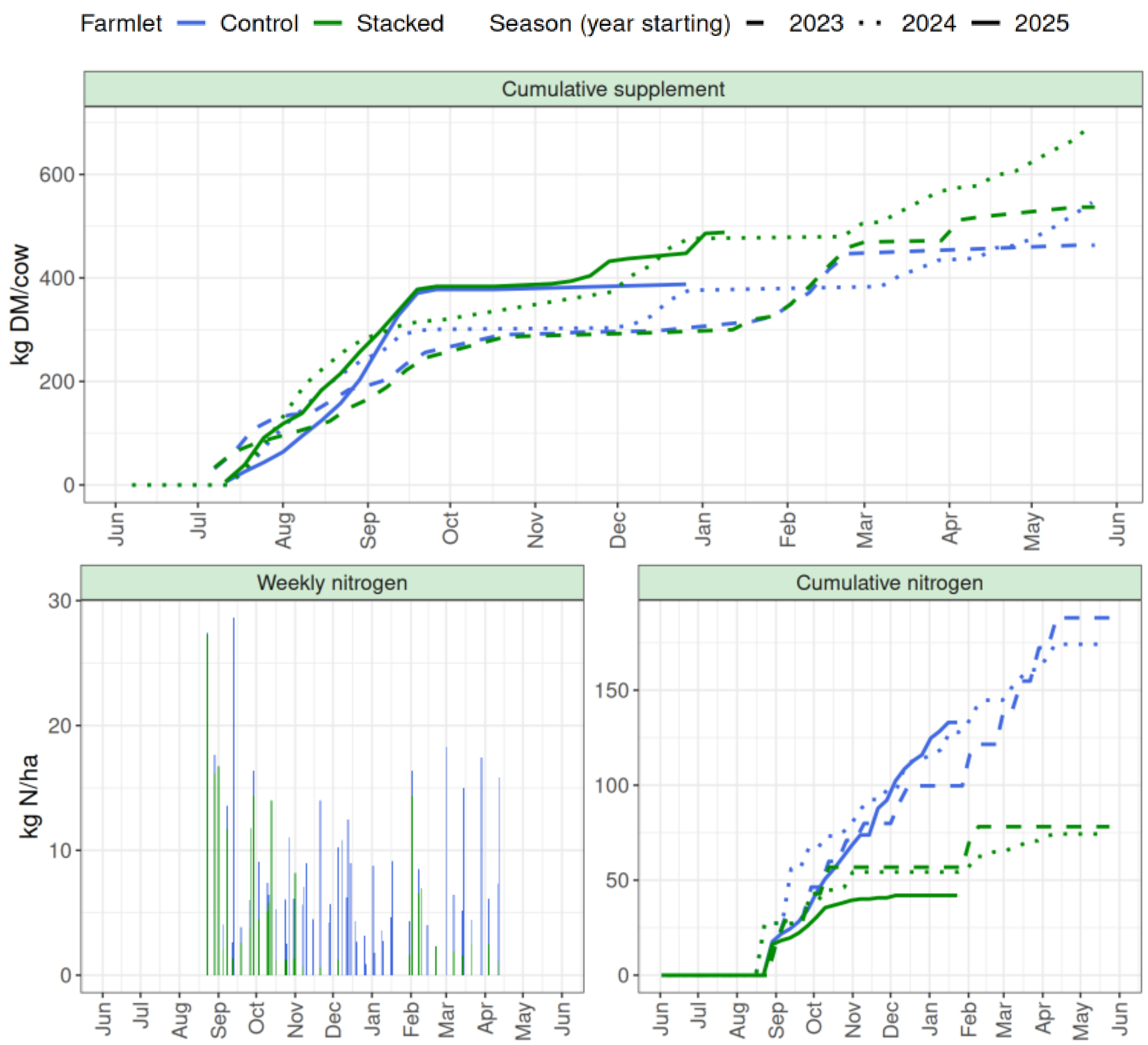
For more details refer to Wheadon et al. 2024: https://australasiandairyscience.com/wp-content/uploads/2024/11/Proceedings-of-the-Australasian-Dairy-Science-Symposium-2024-v24112024.pdf#page=92

2025-26 season to date farmlet results

		Stacked	Stacked	Control	Control
	Key Weekly Info	**26 Jan**	**19 Jan**	**26 Jan**	**19 Jan**
Area	Grazing area (ha)	12.2	12.2	11.7	11.7
Stock No.s	Cows currently milking to vat	37	39	39	38
	Stocking rate (cows/ha)	3.02	3.19	3.33	3.25
Milk prod.	Days in Milk	169	162	172	165
	Milksolids daily (kg MS/cow/day)	1.63	1.62	1.71	1.68
	Milksolids to date (kg MS/cow)	277	266	278	264
	Milksolids per hectare to date (kg/ha)	884	847	885	841
	Milk fat (%)	5.12	5.10	5.0	5.07
	Protein (%)	4.05	4.0	4.02	3.98
	Milk urea (mg/dL)	25	25	25	29
Feed budget	Average pasture cover (kg DM/ha)	2230	2270	2370	2500
	Pasture growth (kg DM/ha/d, RPM)	61	48	60	49
	Pasture demand (kg DM/ha)	54	57	60	61
	Area closed for silage (ha)	0	0	1.1	0.5
	Rotation length (weekly ave. - days)	27	24	24	24
	Silage made cumulative (kg DM/cow)	85	85	129	129
	Silage fed (kg DM/cow/d)		0		0
	Silage fed cumulative (kg DM/cow)	481	481	445	445
	Pasture ME (MJ/kg DM)		10.8		11.1
	Pasture crude protein (% DM)		19.3		19.7
	Average BCS	4.1	4.1	4.3	4.3
Cows	Average LWT (kg)	491	492	504	504
	Current bulk milk SCC ('000)	84570	101750	47330	45000
	Nitrogen applied to date (kg/ha)	45	45	132	124
General info.	Irrigation applied this week (mm)	1.4	27	1.4	27
	Average soil temperature (ºC)	16.3	15.5	16.3	15.5



Farmlet
Control
Stacked
Season (year starting)
2023
2024
2025
Growth rate (kg DM/ha)
00
75
50
25
0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Average pasture cover (kg DM/ha)
3000
2750
2500
2250
2000
kg MS/cow/day
2.0
1.5
1.0
0.5
0.0

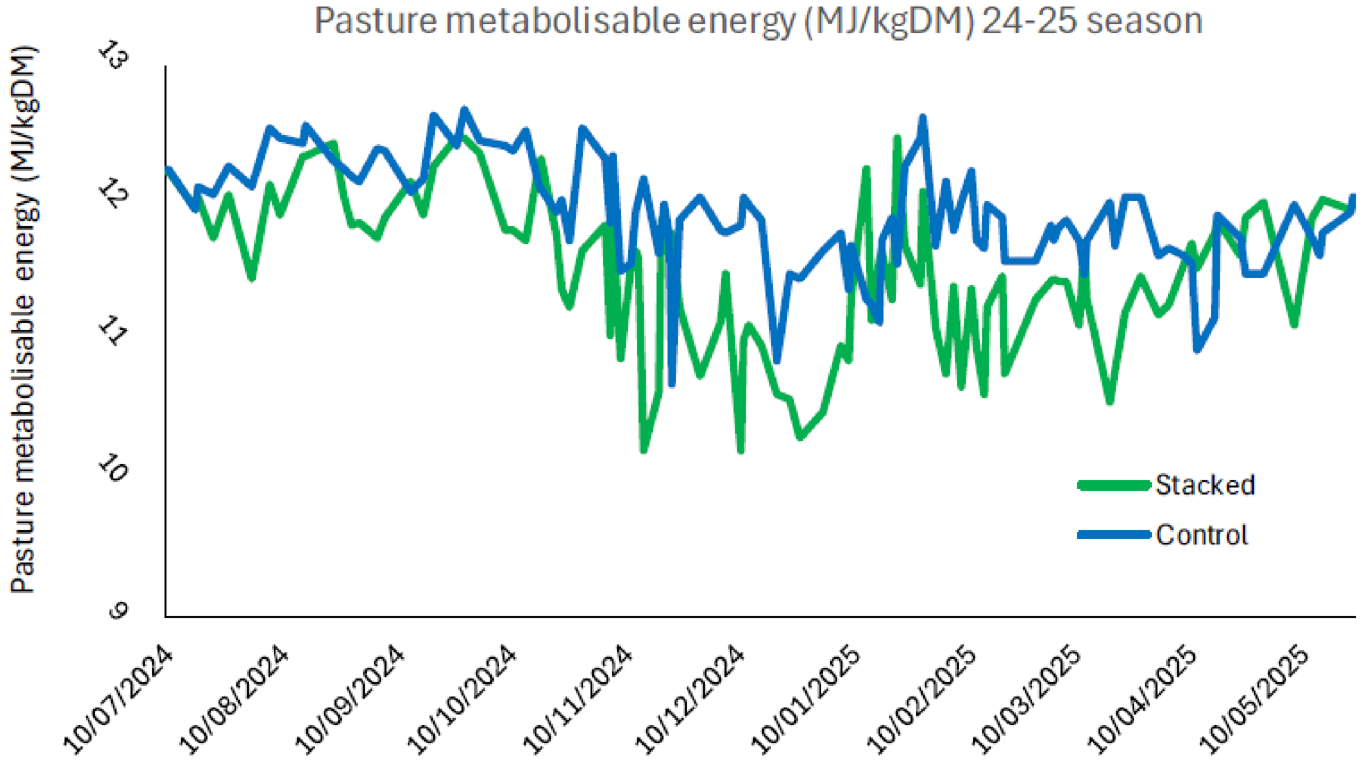


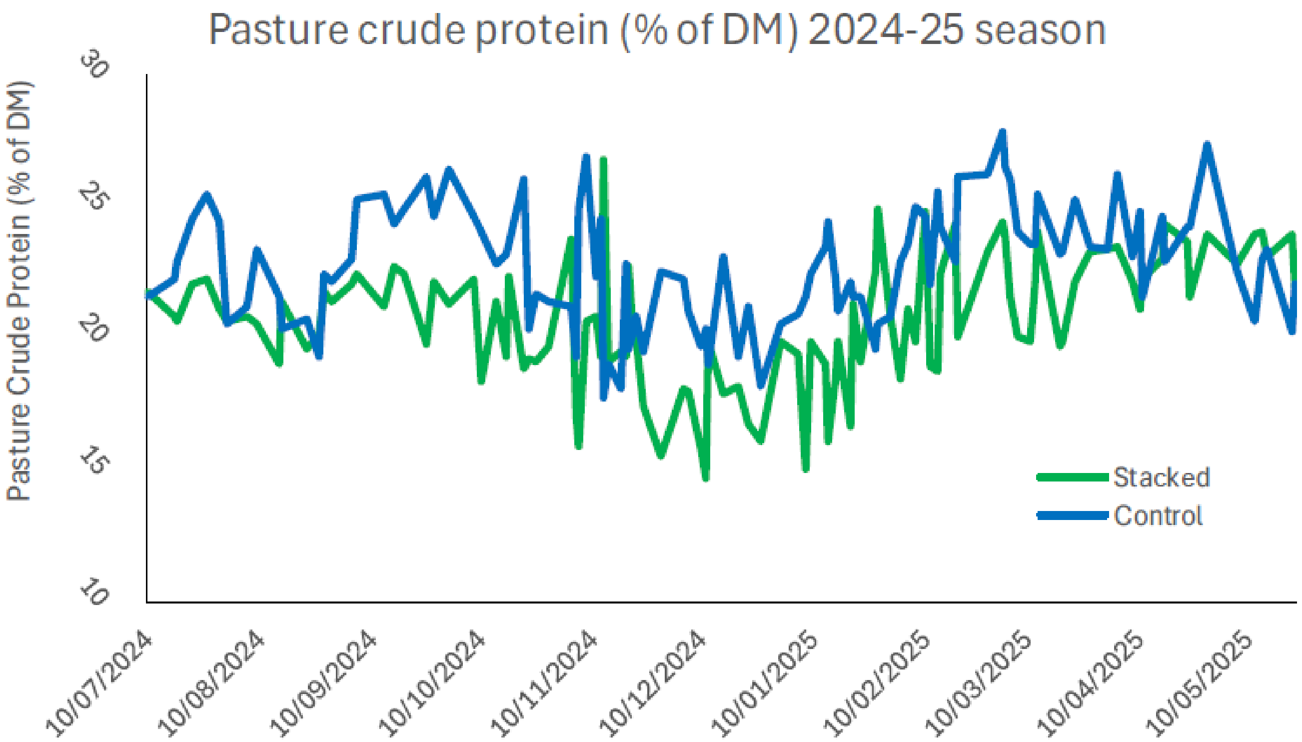
Pasture management, yield and composition

The farmlets were an evolution of a previous farm system trial on the Living Lab area at LURDF that included some diverse pastures under lower N fertiliser. To increase the content of these species each farmlet had 25% new pastures established in autumn 2023, prior to the commencement of the Low N Farmlet Trial in July 2023. New pastures sown were either perennial ryegrass & white clover (Control farmlet) or Italian ryegrass, plantain (target 30%), white & red clover (Stacked farmlet).

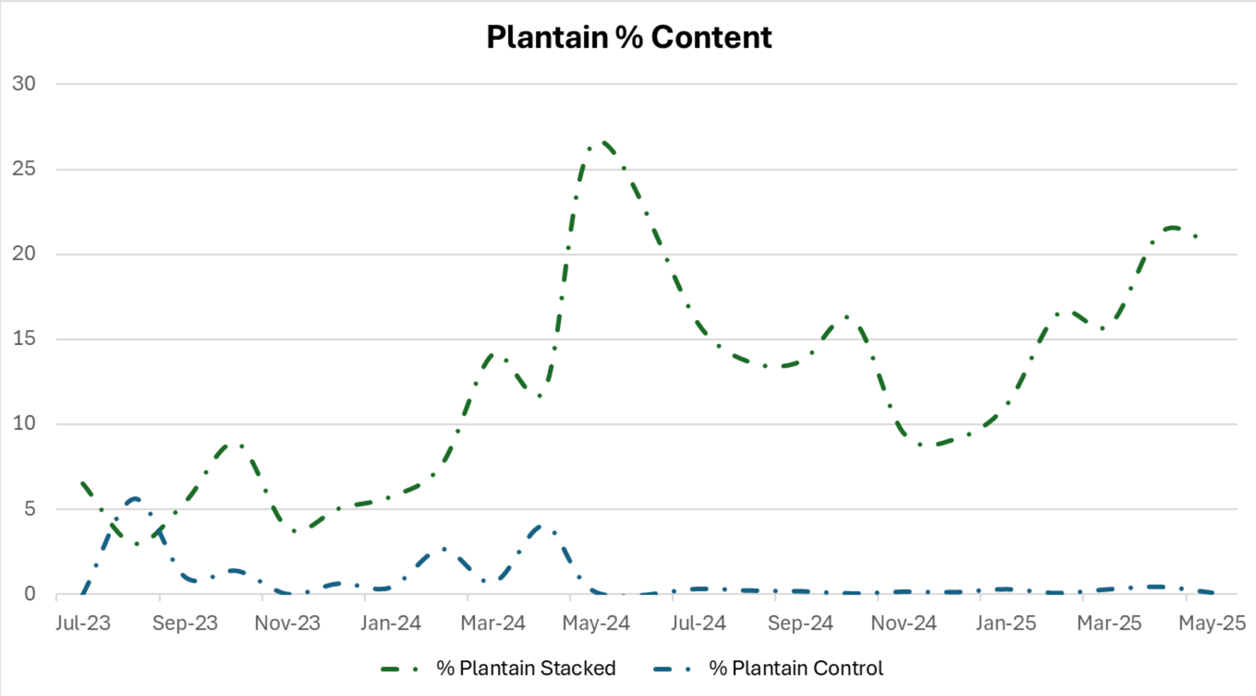
No pasture renovation occurred in the 2023/24 season; however, plantain seed was broadcast (10 kg/ha coated seed) during October 2023 onto all paddocks on the Stacked farmlet to increase plantain content of swards. In 2024/25, 12.5% of each farmlet was cultivated and resown in spring 2024 and a further 12.5% of the Stacked farmlet paddocks were undersown in early autumn 2025.

A further 10% of each farm has been renovated in Spring 2025 (sprayed out and direct drilled). In addition, another 15% of the Stacked farmlet will have additional grass/clover/plantain drilled into the existing sward to help retain sufficient ryegrass and plantain in the swards. Hybrid ryegrasses were established in 2024/25 and again this season rather than Italian ryegrass in the Stacked farmlet, to provide greater longevity and reduce the decline in metabolizable energy noted in the Italian ryegrasses, especially in late spring to early summer.


Pasture metabolisable energy (MJ/kgDM) 24-25 season
Pasture metabolisable energy (MJ/kgDM)
13
12
11
10
9
Stacked
Control
10/07/2024
10/08/2024
10/09/2024
10/10/2024
10/11/2024
10/12/2024
10/01/2025
10/02/2025
10/03/2025
10/04/2025
10/05/2025

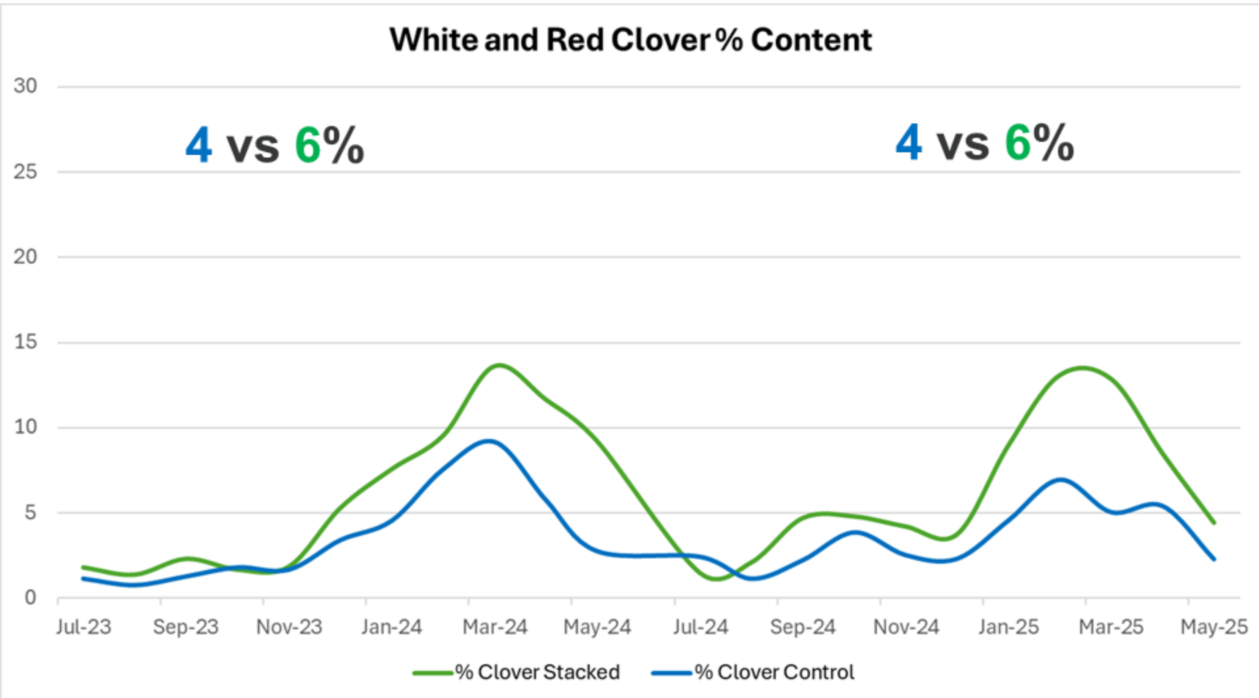

Pasture crude protein (% of DM) 2024-25 season
Pasture Crude Protein (% of DM)
30
25
20
15
10
Stacked
Control
10/07/2024
10/08/2024
10/09/2024
10/10/2024
10/11/2024
10/12/2024
10/01/2025
10/02/2025
10/03/2025
10/04/2025
10/05/2025

Plantain July 2023 to May 2025



Average Plantain Content	Control	Stacked
Year 1	2%	9%
Year 2	0	15%

Clover content July 2023 to May 2025



Average Clover Content	Control	Stacked
Year 1	4%	6%
Year 2	4%	6%

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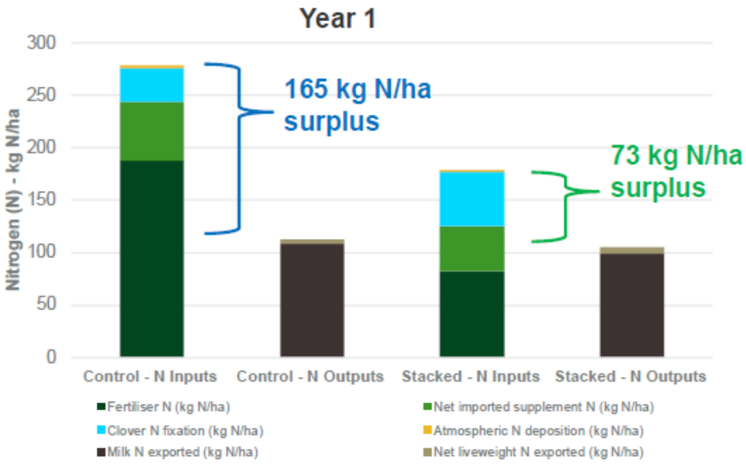
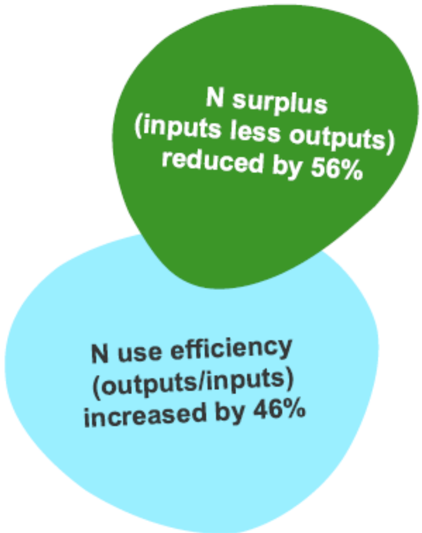
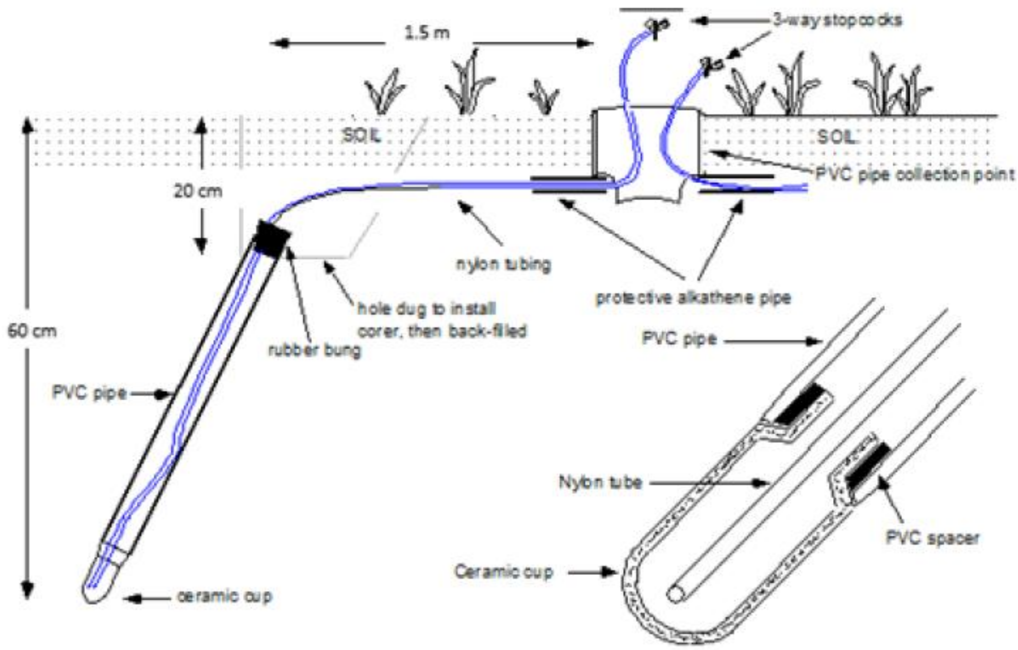
N Balance Calculations



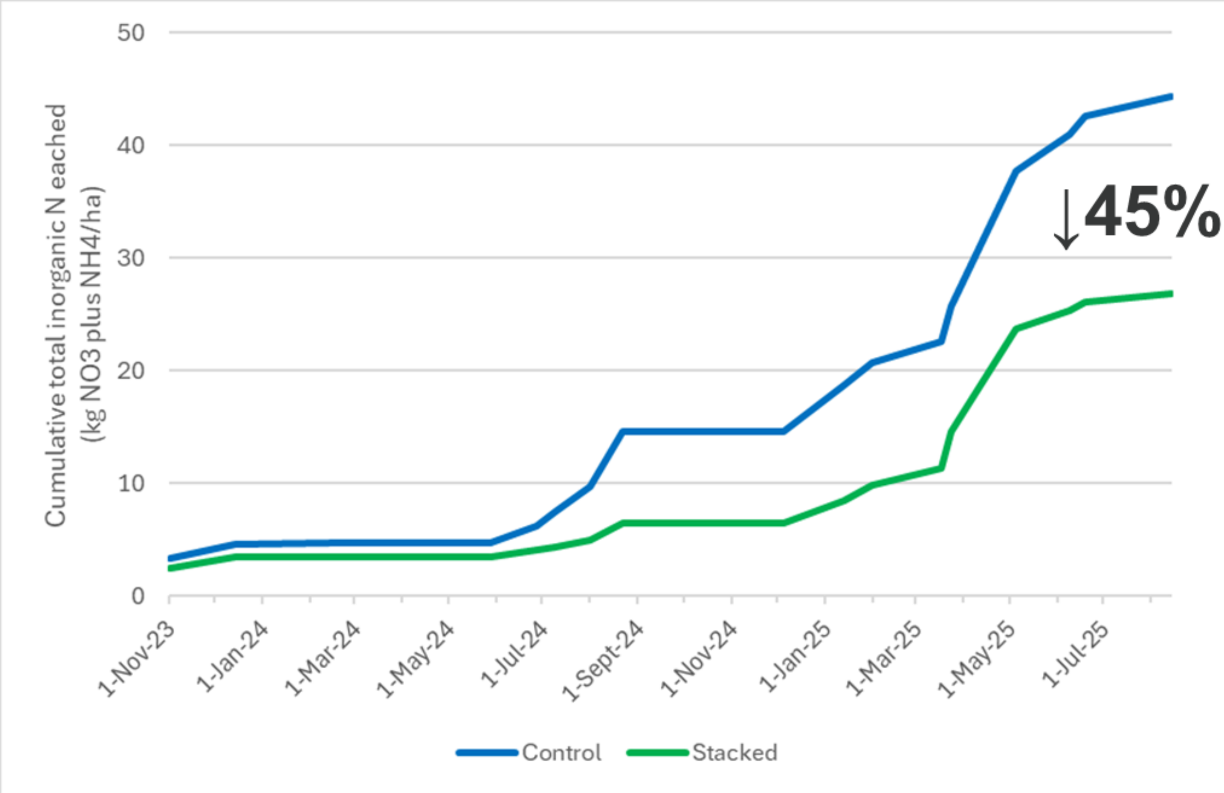


- Fertiliser N is key driver of N inputs and therefore N use efficiency and N surplus in both systems
- Clover N fixation becomes more important in Stacked system
- N balance does not include plantain effects, soil type nor drainage etc. i.e. the “Retain/Transfer”

Suction cup installation



Ceramic suction cups – Cumulative N leaching results to date



Keep up to date with results of the Low N Farmlet Trial by bookmarking LowN_Farmlet_Summary.knit Check this summary page regularly to follow milk production, pasture covers, N fertiliser use, supplementary feeding and other metrics.

Wintering treatments:
Diverse pasture & balage vs kale & balage wintering

Objective

Wintering of the Stacked farmlet on a diverse pasture with balage as supplement has been modelled to reduce N leaching from the winter platform by up to 70%, compared with kale crop-balage wintering (with oats catch crop). We aim to demonstrate a reduction in N leaching risk on the Stacked farmlet while maintaining a similar BCS and post-calving milk production to the Control farmlet.

Wintering system experimental design

	Control – Kale	Stacked - Pasture
Sowing date & mix	08/11/23 Kale	08/11/23 Diverse pasture mix*
Pre-winter harvests	-	1 x grazed, 1 x mowed
Pre-grazing yield (tDM/ha)	14	6
Space allowance (m^2/cow)	7 m^2 break size 21m^2 space allowance	15 m^2 break size 45m^2 space allowance
DM allocation per day (kgDM/cow - total diet)	14	15
Apparent N intake per day (gN/cow – total diet)	300	240
BCS gain	0.5	0.5

*Italian ryegrass, white and red clover, plantain

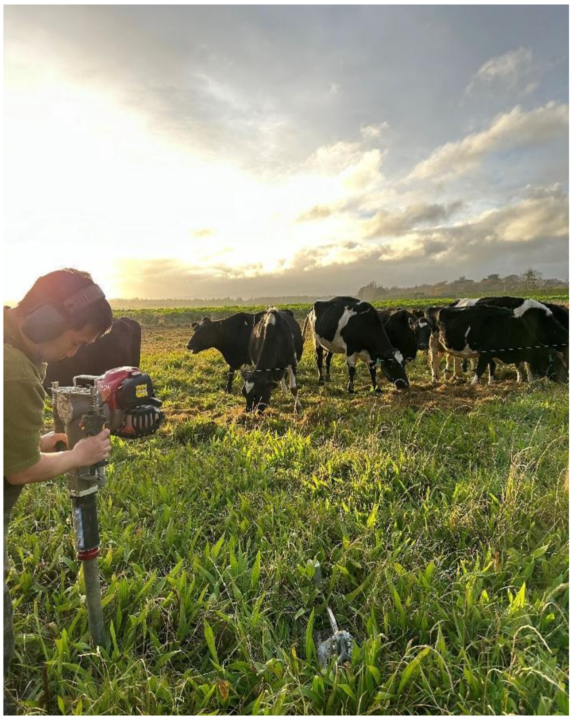
How is N leaching risk influenced?

1) A lower stocking density on pasture will increase urine patch distribution and could decrease the chance of overlap leading to lower soil N load
2) Pasture will continue to uptake N after being grazed, retaining N in organic form in plant, while fallow kale will be more vulnerable to N leaching despite mitigation with oats catch crop
3) Diets will have lower surplus protein leading to lower urinary N excretion
4) Plantain in diverse pasture will result in more dilute urine

What are we measuring?

We cannot directly measure N leaching under the winter paddocks, so take multiple measurements to indirectly assess the risk of N leaching from each farmlet. These target different aspects of the N cycle and include:



Soil Measurements

- Ammonium & nitrate N pre/post/re-growth in 4 soil layers to 60cm
- Surface scoring (pooling, gumboot scoring and mud depth) to relate to cow comfort

Herbage Measurements

- Herbage and baleage quality and N content
- Estimated intake and utilisation

Animal Measurements

- Urine N and urea concentration
- Blood urea concentration
- BCS and liveweight change
- First 60-d milk production and milk composition
- Cow behaviour (cow manager tags, IceQubes and hygiene scoring) to assess cow comfort

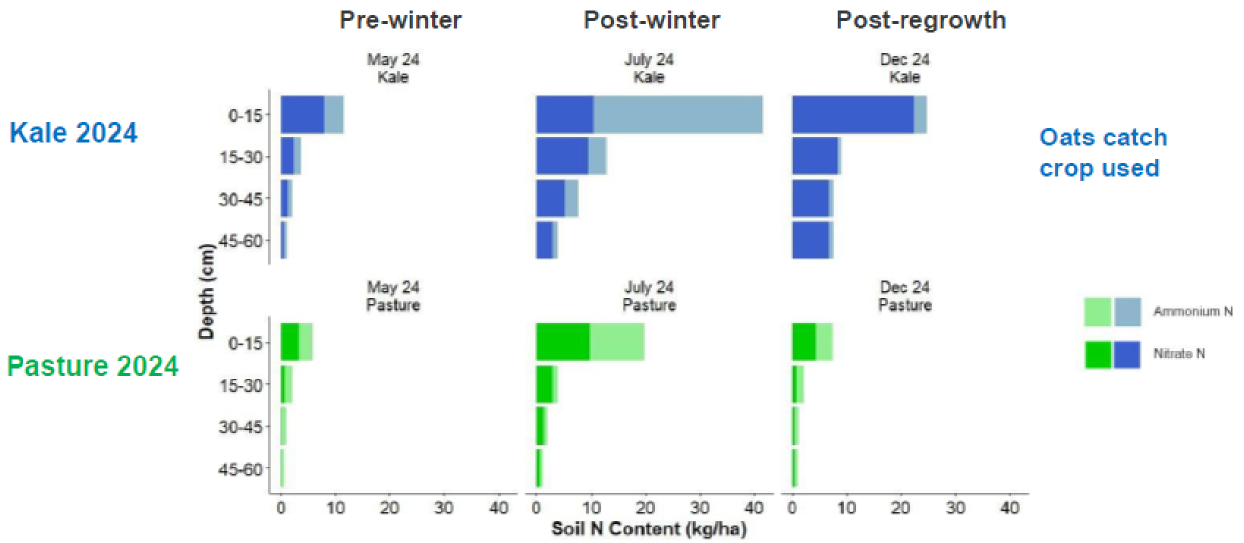
Post-winter management (following year 1)

- Kale and pasture treatments grazed with non-lactating cows from late May to early July
- Cultivation of the Kale paddock occurred late July with Oats sown early August 2024
- Additional grass seed was broadcast or direct drilled as required in the pasture wintering treatments.
- Oats catch crop were harvested for silage early December, while the pasture areas were grazed in October then harvested for silage mid-November.

Preliminary key results to date

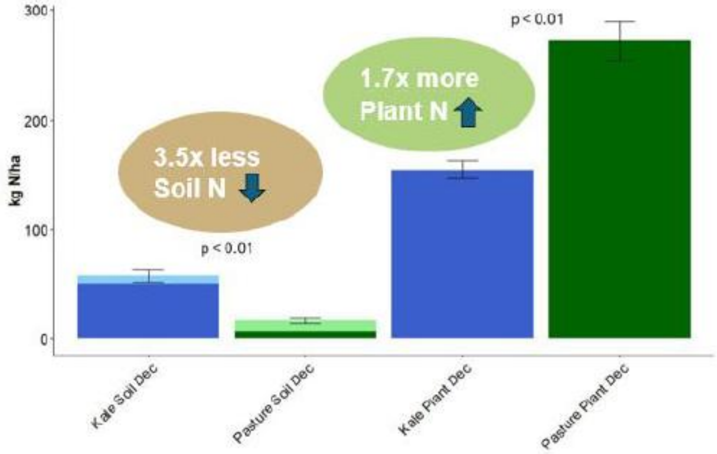
- The diverse pasture-baleage wintering on the Stacked Farmlet was associated with:
    - Lower CP% and ME content but similar N:ME ratio
    - Lower urine N and urea concentration – attributed to a dilution effect of plantain and/or a lower N intake
    - Lower nitrate- and ammonium-N content throughout the soil profile
    - Greater herbage N uptake after winter grazing
- Preliminary results are promising that a pasture-baleage wintering system reduces the risk of N leaching losses compared with a kale-baleage plus oats catch crop wintering
- Both wintering systems resulted in cows reaching, on average, 5.0 BCS prior to calving
- Indications of potential co-benefits to cow comfort from pasture-based wintering:
    - Surface conditions may be less impacted by wet and muddy conditions following rainfall
    - Cows may spend more time lying, be more active, and transition between lying/standing less frequently
- Next steps: Repeat for 2025 winter with addition of older perennial RG/WC treatment with higher plant density that may offer better recovery and N uptake post-winter
- Model different wintering scenarios, including fodder beet comparison.

Lincoln 2024: Soil Inorganic N Content lower in Pasture Wintering



- Lower soil inorganic N content in Stacked - Pasture wintering area at all depths
- Less soil inorganic N in soluble nitrate form below the root zone at risk of leaching

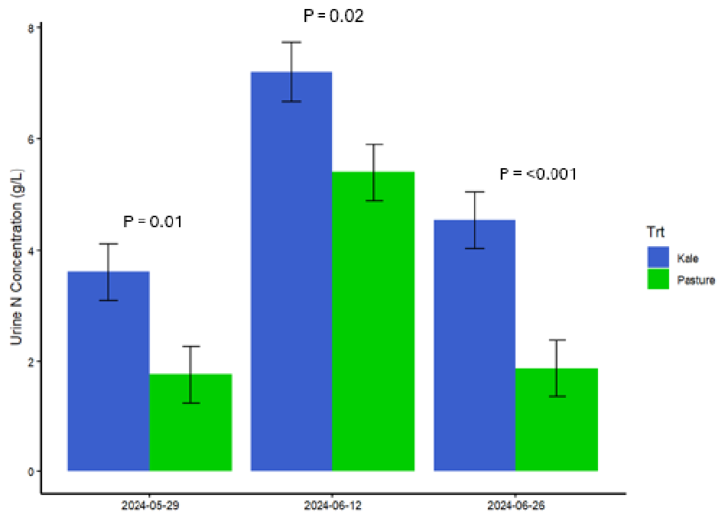
Lincoln 2024: Herbage N Uptake greater post Pasture Wintering



Following the post-winter recovery, regrowth period:

- More organic N in plant form and less inorganic mineral N in soil in Stacked - Pasture paddocks compared with Control – Kale area despite use of oats catch crop
- Total post-winter accumulated forage yield of 7.2t DM as oats vs. 10.8t DM as pasture regrowth (July – Dec 24)

Lincoln 2024: Urine N conc. lower in Pasture Wintered Cows



- Lower urine N conc. in Stacked – Pasture compared with Control - Kale cows at all sampling points during winter
- Consistent with lower dietary N and with plantain (dilution and partitioning effects)

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Using bulk milk urea to support decision making in pasture-based systems

Bulk milk urea concentration is a near real-time indicator of the dietary crude protein status of dairy herds and their nitrogen use efficiency, helping to support feed and nitrogen management decisions in pasture-based systems.

Bulk milk urea is the concentration of urea in the milk sample that is routinely collected from the vat. It is an approximate indicator of dietary crude protein status relative to cow requirements and provides near real-time data on the dietary nitrogen use efficiency of the herd.

Milk urea can be used alongside other information as a **management tool** to support decisions to:

- optimise nitrogen management and reduce nitrogen loss risks from the farm system
- review feed management including grazing management, and the type and amount of supplementary feed

Milk urea concentrations are a near real-time indicator of the herd's dietary crude protein status and their efficiency of converting dietary nitrogen into milk production. Consistently high or low milk urea provides a prompt to review nitrogen use and feed management across multiple aspects that affect the farm system's nitrogen loss risk.

Management options to improve farm efficiency and performance can be identified using milk urea data and complementary annual and seasonal information like purchased nitrogen surplus, farm insights reports, nutrient budgets and Farm Environment Plans.

How urea is produced

The cow's liver produces urea from ammonia. This ammonia mainly comes from the breakdown of dietary crude protein in the rumen, as well as from the metabolism of absorbed amino acids and body protein. Excess ammonia typically occurs when degradable protein in the diet exceeds what the rumen microbes can use, which is influenced by the energy available from fermentable carbohydrates and by how quickly ingested feed moves through the rumen (the passage rate). The resulting urea is excreted in urine, with smaller amounts excreted in milk.

When the diet does not contain enough protein, less urea is excreted, and more is recycled back into the rumen. There, it is converted back to ammonia and reused by the microbes. Read more here: The role of protein | DairyNZ and Technote-6 | DairyNZ

DairyNZ

High milk urea concentrations

High milk urea (>33 mg/dL) indicates surplus dietary crude protein and risk of higher urinary nitrogen excretion, especially when milk urea is above 40 mg/dL. Pasture-based systems naturally tend to show higher bulk milk urea than in housed systems. However, these higher values are generally not a sign of poor cow health or reproductive performance.

High milk urea concentrations can help identify **opportunities to improve dietary nitrogen use efficiency and manage nitrogen loss risks across the farm system.** This is especially useful at key times of the year, such as autumn.

In autumn, nitrogen leaching risk increases because higher dietary protein and urinary nitrogen loads often coincide with cooler temperatures, slower pasture growth, and higher rainfall. These conditions reduce plant nitrogen uptake and increase drainage. Therefore, focusing on management and mitigations during this period can have the greatest impact on reducing nitrogen loss.

Management options include refining grazing management, nitrogen fertiliser and effluent applications, and optimising the profitable use of supplements. Alternatively, excess urinary nitrogen being deposited onto soils can be reduced by using off-paddock areas or by lowering stocking density – for example, through timely culling. Read more here: Reducing nitrogen loss | DairyNZ.

Low milk urea concentrations

Low milk urea (<17 mg/dL) may indicate a dietary crude protein deficit. However, lower values are more common during spring and can simply reflect the early lactation status of cows. If consistently low milk urea concentrations are occurring (especially below 10 mg/dL), check other indicators such as milk production, pasture residuals and body condition score.

Consider feed testing and use DairyNZ tools like the FeedChecker calculator and the Supplement Price Calculator to assess the complete diet and marginal cost:benefit of possible options.

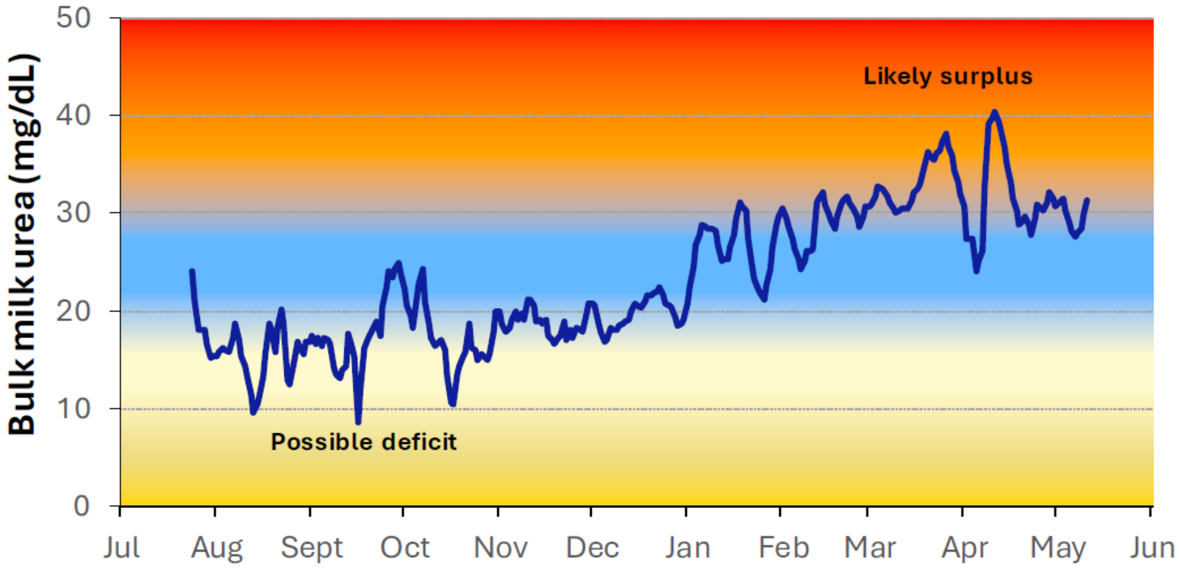
Focus on trends

Look for trends in average milk urea concentrations and compare with regional averages (if available) as values typically vary day-to-day. Investigate large differences relative to regional averages and any extreme values to understand potential contributing factors.

Farm system context

The type and amount of dietary protein and energy relative to animal requirements are key drivers that affect milk urea. However, it is also influenced by other factors like stage of lactation, time of year, body condition loss, milking frequency, water intake, breed, and timing of feeding. Milk urea values should be interpreted in the context of the wider farm system.

Indicator of herd dietary crude protein status*



*Relative to dairy cow requirements

Figure 1. Example of bulk milk urea values through the season, which may identify opportunities to improve herd feed management or manage nitrogen loss risks from the farm system.

Milk urea concentrations

Concentrations can be reported as milk urea (MU) or as milk urea nitrogen (MUN). MUN represents only the nitrogen portion of milk urea, which makes up about 47% of the total MU value.

The conversion equations are:

- MU (mg/dL) = MUN (mg/dL) × 2.14
- MUN (mg/dL) = MU (mg/dL) × 0.47

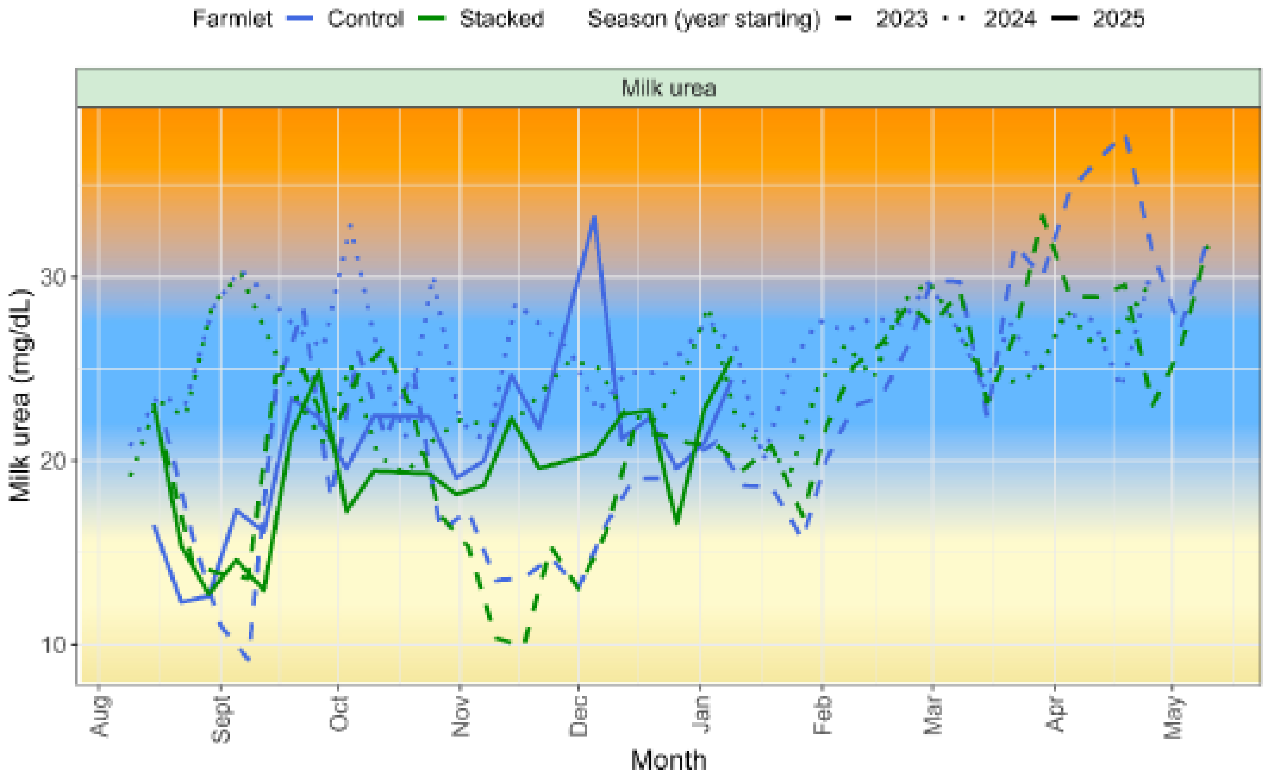
Milk urea can sometimes be reported using different units (e.g. information from NZ laboratories vs USA). In New Zealand, most milk companies and herd test providers report milk urea (MU) in mg/dL.

Additional resources

FeedChecker calculator
Supplement Price Calculator
Reducing nitrogen loss | DairyNZ
Low N Systems | DairyNZ
The role of protein | DairyNZ
Technote-6 | DairyNZ

Prototype bulk milk urea indicator tool dashboard

LURDF Stacked Farmlets comparison of bulk milk urea:



Example below uses nearby Lincoln University Demonstration Farm (LUDF) – top graph is 2024/25 season compared to regional average while the second graph shows LUDF over multiple seasons.