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IN BRIEF

Catch crops for production and environmental benefits

PRUDENT USE OF DRY COW ANTIBIOTICS | PRINCIPLES FROM PASTORAL 21

Contents

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Catch crops for production and environmental benefits

The fallow period after winter grazing of kale or fodder beet crops creates a potential risk for nitrogen leaching. This risk can be significantly reduced when a catch crop is established directly after grazing in winter.

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Catch crops, often referred to as cover crops, are by no means a new phenomenon in the response to reducing nitrogen (N) leaching risks. In arable cropping systems, catch crops are often established in autumn and are very effective at reducing N leaching losses during the following winter period[1,2]. Using this concept to 'mop-up' N after winter forage crop grazing is a novel approach that has only recently generated interest in New Zealand, particularly in the South Island.

The challenge

Winter forage kale and fodder beet are important single-graze crops in livestock production systems. However, given the high-yielding nature of these winter crops, animal stocking densities are typically high, resulting in a large number of urine patches within a relatively small area of land[3]. Urine is the main source of N leaching in grazed systems, particularly when there is no forage growing to use it. Therefore the potential for N leaching losses after crop grazing is high[4,5]. Furthermore, ground often remains fallow for three to five months after grazing. During the fallow period, urinary N is converted into nitrate, which is especially susceptible to leaching loss.

The question is – "can a catch crop be successfully established during the winter-spring fallow period to reduce N leaching, and also produce additional forage biomass?"

Key findings

- A winter-sown cereal catch crop can reduce soil mineral nitrogen and reduce nitrogen eaching by 22–40%.
- Additional forage production is an extra benefit of catch crop establishment in winter.
- The reduction of N leaching risks by growing catch crops varies from year to year depending on weather conditions, particularly during catch crop establishment.
- Oat catch crops could be successfully established by direct-drilling after kale grazing. However, cultivation may be necessary after fodder beet grazing because of greater soil compaction from animal treading.

Reducing N leaching

Research has demonstrated that growing catch crops after winter forage grazing has significant environmental benefits. A Pastoral 21 (P21) programme experiment at Lincoln University indicated that on a stony soil a catch crop of oats sown between 21 and 63 days after urine deposition in early winter could reduce the amount of N leaching loss by 22–40% compared with no catch crop[6] (Figure 1).

In general, the earlier the crop was established after grazing, the greater the potential to reduce N leaching.

On other deeper Canterbury soils, reductions in N leaching are also likely. Data generated from the Forages for Reduced Nitrate Leaching (FRNL) programme indicates that oats sown in either July or August substantially reduced the amount of N remaining in the soil profile, by up to 86% compared with that in fallow plots[7] (Figure 2).

Figure 1: Relative effect of delaying the sowing of oats, following simulated winter forage grazing in 2014, on mineral - N leaching after applying urine to lysimeters[6] (P. Carey pers comms). Based on these findings, earlier sowing of catch crops is recommended.

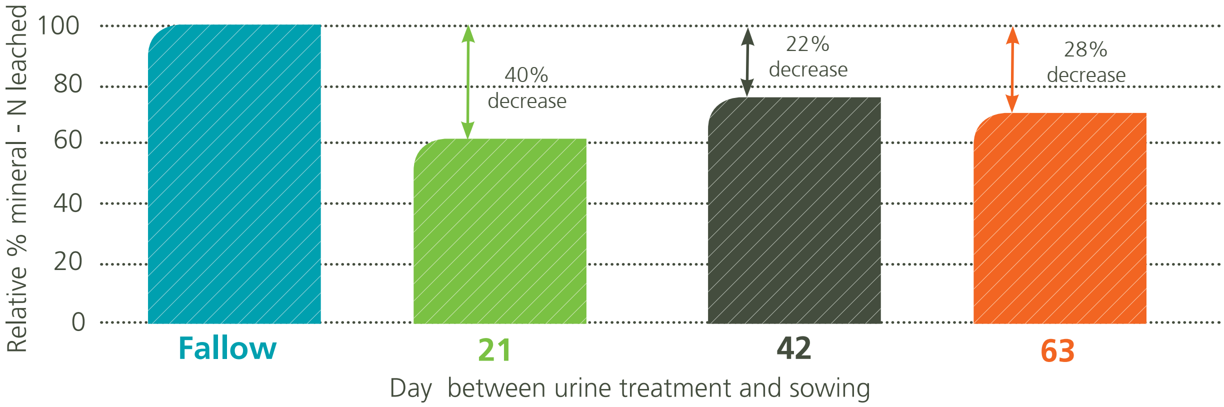
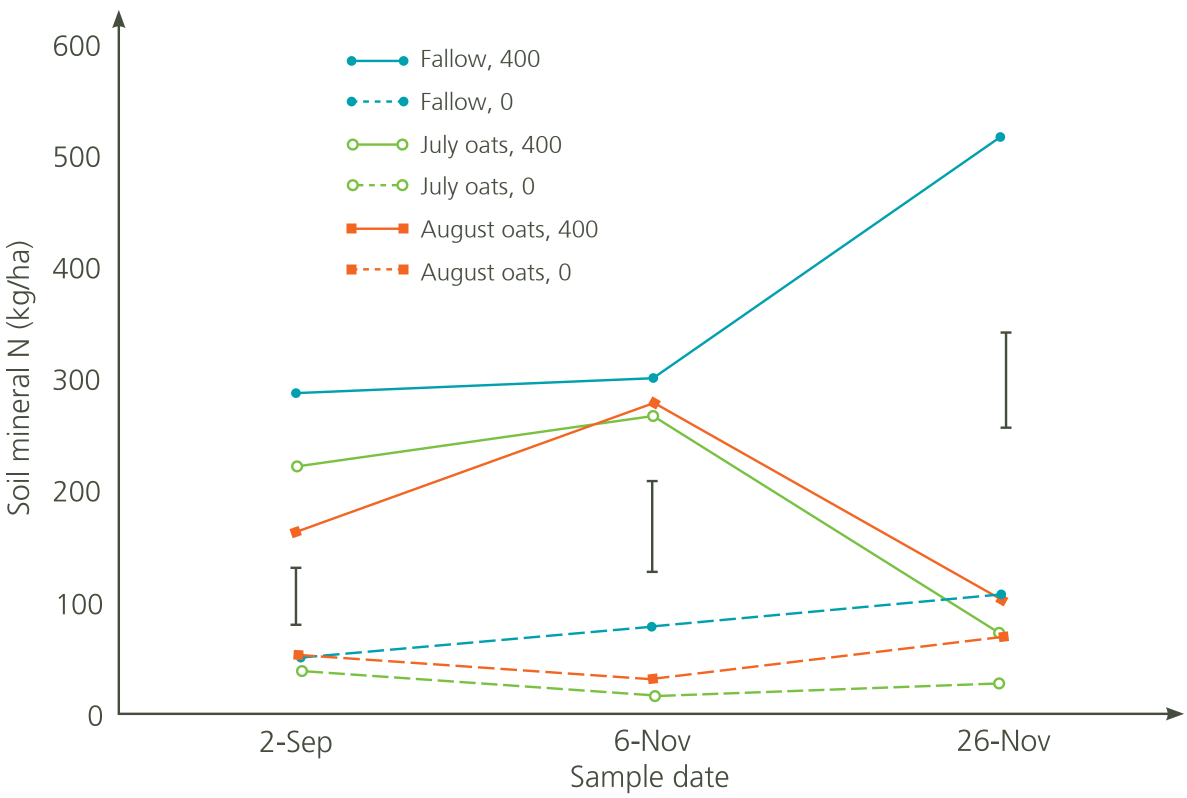


Figure 2: Change in soil mineral nitrogen (kg N/ha between 0–120 cm depth) under an oat catch crop sown in either July or August on Templeton silt loam[7]. Fertiliser rates of either 0 or 400 kg N/ha represent non-urine and urine patch areas of a paddock, respectively, applied on 1 July as urea. Vertical bars represent the least significant difference (LSD) at the 5% level.



Although this is not a direct measure of N leaching outcomes, and the effect is perhaps overemphasised by the apparent high rates of mineralisation in the fallow treatment during November, it demonstrates the ability of a winter-sown oat crop to 'mop-up' residual soil N.

Similar work in the North Island (Central Plateau) also indicates that deep-rooted chicory, sown in spring after winter grazing of a kale-swede mixed forage, could reduce the amount of soil mineral N at a 60–90 cm depth by 35% compared with ryegrass, by the following autumn[8].

It is important to recognise that N leaching is strongly dependent on crop management and the timing and amount of rainfall. Therefore, the reduction in N leaching loss from a catch crop will vary with sowing time and also from year to year[9]. Weather, particularly rainfall and temperature, influences how much N moves through the soil profile and how much, and how quickly, N is used by the catch crop.

Table 1: Average cost of production of crops grown in a kale-only or in a sequence cropping system on a stony Canterbury soil, over three years. Data sourced from DairyNZ website article[10], http://www.dairynz.co.nz/media/3360233/sequence_cropping_kale_and_oats.pdf.

Treatment	Mean yield at time of grazing	Costs	
	(t DM/ha)	($/ha)	(c/kg DM)
Kale-only +	13.4 ±1.7*	$2,789 ± $302	21.1 ± 4.2
Sequence cropping			
Late-sown kale	12.0 ± 2.4	$2,299 ± $341	19.8 ± 5.4
Oats	7.6 ± 2.2	$1,338 ± $82	18.6 ± 4.7
Late-sown kale + oats	19.6 ± 2.3	$3,637 ± $316	18.9 ± 3.7

**± One standard deviation*

+To account for the full cost, imported feed must be added to the early-grown kale scenario; the exact cost will depend on the type of supplement imported.

Biomass production potential

Establishing an oat crop after winter grazing can offer additional annual biomass production, and, in turn, higher farm productivity. For example, an oat crop grown in sequence with kale in Canterbury can yield 3–7 t DM/ha per year more feed than a kale-only system, at a similar cost of production per kg DM[10].

An estimated cost analysis of a kale-oat cropping sequence compared with one of kale-only is provided in Table 1. In this example, the kale–oat sequence crop system provided all the feed needed for dry cows from the end of May until early to mid-August for approximately $0.19/kg DM.

On deeper soils, the production potential of an oat crop is likely to be greater than those grown on stony soils, because of higher soil water-holding capacity. Yields of 6–12 t DM/ha in large field plots have been reported on Templeton silt loam soil when grown through until 'green-chop' maturity stage[7] (50% ear emergence). Importantly, it is evident from this work (and in current FRNL experiments) that most of the biomass is accumulated during October and November.

Therefore, not harvesting before 'green-chop' can result in significant yields. However, delaying harvest beyond 'green-chop' will compromise quality in terms of the amount of metabolisable energy per unit of DM.

It is important that the use of catch crops be analysed in the context of each system. For example, in dryland systems, where subsequent spring crops rely heavily on stored water from winter rains, catch crops may not be a suitable option because they can deplete valuable soil water through transpiration in early spring.

Method of catch crop establishment

There can be practical challenges to sowing a catch crop in the middle of winter, particularly in the South Island. In particular, it is unclear what are the most appropriate methods for successfully establishing catch crops to ensure sufficient soil-to-seed contact without restricting emergence. This will undoubtedly be dependent on soil conditions both at the time of grazing and at sowing. Recent on-farm research in FRNL has investigated three different approaches to sowing catch crops following grazing of either kale or fodder beet, on a free-draining soil:

1. Broadcast (after surface grubbing), then maxi-till
2. Tillage (grub, power-harrow, roll), then drill
3. No tillage (direct-drill).

Preliminary emergence and yield data from this work indicate that the method of establishment is important when establishing oats, particularly after grazed fodder beet. As a result of heavy treading and the formation of a hard surface crust under fodder beet grazing, tillage was necessary for two reasons:

1. to enable the drill coulters to penetrate the soil surface and ensure seed was placed at the appropriate soil depth, and
2. to allow seedlings to emerge without undue surface resistance.

Direct-drilling, after kale grazing, was shown to be a viable option, with good emergence and DM yields that were not too dissimilar to the tillage treatment. Although broadcasting oat seed after grazing seems an attractive low cost option from an operational point of view, some form of surface working is likely necessary to achieve sufficient soil-to-seed contact and a good catch crop establishment.

Overall, yields ranged from 7–10 t DM/ha. For oat seed broadcast two–three days before fodder beet grazing on a 4 m x 20 m strip ('proof-of-concept') results were particuarly poor, with <1% of plants successfully establishing. This was also attributed to the compacted soil.

On soils that are heavier or more prone to surface capping, successful catch crop establishment relies on good management of the fallow soil after grazing to ensure optimum conditions for germination. For example, as conditions allow, immediately grubbing/ripping recently grazed land will facilitate drainage and evaporation of subsequent rain events, and soils will dry out more quickly. This might allow machinery access earlier for catch crop sowing than what might have otherwise been possible.

Conclusions

Growing a catch crop of oats after winter forage grazing can offer significant yield benefits, as well as reduce N leaching losses. The degree of benefit is largely dependent on management for achieving high catch crop yields (e.g. early sowing and establishment method) and on seasonal weather, particularly timing and amounts of rainfall.

The majority of the biomass accumulation in catch crops is during October and November. Therefore, delaying harvesting by only two–three weeks around the 'green-chop' maturity stage (early ear emergence) can have significant yield advantages. This will be governed by the requirements for timing of the following crop.

It is important to consider the most appropriate method for establishing the crop, which will depend on the surface conditions at the time of grazing and at sowing. Fodder beet grazing can result in heavily compacted soils and therefore some form of cultivation may be necessary.

Fast facts

- Growing catch crop oats after winter forage grazing can reduce risks of N leaching.
- Catch crop oats provide additional feed at a similar cost/kg DM as the kale.
- Oat yields at 'green-chop' silage maturity stage can range between 5 and 12 t DM/ha.

Acknowledgement

Forages for Reduced Nitrate Leaching is a DairyNZ-led collaborative research programme across the primary sector delivering science for better farming and environmental outcomes. The aim is to reduce nitrate leaching through research into diverse pasture species and crops for dairy, arable and sheep and beef farms. The main funder is the Ministry of Business, Innovation and Employment, with co-funding from research partners DairyNZ, AgResearch, Plant & Food Research, Lincoln University, Foundation for Arable Research and Landcare Research.

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Prudent use of dry cow antibiotics - what does this mean?

International calls for "prudent" or "judicious" use of antibiotics for food production animals will have implications for how we manage mastitis in NZ dairy herds. Use of antibiotics at dry off is coming under increasing scrutiny and this could change how we dry cows off in future.

Key findings

- Responsible or prudent use of antibiotics means using as little as possible, and as much as needed, to not compromise animal health.
- Since mastitis control accounts for over 85% of the antibiotics used on NZ dairy farms, the use of antibiotics at dry off is a logical place to reduce antibiotic usage.
- There has been some uncertainty about how well non-antibiotic alternatives perform for cows wintered in systems perceived to have a high risk of mastitis due to environmental bacteria.
- A study on two farms in Southland, one wintering cows in a barn and the other on fodder beet, indicated that internal teat sealant can be as effective as dry cow antibiotics for preventing mastitis.
- Planning is underway for a multi-herd study in 2017 to investigate herd-level measures of the risk of mastitis, and support the development of prudent use guidelines for dry cow products.
- Good mastitis health records will be vital for deciding dry cow treatment plans that involve prudent use of antibiotics, appropriate for individual herds. Vets are likely to advocate more bacterial culture work to support antibiotic treatment.

Jane Lacy-Hulbert, **DairyNZ**

Concerns about antimicrobial resistance

Governments and public health organisations around the world are increasingly voicing concerns about the emergence of antibiotic or antimicrobial resistance (AMR) among human and animal pathogens[1,2].

Organisations such as the US Centre for Disease Control and Prevention report that AMR "is one of our most serious health threats"[1] and estimates that over two million people are sickened each year through antibiotic-resistant infections.

Such powerful language is beginning to affect how antimicrobials and, more specifically, antibiotics are used in both human health and agriculture.

One Health

The "One Health Initiative"[3] has been championing global collaboration across many health sectors. Established in the United States in 2008, and supported by a growing number of medical and veterinary organisations around the world, this forum recognises that "human health and animal health are linked, and that a holistic approach is needed to understand, protect and promote health of all species".

One of the main priorities is to address the link between agricultural use and emergence of AMR in human healthcare. Although the connections and causal relations can be debated[4], many reports agree that use of antibiotics in any sector ultimately drives development of AMR.

Each time a new antibiotic is released, new bacterial isolates that are resistant to it emerge within years, months, or sometimes weeks[2]. Extending the life of existing antibiotics, therefore, becomes an important part of prudent stewardship of antimicrobials.

For some countries, the risk of AMR has become real. In the Netherlands in the late 2000's, significant pockets of methicillin-resistant Staphylococcus aureus (MRSA) bacterial strains were detected in pigs and, at the same time, cases of MRSA-infections among farmers and vets involved with the pork industry were reported at hospitals[5].

Over a period of 4 years, the Dutch parliament legislated that antibiotic use across all livestock industries should be drastically reduced, initially by 20%, then 50%, and then 70% in 2015, compared with amounts used in 2009[5].

Similarly, the Department for Environment, Food and Rural Affairs (DEFRA) in the UK has recently committed to an almost 20% reduction in antibiotic use in livestock and fish farmed for food[6].

Responsible stewardship of antibiotics

The UK-based organisation RUMA (Responsible Use of Medicines in Agriculture) suggests that prudent or judicious stewardship means to "use medicines as little as possible and as much as necessary"[7]. But what does this mean in practice? Generally, responsible stewardship of antimicrobials involves four core actions:

- Prevent new infections and prevent the spread of resistance
- Surveillance and tracking of resistant bacteria
- Improve the prescribing and stewardship of today's antibiotics, and
- Promote development of new antibiotics and diagnostics for resistant bacteria.

The challenge for all parties will be to ensure that prudent use can be achieved, without compromising animal health, welfare and productivity.

Prudent use in dairy

About 85% of the antibiotics used on NZ dairy farms is used for mastitis control, with about half used as dry cow antibiotics at drying off[8].

Recent guidelines for dairy vets[9] recommend that antimicrobial treatments are increasingly reserved for situations where; a) there is evidence of a bacterial infection (or sufficient cause to suspect one) and b) that the infection would be unlikely to resolve without antimicrobial therapy.

So, treatment of clinical masitis cases will continue to remain acceptable, but antibiotic use at dry off will require justification.

Current recommendations

In SmartSAMM Technote 14[10], it is recommended that all cows be protected at dry off with either DCT, internal teat sealants (ITS), an effective alternative to antibiotics, or a combination of the two, depending on infection status of the herd.

Internal teat sealants, of which there are now a number available commercially, involves infusion of an inert, dense, non-antibiotic material, called bismuth subnitrate, into the teat at drying off. This material remains in the teat sinus until calving, providing a physical barrier to bacteria, and preventing them establishing an infection in the udder tissues.

Survey data indicates that at least 85% of dairy cows in NZ receive some form of treatment at dry off. The majority (50-60%) of farmers use DCT to treat all cows in the herd, with another 20% treating all cows with a combination of DCT and ITS. These approaches are often referred to as "blanket" therapy.

Only a small proportion, probably less than 10% of farmers, protect low SCC cows with ITS alone. This figure is considerably lower than the 30 to 40% of farmers that use ITS to protect heifers prior to their first calving.

The reasons why ITS alone might not be selected for low SCC cows at dry off are varied, but lack of confidence in the outcomes for older cows and concerns about consequences of poor infusion techniques will be part of the reason.

Also, in systems perceived to have a higher risk of mastitis, antibiotic treatments tend to be preferred, but defining factors that make a system "high risk" are largely based on intuition and past experience. Previous studies of the protective effect of ITS alone used farms that wintered cows on pasture[11, 12], and there are no equivalent NZ data for farms that winter cows on forage crop or in wintering barns.

Southland study

During winter 2015, a study was conducted in Southland. Three interventions at dry off were compared with no protection for low SCC cows. The study was conducted across two farms. One managed cows in a free-stall wintering barn, bedded on water-cushioned rubber mats, and fed predominantly grass silage and straw. Another herd was wintered on fodder beet, supplemented with baled grass silage and hay.

Only cows with a relatively low SCC; i.e. below 250,000 cells/ml at the first three herd tests of the preceeding season, and with no clinical mastitis in lactation, were assigned to this study.

The interventions at dry off are described in (Table 1).

Effect on clinical mastitis

After calving, the proportion of unprotected cows that developed clinical mastitis was almost three fold higher than for protected cows (Figure 1). Of the cows protected with an internal teat sealent, 4.4% developed clinical mastitis. This was statistically similar to cows protected with DCT only (3.6%) or DCT + ITS (3.4%). Despite small numbers of cows developing

cinical mastitis in the dry period, the trend was consistent with post-calving results (Figure 1).

Types of bacteria isolated from clinical cases varied between the herds. For the herd wintered in the barn, *Streptococcus uberis* and *E. coli* were predominant, with both pathogens isolated from 36% of cases. For cows wintered on crop, *Strep. uberis* and *Staphylococcus* aureus were predominant, isolated from 33% and 20% of cases, respectively.

Table 1 Cows enrolled to each treatment in the Southland study.

Code	Treatment	Number of cows
NT	No treatment to 10% of eligible cows	67
ITS	Internal Teat Sealant only	212
DCT	Dry cow antibiotic only	211
DCT + ITS	Combination - 1 tube DCT followed by 1 tube ITS	214
	Total	**704**

Effect on cow SCC

The consequences of no protection at dry off was sufficient to increase group average cow SCC for the herd wintered in the barn only (Figure 2). No differences were observed between the different protective interventions.

Future work

The results from this study were reassuring, with few differences observed between the three forms of protection, in terms of clinical mastitis or SCC. Teat sealant alone was sufficient to achieve almost a 70% reduction in dry cow mastitis, across two quite different wintering systems, and appeared to provide a realistic alternative to DCT, for cows that previously had a relatively low SCC.

A larger study, using up to 40 herds, is planned for 2017 to test the protective effect of ITS alone across many different herds. This study will also shed light on herd-specific risk factors that contribute to the higher incidence of mastitis observed on different farms.

Prudent use of antibiotics will mean using as little as possible, but as much as required. Current recommendations in SmartSAMM Technote 14 provide an important starting point for identifying what this might look like for individual herds, supported by good animal health treatment records.

Discuss with your herd veterinarian how you can develop a prudent approach to antibiotics for your herd.

Figure 1. Proportion of cows enrolled to each treatment that developed clinical mastitis in the dry period (blue bars) or after calving (orange bars), for cows that received no treatment (NT) at dry off or were protected with internal teat sealant (ITS), dry cow antibiotics (DCT), or DCT followed immediately by ITS (DCT + ITS).

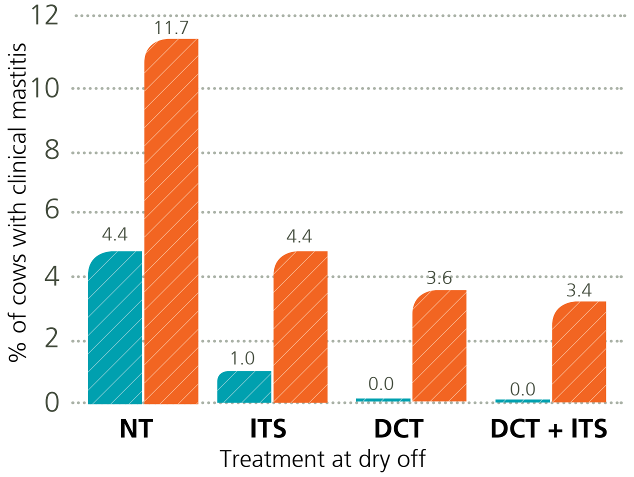
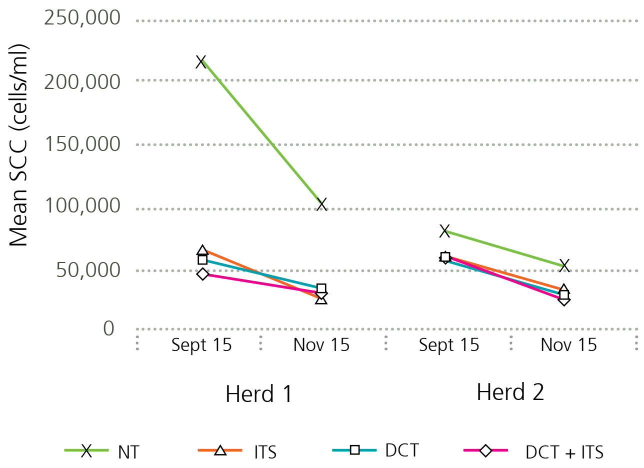


Figure 2. Group average cow SCC at first two herd tests following calving for Herd 1 (barn) and 2 (forage crop), for cows that received no treatment (NT) at dry off or were protected with internal teat sealant (ITS), dry cow antibiotics (DCT), or DCT followed immediately by ITS (DCT + ITS).



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Principles from Pastoral 21: Optimising dairy system strategies to meet nutrient limits

The New Zealand Government released its National Policy Statement on Freshwater Quality in 2011 to trigger Regional Council planning processes aimed at improving long-term water quality throughout the country. It is now clear that dairy farmers in many regions will need to reduce the amount of nitrogen (N) leached from their farm systems to comply with regional nutrient limits. In some regions, phosphorus (P) losses via sediment erosion or transport in overland flow into streams must also be addressed.

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Key points:

- Pastoral 21 (P21) has demonstrated that reducing nitrogen (N) inputs in fertiliser and feed, while increasing N use efficiency and conversion of feed to milk, can reduce N leaching by 30-40% relative to current practice.
- However, this outcome requires a high standard of pasture and grazing management and is associated with small, but important, reductions in profit.
- Identification, and targeted management, of critical source areas for phosphorus (P) loss is a successful, simple approach for reducing P movement into waterways.
- These findings provide confidence that Regional Council limits on the amounts of N and P that can be emitted from farm systems can be met by changes in farm practice that retain the fundamental principles of low-cost, pasture-based dairying.

The task for P21

In 2011, we did not know if there were practical dairy farm systems that could reduce nutrient losses by 30% or more from current practice while retaining high levels of profitability.

The 'default' thinking was that such large nutrient loss reductions would also substantially erode profits – clearly an undesirable outcome. The research and development programme Pastoral 21 (P21) was initiated in 2011 to address this knowledge gap using farm systems demonstrations plus component research[1].

The task for the dairy systems demonstration projects conducted in P21 was to apply current scientific knowledge of the ways that nutrients cycle and move around the farm. This helped to identify where management interventions could reduce nutrient movement into waterways. Whole farm systems studies were undertaken to assess production and profit alongside the nutrient balance outcomes.

Core principles

The complexity involved in managing nutrient losses can be almost overwhelming, since there are so many processes involved and these are highly variable in space and time. To cut through the complexity, it is helpful to settle on some core management principles and cascade the options under these. The management principles stem from biophysical principles, particularly those that define how nutrients move in soil-plant-animal systems. Nitrogen (N) and phosphorus (P) are very different in this regard.

Nitrogen

Nitrogen is a highly mobile element. It has been described as having 'slippery chemistry' because it exists in many forms, and can change between these forms rapidly in response to environmental conditions. The form of N leached below the root zone is nitrate. Nitrate is not retained on soil particles, so moves with water in drainage. In contrast, ammonia is weakly bound to the soil and doesn't move as readily.

Nitrogen is also lost to the air as nitrous oxide (N_20) and dinitrogen gas (N_2). Nitrogen hits the soil under pasture as urea (in cow urine or fertiliser), where it is transformed to ammonia, then to nitrate, and finally to N_2O and N_2. Transformation beyond ammonia means increased risk of N losses. Nitrogen not taken up by plants as ammonia or nitrate (which are continually in flux) or immobilised into soil organic matter is destined to be lost from the system.

It is well known that, across all agricultural land uses, the more N that is added to the system, the more that is lost – this is an inevitable result of the chemistry of N[2,3]. Systems that are highly enriched in N will leach or volatilise (lose to the atmosphere) a lot of N, and vice-versa. It is impossible to 'close' the N cycle and stop N moving: but it is possible to restrain it by not over-enriching the system. For dairy farms, this principle points immediately to the management of N inputs in fertiliser (urea is 46% elemental N), but also in imported feed (since elemental N typically comprises 2-3% of feed dry matter) as an opportunity to reduce losses.

The good news is we already have the scientific knowledge and management tools that can help lift the efficiency with which N fertiliser is used to grow and harvest more pasture[4], and the efficiency with which imported supplement is used to produce milk[5]. The thinking in the P21 farm systems demonstrations carried out in Waikato, Canterbury and South Otago was that, if these are applied accurately and often, large reductions in the amount of N input and N leaching footprint could be achieved while maintaining high production and profit (Table 1).

The other approach applied in P21 was to capture N in urine at critical times and re-distribute it evenly across pasture, rather than in concentrated urine patches. This management principle was used in the P21 system studies in Waikato and South Otago (Table 1) i.e. to capture (and, where feasible, re-use) nutrients on a part of the farm.

This was achieved either with a built facility like a stand-off pad, or in a natural collection and discharge point in the landscape called a critical source area (CSA)[6].

Phosphorus

Phosphorus is a different proposition to N. Phosphate ions, the form that plant roots can access, are relatively immobile forms of P that bind moderately to strongly (depending on soil type) to soil particles. Leaching is much less of a concern with P for most soils.

The main routes by which P leaves the farm are via attachment to sediment (e.g., in sediment run-off after grazing of a winter crop on the downlands of Otago and Southland[7]) or via run-off that may occur on poorly drained or sloping soils shortly after the deposition of P-rich materials, such as dung or soluble P fertilisers[8].

In the P21 study in South Otago (Table 1) the thinking was tested, that if the CSAs that channel most of the P lost from the farm into waterways can be identified, then the amount of P entering the CSA could be reduced, or losses from the CSA could be capped in some way.

Table 1: Principles, strategies and management considerations for targeting reduced N and P losses. P21 sites were in Waikato (W), Manawatu (M), Canterbury (C) and South Otago (SO)

	Management principle	Applies to:	Strategy	Target nutrient	P21 sites	Key management considerations
1	The more you use, the more you lose	Whole farm	• Reduce N fertiliser	N	W, C, SO	N fertiliser efficiency, pasture production, feed supply/demand balance
2			• Reduce imported feed	N	W, C, SO	Feeding efficiency, pasture utilisation, feed supply/demand balance
3	Capture and re-use	Parts of the farm	• Use a stand-off	N	W, M, SO	Timing of use, capital and other costs
4			• Manage critical sources areas	P	SO	Practical implementation

Table 2. Key inputs used in, and results from, P21 dairy systems comparisons in three regions. Results are averages of three (South Otago), four (Canterbury) or five (Waikato) years.

	Waikato		Canterbury		South Otago	
	Regional control[A]	Alternative system	Regional control[A]	Alternative system	Regional control[A]	Alternative system
Strategy (see column 3 in Table 1)		1, 2 and 3		1 and 2		1, 2 and 4
N fertiliser on pasture (kg N/ha/year)	135	60	313	159	109	42
Imported feed offered (t DM/ha/year)	1.2[1]	1.4[2]	1.7[1]	0.9[6]	0.6[9]	0.2[9]
Stand-off/restricted grazing	No	Yes[3]	No	No	No	No
Stocking rate (cows/ha)	3.2	2.6	3.9	3.5	2.9	2.8
Comparative stocking rate (CSR, kg liveweight per tonne feed offered)	89	79	79	83	89	89
Key results						
Pasture eaten (t DM/ha/year)	14.2	13.0	16.3	15.1	11.9	11.3
Milksolids (kg/ha/year)	1201	1151	1821	1782	963	930
Estimated operating profit ($/ha/year)	4310[4]	4083[4]	4395[7]	4205[7]	2234[10]	2103[10]
Nitrate-N leached (kg N/ha)	60[5]	34[5]	57[8]	34[8]	18[11]	14[11]
Phosphorus loss risk (kg P/ha/year)	n.m.	n.m.	n.m.	n.m.	0.60[11]	0.41[11]

A 'Current' farmlet, operated alongside the alternative system, B Lincoln University Dairy Farm (LUDF) 2011/12 to 2013/14 seasons, C 'Control' farmlet operated alongside the alternative system.

[1] all pasture silage; [2] 57:43 pasture silage : maize grain; [3] cows on stand-off for 8 or 16 hours between March and June, [4] at milk price $7.30/kg milksolids; [5] measured using suction cup samplers; [6] 76:24 pasture silage : cereal grain; [7] at milk price $6.30/kg milksolids; [8] modelled Overseer version 6.2; [9] pasture and cereal silage; [10] at milk price $6.45/kg milksolids; [11] a risk-based approach using a combination of measured values (milking platform and winter forage crop areas) and modelled estimates (remaining areas).

n.m. not measured.

P21 comparisons and conclusions

In all regions, one or more strategies for reducing nutrient losses were tested against a regional 'control' system. The main differences in inputs between the alternative system and the regional control are shown in the top half of Table 2. For example, in Waikato, the alternative system reduced N inputs by more than 50% compared with the control (total of 75 kg N/ha less applied), kept similar imported feed amounts, reduced actual and comparative stocking rate, and stood cows off on a wood chip loafing pad for between eight (milking cows) and 16 (dry cows) hours per day from March until June (Table 2). There were other factors that differed between the two systems in all cases, and though these were important in some situations, they cannot be covered in detail here.

The key results are shown in the bottom half of Table 2.

Lower inputs

The lower input strategy as applied in Waikato and Canterbury reduced N leaching by around 20-40% compared with the control system (in Waikato, about half of the N leaching reduction was attributed to the stand-off). Production and profit per hectare were lower than the control system, but proportionally less than the substantial reductions in fertiliser N and in the case of Canterbury and South Otago, imported feed.

In 2014/15 and 2015/16, after the results of the first three years of the P21 systems study in Canterbury were available, the Lincoln University Dairy Farm (LUDF), herd size 560 cows, adopted the same management practices used in the P21 alternative system.

Over those two seasons, LUDF exceeded the production achieved in the P21 farmlet and maintained its profit ranking position relative to a group of leading Canterbury farms that LUDF is benchmarked against each year[9]. This provides evidence that the strategy can be implemented at commercial scale, giving a level of confidence that there are ways in which farms can cope with N leaching limits while retaining the fundamentals of successful NZ dairy systems: pasture-based and low-cost.

What you need to know - managing a Low N system.

What is required to make the lower input strategy work?

- Recognition that lower inputs = lower total feed supply, and willingness to adjust cows/ha to maintain comparative stocking rate (CSR) in the target range of 80-85 kg liveweight/t DM[10] with 90% of feed requirements coming from grazed pasture. In P21 Canterbury, 95% of total requirements on the milking platform came from grazed pasture. This strategy is about balancing feed supply and demand, using pasture first and minimising supplement required.
- Strong focus on pasture monitoring (feed wedges) leading to good pasture allocation decisions and achieving consistent target residuals in the range 1500 – 1650 kg DM/ha[11].
- A 'little and often' approach to N fertiliser application, including preparedness to withhold N for one or more rounds if expected feed supply meets current and expected demand so that N can be spared for use at the key times of start and end of lactation.
- Close adherence to body condition score and pasture cover targets.

What must be considered on farm to meet these requirements?

- Pasture growth potential, as set by climate and soils – adjust CSR based on expected pasture grown (including expected reduction in total pasture growth if N fertiliser is reduced).
- Cow liveweight – which is why CSR is a more useful tool than just cows/ha.
- Skills available for pasture monitoring and decision-making.
- What surprises emerged, and what should farmers be mindful of?

1. Pastures receiving lower N fertiliser can appear visibly N deficient at times (e.g. with urine patches showing out strongly), but this may not be reflected in the feed wedge/growth rates. The wedge is a better indicator, and the deficiency symptoms will pass with time.
2. Cows can respond very well to the management regime if it is well executed. In P21 Canterbury, and LUDF, per cow production increased to over 500 kg MS/cow (we expected about 450kg) from a pasture-dominant diet, even though high per cow production was not a target.
3. There is a lower margin for error in the lower input system if the N fertiliser use and feeding efficiencies required to achieve the N leaching reductions are to be realised. There is a smaller safety net in the form of available N and imported feed to dig yourself out of a hole. It is more risky, but the risk is manageable if the skills are available.

Nutrient capture

In the P21 alternative system in South Otago, the risk of P loss was reduced by about one third (Table 2), due to large reductions in sediment run-off under the winter crop (kale) that was grown and fed on the milking platform. The solution in this case was relatively simple. In the crop paddock, the CSA where sediment was likely generated and then discharged into surface water was identified, and this became the crop block that was grazed last.

The effects of doing so were two-fold: it reduced the amount of soil treading damage, and thus sediment generation, and the standing crop in this area helped to trap sediment transported in overland flow originating in the upper areas of the paddock.

Preparedness to forego some crop harvest in the CSA is necessary if soils are very wet. Otherwise, the strategy is relatively simple, and incurs little direct or indirect cost. Most producers on downland country should be able to implement the strategy with ease, and thereby substantially improve their P loss footprint.

Concluding comment

In 2011, when regulations to limit nutrient losses from farms became government policy, there was no evidence available to show dairy farmers that farm systems options existed that could meet those limits.

With the benefit of the findings from P21 systems demonstrations and other work, we now know there are viable system options that can reduce N and P losses by 30-40% below current practice. We also know that those options generally come with associated reductions in profit. Reductions in profit and nutrient losses are not linearly related: the relationship can be 'de-coupled' so that substantial water quality gains can be achieved without eroding the fundamentals of the low-cost, pasture-based system.

These outcomes should provide some confidence to farmers that they can continue to operate profitably in the new regulatory environment. Research underway currently will present farmers with further viable options.

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Science snapshot

Increased stocking rate without imported feed but with shorter lactation length reduced nitrate-N leached[1].

The effect of intensive agricultural systems on the environment is of increasing global concern, with nitrate (NO_3-N) leaching to groundwater being a focus for most regions in New Zealand. Many consider stocking rate to be a key contributor to the amount of NO_3-N leached from dairy pastures; however, in most situations stocking rate has been confused with the importation of feed from off farm to feed the additional cows. In recent research from Ireland, NO_3-N was reduced, even though stocking rate was increased; however, there were many changes to farm management and it was not possible to determine the actual effect of stocking rate from that work. A subsequent Irish study showed no effect of stocking rate on N leaching when this was the only factor changed.

In New Zealand, Macdonald et al.[2, 3] compared five different stocking rates ranging from 2.2 to 4.3 cows/ha in self-contained farmlets (i.e., no purchased feed) producing approximately 18 t DM of pasture with 200 kg applied N/ha. The amount of NO_3-N leaching was measured using ceramic cups placed below the root zone. The results indicated a linear decline in NO_3-N leached as stocking rate increased (12 kg NO_3-N less leached/ha for every extra cow/ha in stocking rate).

It isn't clear why this unexpected result occurred. All treatments deposited similar amounts of urine N per hectare in the February-June period, leading to an expectation that N leaching would be similar as in the Irish study. Further research is being undertaken to understand the reason for the reduction in NO_3-N leaching with increasing stocking rate in this experiment. Possible explanations include:

- Lower urinary N concentration in dry cow urine compared to lactating cows during the high leaching risk autumn period. The high stocking rate treatments dried cows off earlier.
- Soil compaction under high stocking rates leading to urine patch spreading.
- Differences in N balance due to pasture uptake.
- High variability in the trial data leading to an overestimate of the true effect, noting that an underestimate is equally statistically likely.

It is very important to note, however, that this work was undertaken in a closed system, i.e. almost no feed was imported. The increase in stocking rate was managed through a lower feed allowance/cow and by reducing lactation length. If stocking rate was increased AND additional feed was purchased onto the milking platform or for the winter period, NO_3-N leached would probably have increased, unless cow urine was captured in a stand-off facility and applied evenly to the pasture. This would require considerable capital investment in depreciating assets and, even then, may not limit an increase in NO_3-N leached completely.

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