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SCIENCE IN ACTION

FODDER BEET: DOES IT AFFECT THE COW'S LIVER?

Productivity gains from lowered footprints

Ryegrass hybrid breeding breakthrough

Designing great future dairy workplaces

DairyNZ

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Fodder beet's effect on the liver

What happens to a cow's liver during the transition to a fodder beet diet? DairyNZ has been investigating.

Talia Grala, scientist, DairyNZ
Dawn Dalley, senior scientist, DairyNZ

KEY POINTS

- Recent DairyNZ research has investigated the effect of fodder beet on cows' liver metabolism.
- Liver markers of stress do not increase during cows' transition to fodder beet.
- Liver function markers in the blood are minimally affected on a full allocation of fodder beet.
- Cell protective mechanisms increase in the liver, but only in the short term.
- Overall, fodder beet has only minor effects on liver health.
- DairyNZ recommends transitioning cows onto a fodder beet diet gradually to minimise ruminal acidosis and liver dysfunction.

Fodder beet benefits and risks

Fodder beet's uptake has been exponential in New Zealand, as more dairy farmers adopt this high-quality, high-yield option for supplementary feed. The fodder beet bulb has a low nitrogen content and offers flexibility in that it can be either grazed in the paddock or lifted for storage.

However, the crop comes with risks. The beet's bulb is 50 to 70 percent sugar, so is both palatable and rapidly fermented in the cow's rumen. Rumen microbes must adapt to this high sugar content. If cows eat high quantities of fodder beet before their rumen microbes have adapted, they can develop ruminal acidosis and liver dysfunction.

Overseas studies have shown that acidosis can cause certain bacteria in the rumen to release toxins[1], which trigger inflammation and stress throughout the body. Acidosis can change the metabolism of fat in the liver[2]. This overseas research involved cows with clinical ruminal acidosis, produced by purposely feeding a high-sugar diet. At DairyNZ, we wanted to know whether similar responses occur when cows transition onto fodder beet.

Testing liver stress markers

To better understand the effects of fodder beet on liver health, DairyNZ carried out a levy-funded trial* in May 2016. We compared non-lactating cows transitioning onto a diet of fodder beet (eight kilograms of dry matter per cow – 8kg DM/cow) and pasture silage (4kg DM/cow), with cows maintained on a diet of pasture (8kg DM/cow) and supplemental maize silage (4kg

DM/cow). The cows were transitioned onto fodder beet over a 14-day period. We sampled blood and took liver biopsies twice: halfway through the transition (day seven), and after the cows had been on the full allocation of fodder beet for seven days (day 21).

We tested six biomarkers of liver function at both time points. Concentrations of these biomarkers typically increase in the blood when the liver is damaged, except for total protein (TP) concentrations, which decrease *(Table 1)*.

Table 1. Markers of liver function in the blood

A cow's liver produces many enzymes released into the blood. We can then measure these enzymes, and their concentrations give us an indication of the liver's health and the cow's overall health.

Marker	Full name	Role of the liver	Role in diagnosing liver health	Role in other tissues
AST	Aspartate aminotransferase	Amino acid metabolism	↑ if liver is damaged	also produced by muscle
	Bilirubin	Detoxification	↑ if liver is damaged	↑ by damage to blood cells
GGT	Gamma-glutamyl transferase	Amino acid metabolism	↑ if liver is damaged	also produced by kidneys and udder
GLDH	Glutamate dehydrogenase	Amino acid metabolism	↑ if liver is stressed	None
HP	Haptoglobin	Synthesis of HP	↑ if liver is stressed	↓ by damage to blood cells
TP	Total protein	Amino acid and protein synthesis	↓ if liver is damaged	↑ during inflammation

Transitioning stage — results

During the transitioning stage, three markers – TP, haptoglobin (HP) and gamma-glutamyl transferase (GGT) – did not differ between cows fed fodder beet and those fed pasture. However, concentrations of the other three – aspartate aminotransferase (AST), bilirubin and glutamate dehydrogenase (GLDH) – were lower in the cows fed fodder beet than in pasture-fed cows. This indicates the cows were adapting well to the fodder beet diet, and no negative effects were detected in their blood during the transition.

Full beet allocation — results

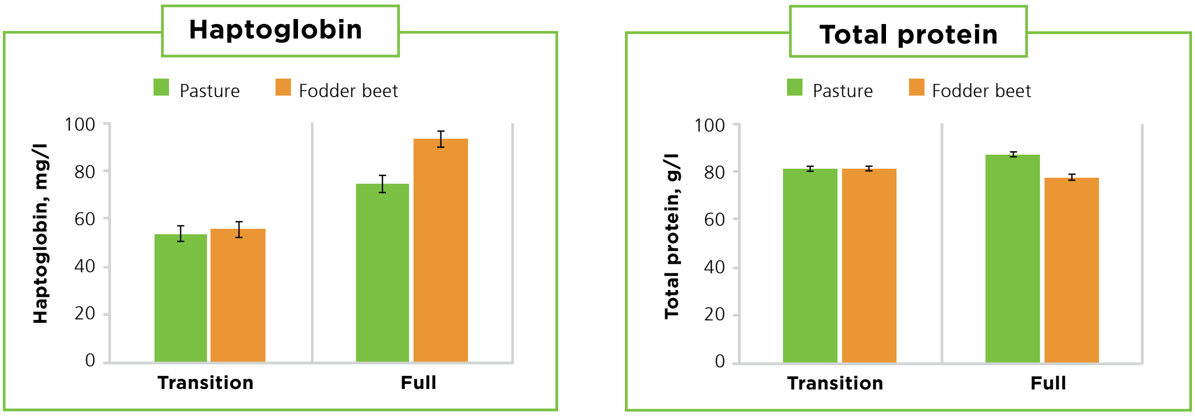
In cows on the full fodder beet allocation, GGT remained unchanged, while AST, bilirubin and GLDH remained lower in cows fed fodder beet than in pasture-fed cows. However, TP was also lower in cows fed fodder beet than in pasture-fed cows, which indicates the liver's ability to produce proteins is impaired. Additionally, HP increased in cows fed fodder beet, which indicates a response to inflammation *(Figure 1)*. HP is also reported to have a role in lipid metabolism and development of fatty liver^3.

Recommendation for transitioning non-lactating cows to fodder beet

When cows start being fed a high-sugar diet, the most important changes to their rumen microbe population take approximately 14 days^4. This is why DairyNZ currently recommends starting with one to two kilograms of dry matter (kg DM) fodder beet allocated behind a wire, then increasing by 1kg DM every second day for 14 days (providing all cows are eating the bulbs) until cows are eating about 9 to 10kg DM/day.

Figure 1. Blood markers of liver stress

DairyNZ's research measured six blood markers of liver stress in cows during their 14-day transition onto the fodder beet diet (Transition), and while they were on the full allocation of fodder beet (Full). Both HP and TP were altered while cows were on the full allocation of fodder beet indicating that the liver of cows consuming fodder beet is under some stress.



Measuring liver gene expression

Not all the genes of a cell (the DNA) are used at the same time. By measuring which genes are being used (or 'expressed') we can determine what processes are happening in a particular tissue *(Figure 2).*

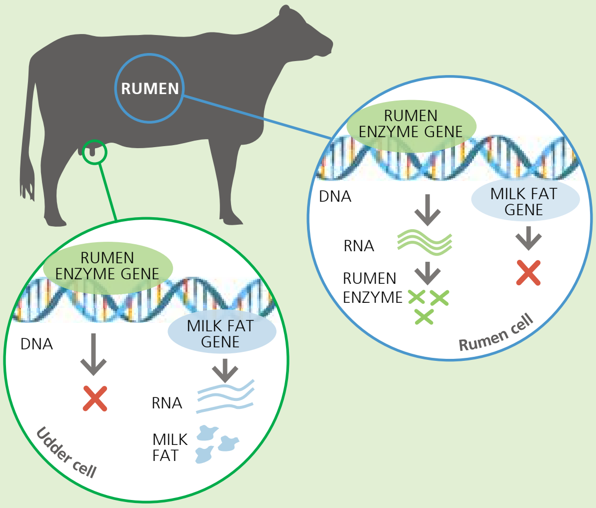
To determine if the altered production of liver stress markers affected the function of the liver, we measured the expression of key genes. We targeted genes that code for enzymes involved in glucose synthesis, lipid synthesis, fatty acid breakdown, cell stress and inflammation. Our first objective was to determine if fodder beet results in liver stress, and secondly, to determine if normal liver functions are affected by the transition.

Figure 2. Gene expression explained

Every cell in the body contains the same DNA. DNA is made up of thousands of genes, but not all of these are being used in any given cell at any point in time. Genes can be switched on (or 'expressed'), allowing different cells to perform different tasks.

The genes that code for milk fat and protein synthesis are highly expressed in a cow's udder during peak lactation, because the DNA 'recipe' or code is being copied into RNA and read continuously to make lots of milk. However, during the non-lactating period ('dry' period), when the cow isn't producing milk, these genes are not actively expressed.

By measuring which genes are being expressed (what RNA is in the tissue), we can measure what processes are happening.



The main difference between cows fed fodder beet and those on pasture was the expression of two genes involved in the stress response of the endoplasmic reticulum *(Figure 3)*. This stress response is initiated when the liver cells become stressed and produce misfolded proteins that do not function properly. These proteins can accumulate and cause cell death.

As part of the experiment, we also measured the expression of genes involved in the breakdown of fatty acids into ketones. Once cows were on the full allocation of fodder beet, these genes were more highly expressed in cows fed fodder beet than pasture. This indicates a change in the amounts of various volatile fatty acids absorbed from the rumen, due to differences in rumen fermentation between fodder beet-fed and pasture-fed cows[5].

Expression of the other genes measured (those involved in glucose synthesis and fatty acid synthesis) didn't differ between the pasture and fodder beet cows. This indicates that fodder beet has no adverse effects on glucose synthesis or excessive fat synthesis in the cow's liver.

Careful transition, minor effects

DairyNZ's research shows that, when cows are properly transitioned onto fodder beet, there is only a minor effect on the liver. So, although transitioning cows onto fodder beet has to be managed carefully, the risk to cows is low if farmers follow the current recommendations.

To learn more about fodder beet, follow these links:

- DairyNZ's online fodder beet section – **dairynz.co.nz/fodder-beet**
- *Inside Dairy* September 2017 (special fodder beet issue) – **dairynz.co.nz/ID-Sept-2017**
- *Technical Series* February 2013 ('Delving into DNA', page 18) – **dairynz.co.nz/TS-Feb-2013**

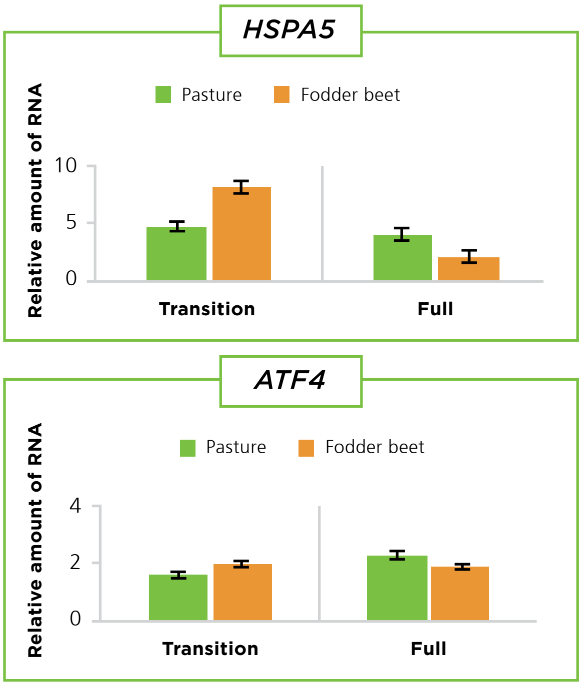
** This research was an aligned project with the DairyNZ-led Forages for Reduced Nitrate Leaching programme (FRNL). Learn more at dairynz.co.nz/frnl*

Figure 3. Expression of two genes involved in the endoplasmic reticulum stress response

HSPA5 is involved in degrading misfolded proteins and *ATF4* activates genes that down-regulate protein synthesis, thereby enabling the cell to recover[6]. We measured the expression of these genes during the cows' 14-day transition onto fodder beet (Transition) and while on the full allocation of fodder beet (Full).

The expression of these genes was greater in cows transitioning onto fodder beet compared with cows fed pasture.

However, once the cows had been on the full allocation of fodder beet for one week, *HSPA5* expression was lower, and *ATF4* expression was similar in cows fed fodder beet compared with pasture-fed cows, indicating the liver cells were no longer under stress.



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Important drivers of a lower footprint are reducing nitrogen fertiliser and imported feed.

Farming for a lower footprint – what should we focus on?

Find out about the latest research, co-funded by DairyNZ's levy, on mitigating greenhouse gases and nitrogen leaching. Do they reduce farms' environmental footprints and improve profitability?

Pierre Beukes, senior scientist, DairyNZ
Ina Pinxterhuis, senior scientist, DairyNZ
Taisekwa Chikazhe, developer, DairyNZ

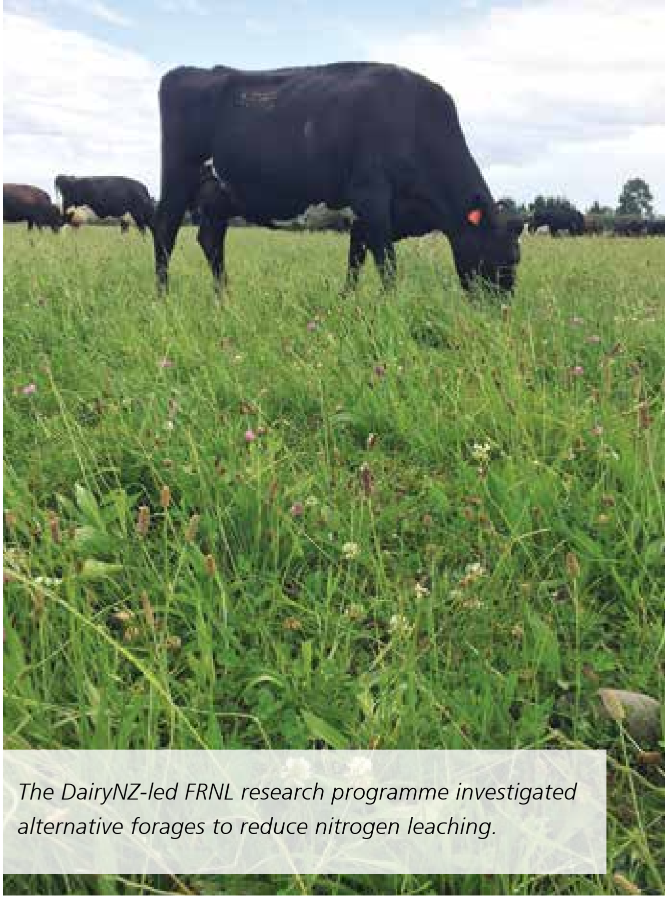
KEY POINTS

- Whether you focus on GHGs or N leaching, reducing one generally reduces the other.
- Important drivers of a lower footprint are reducing nitrogen fertiliser and imported feed. This reduces nitrogen surplus and feed flow through the herd and drives down both GHG emissions and N leaching.
- Systems with off-paddock infrastructure, e.g. barns, feed pads etc., are likely to reduce N leaching, but they also generate more effluent storage and handling, which may increase GHGs.
- Opportunities currently exist on many farms to reduce imported feed and N fertiliser and to achieve a five to 10 percent reduction in GHG emissions, with no or minimal negative impact on profitability.
- Targets beyond a 10 percent reduction in GHG emissions that do not reduce profit will require new technologies, such as different animal and/or plant genetics, different feeds or feed additives, or ruminal methane inhibitors.

Farming businesses are facing growing pressures to reduce their nitrogen (N) leaching and greenhouse gas (GHG) footprints, driven by society and national/international water quality and GHG targets.

The challenge is to alter the farm system with a focus on sustainability while maintaining profitability. This requires planning and management to ensure the altered business's success[1]. Several studies have looked at production systems that maintain or increase profitability, while reducing impacts on receiving environments, including water and air. In some, the focus was on GHG[2] and in others, on N leaching[3].

A sustainable system must achieve multiple objectives: lifestyle for the farmer, welfare for the animals, quality product for the dairy processor, responsibility towards the environment, contribution to the community, goodwill from the public and



The DairyNZ-led FRNL research programme investigated alternative forages to reduce nitrogen leaching.

profitability of the business.

This article summarises three of these DairyNZ levy-funded studies to answer the question: 'If I focus on mitigating GHG or N leaching, are there co-benefits to the total environmental footprint, and what is the impact on profitability?'

Focus on GHG emissions

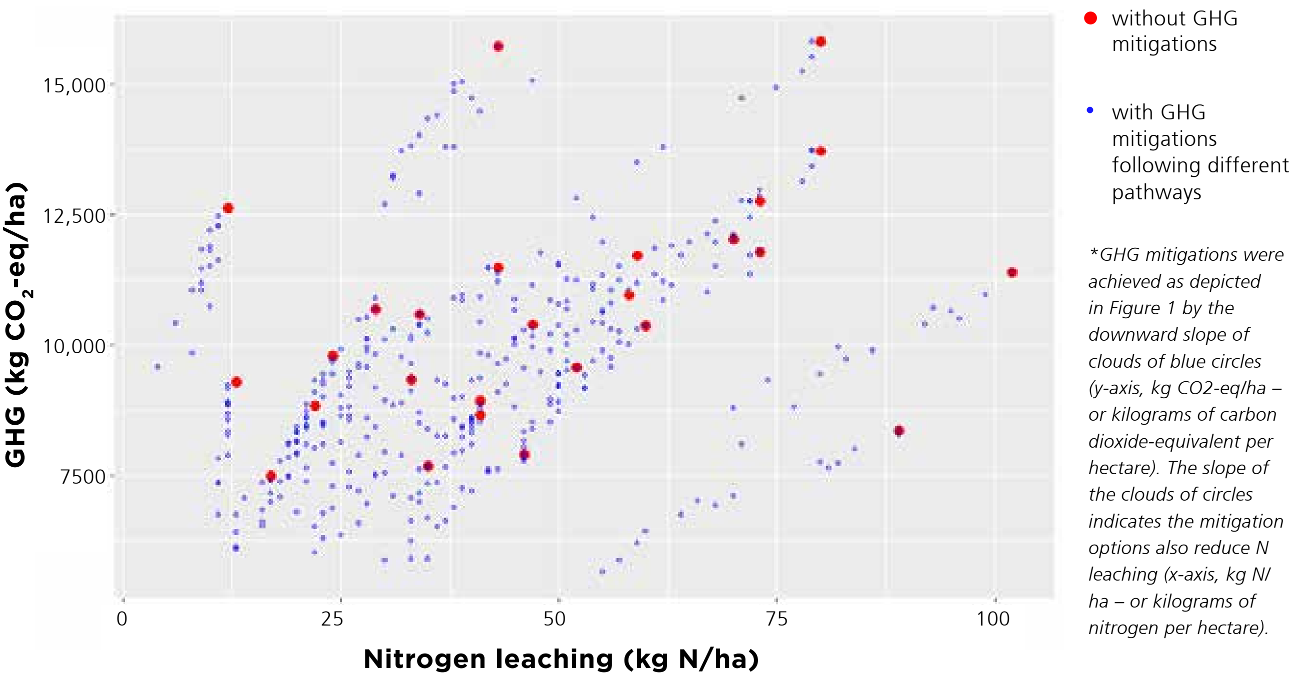
A DairyNZ modelling study[4], using Farmax and Overseer, identified 27 typical dairy farms across New Zealand. The outputs of the models for these farms were regarded as the baselines.

Farm system changes were made to mitigate GHG emissions by changing input combinations (e.g. fertiliser, amount and type of imported feed), with stock numbers altered to match feed supply.

In *Figure 1* below, the baseline farms cover a range of N leaching and GHG emissions due to the range of environmental conditions across the regions (e.g. soils and rainfall), and the range of farm systems (low to high input) modelled. The relationship between the pathways of the blue circles indicates that mitigation options to reduce GHG emissions also reduce N leaching.

Figure 2 on page seven shows for the same dataset that, in general, more GHG reductions means less profit, but there are a number of situations where mitigations had minimal negative impact on profit or increased profit (dots close to or above the horizontal line).

Figure 1. Predicted greenhouse gas emissions versus nitrogen leaching for typical regional dairy farms[4]*



**GHG mitigations were achieved as depicted in Figure 1 by the downward slope of clouds of blue circles (y-axis, kg CO2-eq/ha – or kilograms of carbon dioxide-equivalent per hectare). The slope of the clouds of circles indicates the mitigation options also reduce N leaching (x-axis, kg N/ha – or kilograms of nitrogen per hectare).*

Focus on N leaching

Farmlet trials co-funded by DairyNZ (Pastoral 21, or 'P21') were conducted in Waikato, Canterbury and South Otago over five seasons from 2011 to 2016, with the aim of developing system-level solutions to lower N leaching in a profitable manner[3] (see **dairynz.co.nz/P21**). Data from these trials were used to determine the impacts of N leaching mitigations on total GHG emissions ('Future' systems; Control = 'Current' – see *Table 1* below, right). Methodologies varied across the regions, but N leaching was measured using either soil suction cups, soil mineral N, or lysimeters (large barrels with undisturbed soil and sward to collect and measure drainage).

Annual average GHG emissions were calculated based on New Zealand's Greenhouse Gas Inventory methodology and included off-platform feeding and imported supplements. Milk production was determined from daily volumes and weekly milk compositions. Actual milk prices and actual or regional average costs of inputs (fertiliser, feed, etc.) were used for estimating profitability for those years.

In the Waikato, the Future system had lower N inputs (fertiliser and imported supplements), a lower stocking rate with higher genetic merit cows, and used a stand-off pad in autumn and winter. The Future system reduced GHG emissions by 16 percent, i.e. 2.2t (tonnes) of CO_2-eq/ha. However, averaged over five farming seasons, milk production was reduced by four percent, i.e. 50 kilograms of milksolids per hectare (kg MS/ha) and profitability by 13 percent – $280/ha compared with the Current system.

In Canterbury, the Future system with lower N inputs and stocking rate reduced GHG by five t CO_2-eq/ha (24 percent), milk production by 542kg MS/ha (24 percent) and profit by $358/ha (nine percent), compared with a high-input system (Current).

Figure 2. Predicted change in operating profit (%) versus change in GHG emissions (%) for typical dairy farms. The curved line is the best-fit local regression line with error margins. The dots above the horizontal line indicate situations where profit increased when reducing GHG emissions.

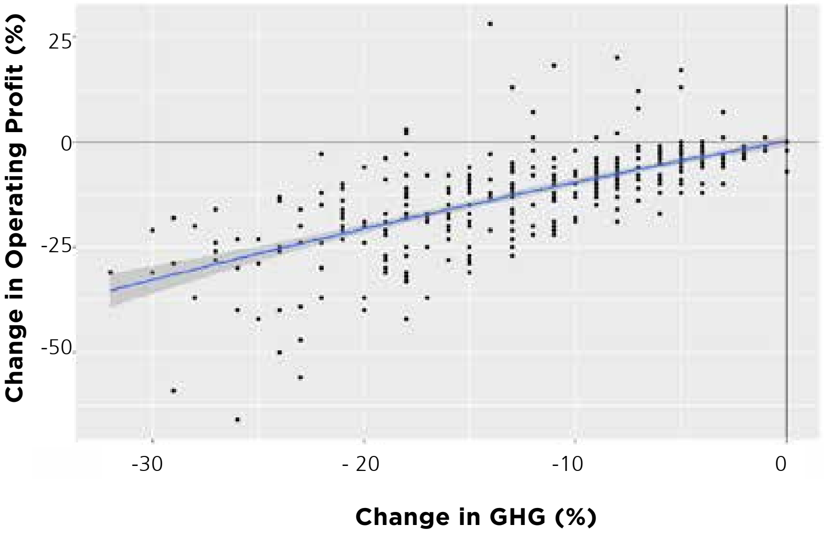


Table 1. Average performance (production, profit and environmental footprint) of three regional farm system trials

Region	Farm system	Milk production (kg MS/ha)	Operating profit ($/ha)	N leaching (kg N/ha)	GHG emissions (t CO2-eq/ha)
Waikato	Current	1200	2086	62	13.6
Waikato	Future	1153	1807	46	11.4
Canterbury	Current	2242	3893	Kale 114 FB 75	20.6
Canterbury	Future	1700	3535	Kale 80 FB 53	15.6
South Otago	Current	964	715	29	11.9
South Otago	Future-barn	949	20	16	11.6
South Otago	Future-opt	931	777	22	10.8

**All metrics are presented as 'per hectare of the milking platform', averaged over all farming seasons. In the Canterbury region, wintering of non-lactating cows can be either on kale followed by an oat catch crop (Kale), or fodder beet (FB).*

At Telford in Otago, there were two low-N leaching systems, one using a barn to house cows during winter and wet days in spring and autumn (Future-barn), and one attempting to optimise feed intake by changing calving date and type of home- grown feed (Future-opt). GHG emissions were reduced in the Future systems by between 0.3 and 1.1t CO -eq/ha (three to nine percent), compared with Current.

However, the profitability of the system that included the barn was significantly lower (NZ$700/ha or 97 percent), mainly due to capital and maintenance costs.

In summary, N mitigations in the farmlet systems achieved leaching reductions of 22 to 30 percent. In addition, these lower-input (less imported feed and N fertiliser) systems also reduced GHG emissions by between nine and 24 percent.

The exception was the Future-barn system in South Otago, where N leaching was reduced by 45 percent but GHG emissions were not reduced due to greater manure storage and handling. GHG reductions in the lower input systems of Waikato and Canterbury came at an average loss of profit of approximately NZ$100t CO_2-eq.

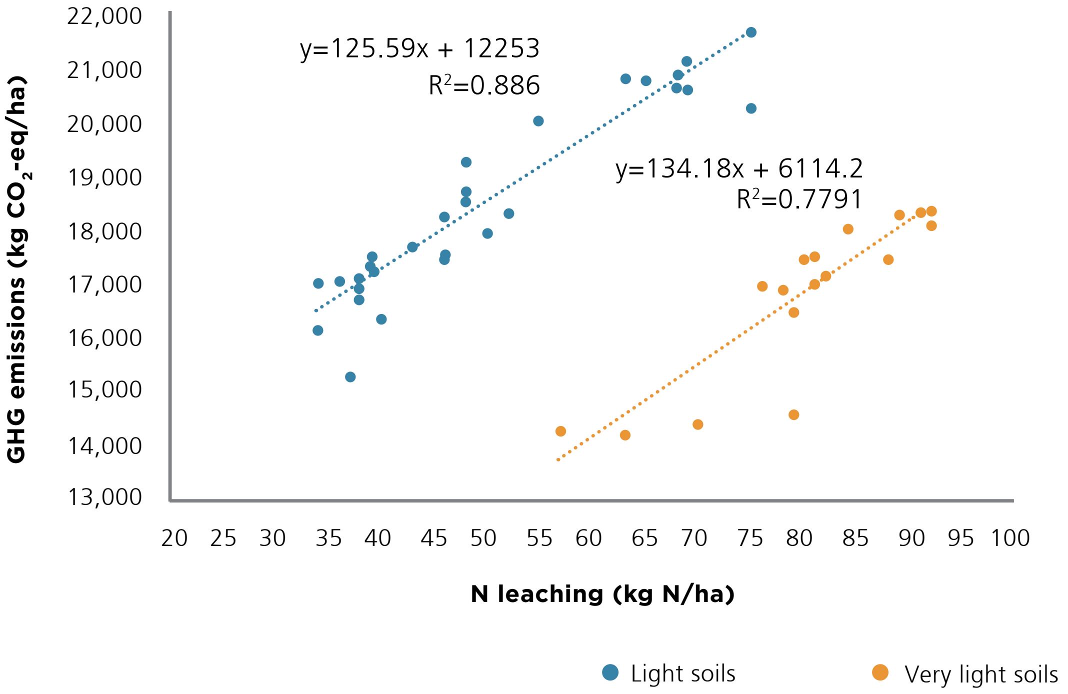
Focus on forages

The DairyNZ-led Forages for Reduced Nitrate Leaching programme (FRNL; 2013 to 2019) focused on N leaching by using alternative forages, e.g. plantain-mixed pastures, fodder beet (for wintering and shoulders of the season), and catch crops following forage crops.

The programme involved five monitor dairy farms in the Canterbury region (joining in 2014), and featured experiments with forage-based mitigations over the next years[5]. Data from the farms were used to estimate N leaching and GHG reductions using the Overseer model. Alternative scenarios proposed by the monitor farmers (e.g. using a feed pad, changing stocking rates and/or fertiliser rates) were also modelled. Results for the five FRNL monitor farms are presented in *Figure 3* below.

As N leaching decreased, so did GHG emissions, with N leaching accounting for 89 and 78 percent of GHG variability for light and very light soils, respectively. This is similar to the results in *Figure 1* on page six. In *Figure 1*, the focus was on GHG emissions with N leaching following, but in *Figure 3*, the focus is on N leaching with GHG following.

Figure 3. Predicted greenhouse gas emissions versus nitrate leaching for five dairy monitor farms (part of the Forages for Reduced Nitrate Leaching (FRNL) programme[5])*



**The focus was N leaching reduction. The results were clustered based on soils: three farms on light soils and two on very light soils.*

Telford's 'Future-opt' system focussed on better feeding and optimised grazing management of winter brassica crops.

Conclusion

Farm system mitigations that focus on lowering GHG emissions/ha or on N leaching/ha can result in a reduced overall farm environmental footprint. Key drivers for GHG emissions and N leaching are the same: feed eaten/ha, and N surplus (from N fertiliser and imported feed). Systems with off-paddock facilities (e.g. a wintering barn) may be the exception, these can reduce N leaching, but not necessarily GHG emissions. Depending on the current status of the farm, mitigation options that reduce imported feed and N fertiliser can achieve reasonable reductions (e.g. up to 10 percent) in GHG and N leaching. This can be achieved while maintaining or improving profitability. However, larger reductions that do not reduce profit will require technological solutions such as different animal and/or plant genetics, different feeds or feed additives, or ruminal methane inhibitors.

The Forages for Reduced Nitrate Leaching programme (FRNL) had principal funding from the Ministry of Business, Innovation and Employment (MBIE). The programme was a partnership between DairyNZ, AgResearch, Plant & Food Research, Lincoln University, the Foundation for Arable Research and Manaaki Whenua. Learn more at **dairynz.co.nz/frnl**

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Advances in genetic mapping now allows breeders to capture hybrid vigour in perennial ryegrass breeding programmes.

Capturing hybrid vigour in perennial ryegrass breeding

DairyNZ has co-invested in a research project to develop a hybrid breeding method for perennial ryegrass with the potential to increase gains in annual dry matter yield.

Cáthal Wims, senior scientist, DairyNZ

DairyNZ is investing in the development of new hybrid perennial ryegrass cultivars as part of a research programme led by Australian organisation DairyBio, a joint venture between Agriculture Victoria, Dairy Australia and the Gardner Foundation. This will allow breeders to exploit hybrid vigour in perennial ryegrass, which hasn't been possible until now. Maize breeders have been successfully exploiting hybrid vigour in their breeding programmes for over 70 years – which has contributed to maize's superior rates of genetic gain compared with perennial ryegrass. Initial field trial evaluations of the new cultivars in New Zealand and Victoria, Australia, are promising.

Perennial ryegrass: New Zealand history

Following perennial ryegrass's introduction to New Zealand in the 1800s, plant breeders identified local ecotypes (local populations that had adapted to their environmental conditions), which exhibited superior performance. One particularly persistent ecotype was identified in Hawke's Bay, from which a strain with superior winter and spring growth was selected. This strain was certified in 1934 and later named Grasslands Ruanui.

Further progress was made when the Mangere ecotype of perennial ryegrass was identified on the farm of Trevor Ellet in South Auckland. This out-yielded Grasslands Ruanui in on-farm trials[1]. Many important cultivars have been developed from the Mangere ecotype, including, Nui, Yatsyn and Bronsyn[1].

More recently, plant breeders incorporated genetic material from northwest Spain into their breeding programmes, leading to the development of winter-active, late-flowering cultivars, e.g. Bealey[2].

KEY POINTS

- Heterosis, or hybrid vigour, occurs when the progeny of two diverse varieties of a species exhibit greater yield, growth rates and fertility than either parent.
- It's a contributing factor to the superior rates of genetic gain observed in maize breeding programmes compared with perennial ryegrass.
- Capturing heterosis in perennial ryegrass (an outbreeding, self-incompatible species) has so far been difficult.
- Recent advances in genetic mapping mean plant breeders can now select perennial ryegrass lines suitable for hybrid breeding, based on a method first proposed in the 1970s.
- While this breeding method is at the early stage of development, initial results are promising.

Gains in dry matter yield

Estimates of genetic gain in annual dry matter (DM) yield for New Zealand perennial ryegrass cultivars have ranged from 0.25 to 0.76 percent per annum, with an average estimate of 0.5 percent per annum[1,3]. Similar values have been reported from Europe[4]. One study showed that genetic gains in the DM yield of Australian and New Zealand bred cultivars was limited prior to 1990, but since 1990, consistent genetic gains of 0.76 percent per annum have occurred[3].

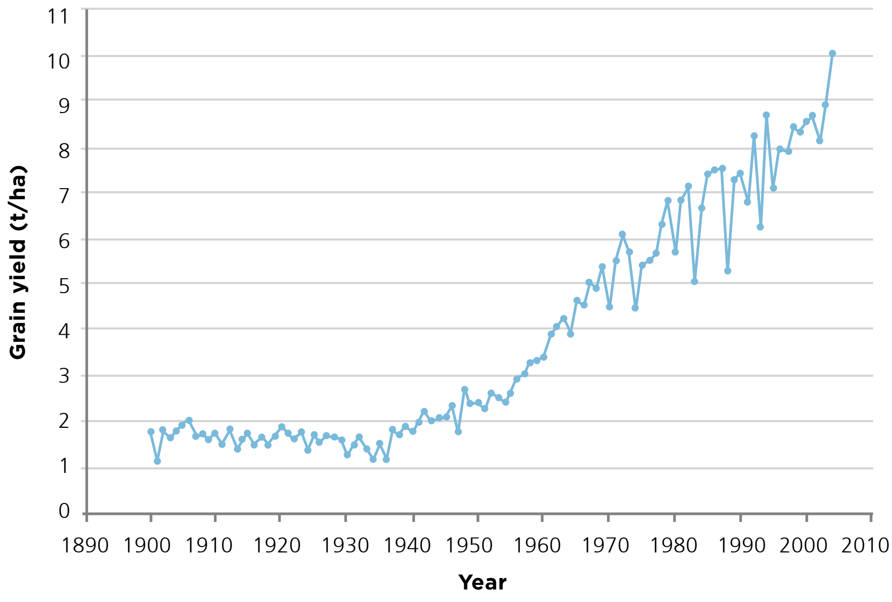
These gains can be considered quite modest compared with the genetic gains delivered by maize improvement programmes (for example, gains of 2.6 percent per annum in machine-harvestable grain yield have been reported[5]). Researchers have cited lower levels of investment and longer breeding cycles among the reasons. Another important constraint has been an inability to exploit hybrid vigour (‘heterosis’) effectively in commercial perennial ryegrass breeding programmes.

Heterosis, or hybrid vigour

Heterosis occurs when the progeny of two diverse varieties of a species, or crosses between species, exhibit greater yield, speed of development, and fertility than either parent[6]. New Zealand dairy farmers are already familiar with this concept – the common practice of cross-breeding dairy cattle can result in an animal that’s more productive than either of the parental breeds[7].

Heterosis has also been captured in many agricultural plant breeding programmes. For example, hybrid breeding has been successfully used in maize breeding programmes since the 1930s and has led to significant gains in yield (*Figure 1*)[8].

Figure 1. Trend in US maize grain yield[8]



Capturing heterosis in perennial ryegrass (an outbreeding, self-incompatible species) has so far been difficult.

Suitability for hybrid breeding: maize vs. ryegrass

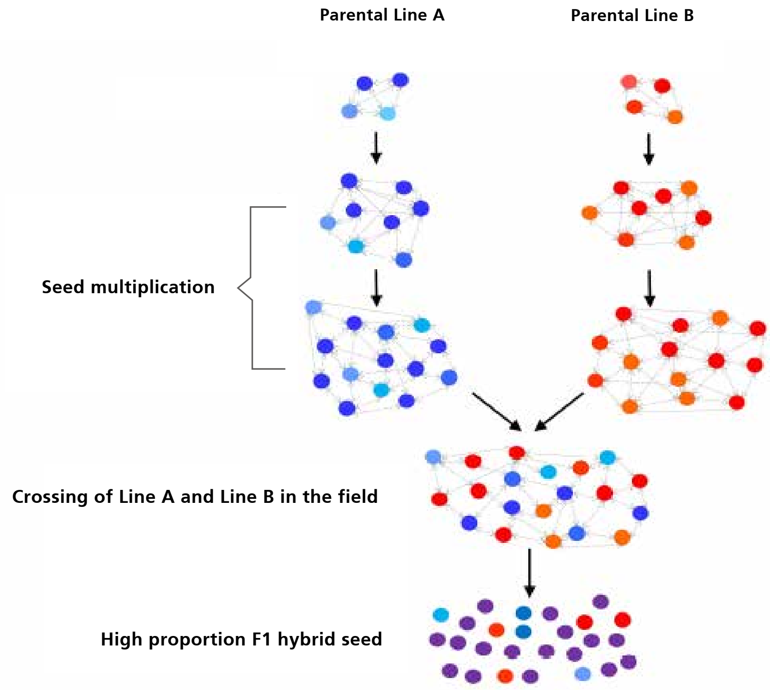
The commercial production of hybrid plants requires two important steps. Firstly, inbred lines are created to reduce genetic variation, by self-fertilising individual plants through successive generations. This ensures the offspring of these lines are predictable and uniform.

The inbred lines are then mated (cross-pollinated). In the field, breeders ensure that cross-pollination between the inbred parent lines occurs (to avoid further self-fertilisation). The resultant ‘F1’ hybrid plants display significant levels of heterosis on-farm.

Maize lends itself well to hybrid breeding because it’s possible to self-fertilise plants and create inbred-parent lines. Also, cross-pollination in the field can be easily achieved by mechanically removing the male flower (de-tasselling) from one of the parent lines.

Because perennial ryegrass is an outbreeding, self-incompatible species (see next section), so far it has been difficult to effectively exploit heterosis in perennial ryegrass breeding programmes. It’s not that heterosis doesn’t occur in current commercial ryegrass breeding programmes. The problem is, it's not captured in the seed that farmers purchase. That's because the initial hybrid vigour present in the small number of plants initially crossed (five to 10 plants) is lost as their offspring plants are back-crossed and crossed again.

Figure 2. Overview of the perennial ryegrass F1 hybrid breeding process[10]



Self-incompatibility in ryegrass

Self-incompatibility is a mechanism employed by some plants to maximise cross-pollination and restrict self-fertilisation and inbreeding. In nature, this mechanism ensures genetic diversity and limits the loss of vigour associated with inbreeding. This characteristic naturally causes problems for perennial ryegrass breeders who want to create inbred parent lines for use in a hybrid breeding programme.

However, genetic diversity occurs in the mechanisms controlling self-incompatibility in perennial ryegrass. This forms a basis for a hybrid breeding method known as the self-incompatibility method[9]. This method relies on the self-incompatibility system in ryegrass not being fully effective, which means some specific parental lines can be inbred.

This approach turns the traditional breeding process on its head, so that the final cross is carried out on a large scale (tens of hectares) to release hybrid vigour. The lead-up to this involves several years of inbreeding using two selected parental lines. This ensures enough seed can be generated from each line so they can be cross-pollinated in the final seed crop to produce commercial quantities of seed. That seed then goes directly into farmers paddocks, carrying a high level of heterosis.

There's always a catch

There is still a catch in this method that breeders need to overcome. In this case, it's managing the multiple crosses of the parental inbred lines to generate the amount of seed needed to grow the final crop. To successfully produce hybrids, crossing of the inbred lines must be controlled to ensure the resultant plants are not a result of self-fertilisation (or further inbreeding). This isn't so straightforward with an outbreeding, wind-pollinated species such as perennial ryegrass.

Controlled pair-crossing of perennial ryegrass lines in the field isn't realistic, as fertilisation occurs via a pollen cloud from numerous surrounding plants[10]. While the self-incompatibility mechanism generally ensures that perennial ryegrass cross-pollinates, the inbred lines, by their nature, can potentially inbreed further[11], leading to a reduction in the proportion of F1 hybrid seed.

In order to generate a high proportion of F1 hybrid seed, the inbred parental lines must cross-pollinate. Therefore, the breeding lines must be selected to ensure the compatibility between the two inbred parental lines (i.e. ability to cross-pollinate) is greater than the compatibility within each inbred parental line (inbreeding). (See *Figure 2*).

Gene marker breakthrough

Predictive genetic markers (segments of DNA that can be used to track genes) for the genes controlling self-incompatibility in perennial ryegrass have now been identified. Using this technology, breeders can selectively target parental lines to achieve the compatibility targets noted above.

Analysis by researchers indicates that breeding schemes based on the self-incompatibility method, when combined with the use of genetic mapping to target specific breeding lines, has the potential to generate seed lines with an 83 percent proportion of F1 hybrids[10].

To date, there has been little evaluation of the F1 hybrid plants generated by this breeding method. To be commercially viable and of value to famers, the breeding method must generate F1 hybrids that are superior to the better parent (high-parent heterosis)[12], and indeed, superior to the elite ryegrass cultivars commercially available now.

Louise Brok's research results indicate that the self-incompatibility breeding method has the potential to produce plants that out-yield current commercially-available cultivars.

Glasshouse study – DairyNZ

Recently DairyNZ funded a study by Louise Brok, a DairyNZ and Massey University Masters student, which evaluated F1 hybrid plants developed using the self-incompatibility breeding method. The objective of her work was to detect early proof of increased yield performance in F1 hybrid plants. Due to limited seed availability, Louise's experiment was conducted at an individual plant scale in a glasshouse. F1 hybrid plants produced by the self-incompatibility breeding method displayed mid-parent heterosis, i.e. the F1 hybrid was superior to the parental average.

This provides evidence that the proposed breeding method can successfully exploit heterosis. In addition, high-parent heterosis was detected, which indicates the breeding method has the potential to produce plants that out-yield current commercially-available cultivars.

Further research

More data from field trials will be required to corroborate results from Louise Brok's glasshouse experiments. In addition, further work will be required to identify parent lines most suitable for the breeding method which will maximise heterosis, and DM yield on-farm. New Zealand plant breeding companies are testing hybrid perennial ryegrass cultivars developed using the methods described above in the field, and seed could be commercially available within five years.

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SCIENCE SNAPSHOT

Dairy workplaces of the future

What kind of workplaces will dairy farmers need to offer in the coming decades? DairyNZ's been looking into it, explains senior scientist Callum Eastwood.

Dairy farmers around the world are struggling to attract and retain talented staff, and New Zealand is no different. It's clear that our dairy workplaces must change – if not now then in the near future – to meet the evolving expectations of farmers and farm employees.

DairyNZ has been carrying out a New Workplace Design research project to learn what talented people are seeking in a job and what an attractive dairy farm workplace will look like in 2030[1]. We've used stakeholder workshops, interviews with farmers and workplace experts, and design-thinking processes to uncover the major dairy workplace trends.

What have we found?

1. New Zealand's workforce is ageing, and will have a greater proportion of young Māori, Pasifika and Asian people. There'll be more part-time employees in future. As such, dairy workplaces must be designed to attract and embrace this diverse mix.
2. Technological change is automating tasks, providing better information for on-farm decision-making and enhanced learning methods. Sensor and automation technology has already made an impact on Kiwi farms[2]. Future dairy farmers will need to use novel technologies to their advantage.
3. Job tenures will shorten and dairy employees will prefer variety in their careers. Farm workplaces will need to allow for people moving in and out of our sector, rather than fighting this trend[1]. Our future employees could include career changers, urbanites seeking a farming lifestyle, and casual employees. These people will quickly need to connect with farming values and understand that they work at the start of a food value chain.
4. Casual or short-term 'gig-economy' work is becoming common, e.g. Uber. Farmers need to adapt their farm system, such as by changing milking time and frequency, to access 'under-employed' people who may work for only parts of the day, or on certain tasks (e.g. non-physical).
5. Demand is growing among farm staff for ongoing learning and upskilling through virtual and remote methods, e.g. short video tutorials. Our research shows virtual interactions, such as Skype meetings, are already changing the way farmers and rural professionals interact[3].

A word cloud highlighting the themes mentioned by participants of a dairy workplace design workshop in April 2019.

Find out more about this research at
dairynz.co.nz/new-workplace-design

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