Pasture species mixtures to reduce nitrogen leaching

The Forages for Reduced Nitrate Leaching (FRNL) Programme is a six-year study investigating how any of a wide variety of forages can be used within modern grazing systems to both improve animal production and reduce nitrate leaching

Key findings

- Mixed-species pastures (herb species added to grasses and white clover), can increase herbage production and reduce the risk of nitrogen leaching.
- Milk production from mixed-species has sometimes been shown to be greater, but is no less than from cows grazing ryegrass/white clover.
- Plantain is a key species for increasing dry matter production and reducing urine nitrogen concentration. A critical threshold of plantain in the animal diet should be clearly established.

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Background

One of the major aims of the FRNL programme is to determine whether novel pasture species mixtures can contribute to reduced nitrate leaching to see whether they reduce urinary nitrogen (UN) output from cows, rather than looking at individual forage species in monocultures.

When plant attributes are combined in a multi-species pasture, the mixtures typically have greater annual herbage production than conventional grass-clover pastures. These mixtures can achieve greater total annual N uptake due to their complementary root systems and seasonal growth patterns[1]. In New Zealand, the early interest in using diverse pasture mixtures arose from a need to maintain animal production in environments where conventional perennial ryegrass/white clover pastures lacked persistence because of summer drought and pest damage. Herbs such as chicory and plantain were used as they had already shown promise in monoculture, good quality seed was available and their management was understood.

Several experiments comparing the animal feeding benefits of diverse pasture mixtures with conventional ryegrass/clover pastures have been conducted in the last decade (Table 1). These have shown similar or greater milk production and consistently reduced urinary nitrogen concentration. An indoor feeding experiment with forage mixtures including chicory, plantain and lucerne demonstrated greater milksolids (MS) production and N intake allocated to milk[2]. A concurrent grazing experiment in the Waikato with similar diverse pastures supported the expectation of better summer DM production but this did not translate into greater milk production[3]. A series of grazing trials in Canterbury demonstrated the benefits of diverse pasture mixtures (chicory, plantain, red clover and lotus added to the conventional ryegrass/clover sward) [4,5,6]. They showed similar or better MS yield and lower urine N concentration compared with the ryegrass/clover pasture. The milk yield advantage was more closely linked to the legume content, but reductions in UN concentration were influenced by the herb component.

It is important to know whether the benefits can be attributed to the greater diversity of species in the pasture mixture, or to the presence of individual species. Vibart et al.[1] suggested that the presence of specific well-adapted species is more important than the number of species in driving herbage production and N dynamics. A Lincoln grazing study showed an 11% greater MS production per day in late lactation combined with a 56% reduction in UN concentration from cows grazing pure plantain in comparison with irrigated perennial ryegrass and white clover pastures [7].

ryegrass vs. tall fescue as the base pasture grasses, and grass/legume pastures with or without plantain. The pastures were sown at the DairyNZ Scott Farm in spring 2015, and rotationally grazed by dairy cows throughout the year. Paddocks were grazed when pasture cover reached 2800-3200 kg DM/ha to a residual of 1500-1600 kg DM/ha. Sample plots were harvested prior to each grazing with a mower to 4 cm height to determine the component species and dry matter yield. The milk production and UN concentration of small herds were measured during two 10-day periods in February 2016 (mid-lactation) and November 2016 (early lactation).

Table 1: Summary of recent New Zealand published experiments examining the effect of various pasture mixes in comparison with conventional ryegrass/white clover swards, on dairy cow milk production (MS) and urinary nitrogen (UN) concentration. Statistically significant effects are quantified.

Pasture type compared with ryegrass/white clover	Season	Change in MS yield (kg MS/cow/day)	Change in UN concentration (g N/L)
Ryegrass +white clover +chicory +plantain[4]	Autumn	Nil	-40% (5.7 v 3.4)
Ryegrass +white clover +chicory +plantain +lucerne[5]	Spring	Nil	-20% (6.1 v 4.9)
Ryegrass + white clover +prairie grass +chicory +plantain +red clover[6]	Spring	Nil	-30% (4.2 v 2.9)
	Summer	+17% (1.47 v 1.72)	Nil
	Autumn	Nil	Nil
Ryegrass* + white clover +prairie grass +chicory +plantain +red clover[6]	Spring	Nil	-28% (4.6 v 3.3)
	Summer	Nil	-28% (4.4 v 3.1)
	Autumn	Nil	-22% (6.8 v 5.3)
Plantain[7]	Autumn	+11% (1.50 v 1.67)	-56% (5.4 v 2.4)
Ryegrass + white clover +plantain[7]	Autumn	+7% (1.50 v 1.60)	-33% (5.4 v 3.6)

** comparison using high sugar ryegrass*

Waikato grazing trial

In a recent grazing trial in the Waikato, the milk production and UN output were measured for cows grazing four pasture mixtures. These mixtures were chosen to provide greater MS production and to reduce UN excretion relative to a conventional ryegrass/white clover pasture. The species were selected based on simulations with the MOLLY animal model, using data on chemical composition and metabolisable energy for a range of pasture species[8]. The modelling tested perennial ryegrass, tall fescue, cocksfoot, kikuyu, prairie grass, white clover, lucerne, red clover, lotus, chicory and plantain, in 72 simulated combinations. Combinations of tall fescue, lucerne and plantain were predicted to maximise the ratio of MS:UN. Therefore, the species combinations chosen for the grazing experiment were:

Ceres One50 perennial ryegrass, Grasslands® Torlesse lucerne, Grasslands® Hummer tall fescue and Ceres Tonic plantain.

1. Perennial ryegrass + Lucerne **PR+L**
2. Perennial ryegrass + Lucerne + Plantain **PR+L+P**
3. Tall fescue + Lucerne **TF+L**
4. Tall fescue + Lucerne + Plantain **TF+L+P**

This field study allowed two main comparisons; perennial

Over the 2016 calendar year of pasture harvests, there was little difference in the total herbage accumulation of the ryegrass and fescue-based pastures. However, the paddocks with plantain grew on average 2.6 t DM/ha (for ryegrass-based pastures) or 1.6 t DM/ha (for fescue-based pastures) more forage in total than those without plantain. During the short-term measurement period in summer the pastures comprised 25% perennial ryegrass and 34% lucerne in the PR+L pastures; and 24% tall fescue and 43% lucerne in the TF+L pastures. Where plantain was included, this made up 51% (PR+L+P) and 38% (TF+L+P) of the herbage, reducing both the grass and lucerne content by more than half. During the short-term measurement period in spring the pastures comprised 60% perennial ryegrass and 24% lucerne in the PR+L pastures; and 48% tall fescue and 31% lucerne in the TF+L pastures. Where plantain was included, this made up 51% (PR+L+P) and 36% (TF+L+P) of the herbage, again reducing the grass and lucerne content by more than half.

In both summer and spring there were few differences in milk production and percent fat or protein between the treatments. There were never any differences between ryegrass and fescue-based pastures, so the results in Table 2 show only the effects of

Table 2: Milk production from cows grazing pastures with and without plantain in the Waikato, in summer 2016 (mid-lactation) and spring 2016 (early lactation). The results show similar milk production across all four treatments but a lower Fat% from the cows grazing pastures that include plantain. Different letters following the data indicate significant differences between pasture types. MS = milksolids.

Milk production measurement		Grass+ Lucerne	Grass+ Lucerne+ Plantain
Summer 2016 Mid-lactation grazing trial	Milk volume (L/cow/d)	12.2	13.8
	Fat (%)	5.04 a	4.45 b
	Protein (%)	3.80	3.74
	MS (kg/cow/d)	1.09	1.11
Spring 2016 Early lactation grazing trial	Milk volume (L/cow/d)	19.3	19.5
	Fat (%)	4.24 a	4.12 b
	Protein (%)	3.54	3.59
	MS (kg/cow/d)	1.47	1.48

the inclusion of plantain. The daily milk volume of cows grazing the TF+L+P in summer was 26% greater than the other three treatments, although this did not translate into greater daily MS production. The only significant pasture treatment effect was a 12% decrease in milk fat content for the cows grazing pastures with plantain during summer and a 3% decrease during spring.

The UN concentration from cows grazing plantain pastures was significantly less than from those grazing non-plantain pastures in both summer (38% lower) and spring (21% lower, Figure 1). When the data are adjusted for urine volume (i.e. creatinine-corrected) to produce a proxy for daily N excretion, this was also 38% lower in summer, indicating that the cows were excreting less N in total (Figure 2). In spring, the creatinine-corrected N concentration differences were not significant, indicating that total daily N excretion was similar, but diluted by greater water intake when grazing plantain. This seasonal difference may be an important consideration, depending on the period of high N leaching risk.

During early lactation, two herds of 10 cows spent 5 days break-grazing a single paddock of either the PR+L or PR+L+P treatments, while wearing urine sensors (AgResearch MkII[9]). While each herd had a similar mean daily UN output, in the PR+L+P treatment this was spread across a greater urine volume (more urination events and greater volumes), resulting in a 44% lower UN concentration (Table 3). The increase in urine volume may be a result of the diuretic effect of plantain, which has been reported in sheep[10]. Dilution of UN should decrease the risk of N leaching, given that the number of urine patches with very high concentrations of soil nitrate will be reduced, allowing plants to take up a greater proportion of excreted nitrogen[11]. A similar grazing trial with urine sensors at Lincoln, where the proportion of plantain in the pastures was 16-21%, did not detect a significant difference in UN output or concentration (Bryant et al., unpublished report). Since the latest Waikato trial showed an effect at 26% plantain in the pastures, it appears that cows must consume pastures with >25% plantain content to achieve the desired effect of lower UN concentration.

Implications

While the inclusion of plantain in pasture mixtures has been shown to have a positive effect on DM production and urinary N concentration, it appears the content of plantain in the pasture must be above a critical level. This level will be verified in future animal feeding trials in the FRNL programme. Another key information gap that remains is how to establish and manage pastures containing plantain to achieve and maintain this desired level, and whether this applies to the whole year or just the

Figure 1: Urinary nitrogen concentration (UN%) of cows grazing four pasture types in summer 2016 (mid-lactation) and spring 2016 (early lactation). The results show no effect of the base pasture grass but a consistent effect of including plantain on reduced UN%. Bars indicate standard errors. PR = perennial ryegrass; TF = tall fescue; L = lucerne; P = plantain.

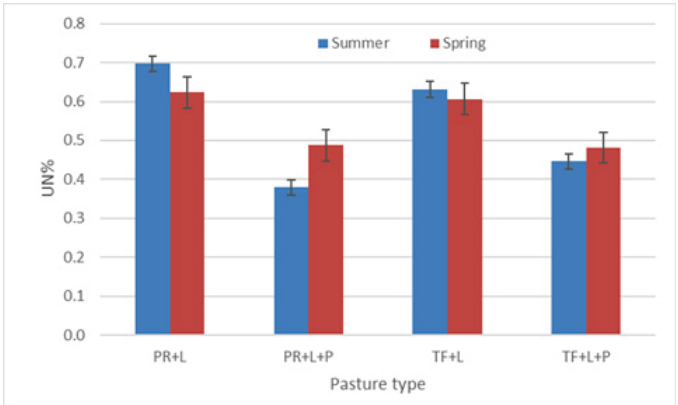

Figure 2: Creatinine-corrected urinary nitrogen excretion (a proxy for daily N excretion) of cows grazing four pasture types in summer 2016 (mid-lactation) and spring 2016 (early lactation). The results show no effect of the base pasture grass but a significant effect of including plantain on reduced total N excretion in summer only. Bars indicate standard errors. PR = perennial ryegrass; TF = tall fescue; L = lucerne; P = plantain.

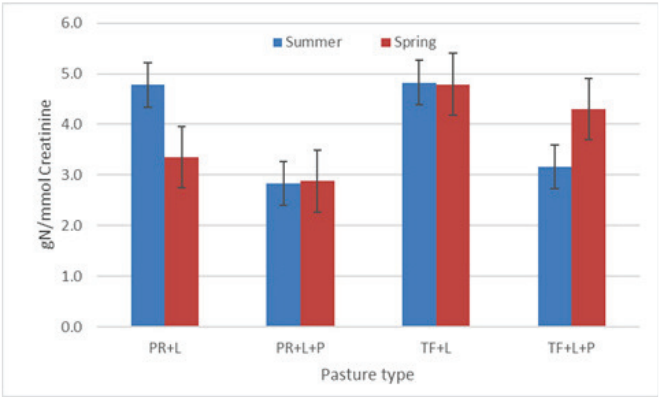

Table 3: Urine sensor measurements on two herds of lactating cows grazing two pasture types in the Waikato, November 2016. The results show greater urine volumes and urination frequency on the plantain pastures, leading to reduced UN concentration. Different letters following the data indicate significant differences between pasture types. PR = perennial ryegrass; L = Lucerne; P = plantain.

Urine measurement	PR+L	PR+L+P
Mean daily N excretion (g/d)	183	178
Mean urine volume (L/d)	31 b	51 a
Mean number of urination events (#/d)	11 b	15 a
Mean UN concentration (%)	0.62 a	0.35 b

period immediately preceding and during periods of high risk of nitrogen leaching.

The benefits of mixed-species pastures for milk production are less clear. Although some studies have demonstrated significantly greater MS production from diverse pastures that have included plantain and chicory[4,7], others have not[3,5,6]. The results from the latest Waikato research did not show any difference in MS production when cows grazed pastures including plantain.

References

1. Vibart, R.E., I. Vogeler, M. Dodd, and J. Koolaard. 2016. Simple versus Diverse Temperate Pastures: Aspects of Soil–Plant–Animal Interrelationships Central to Nitrogen Leaching Losses Agronomy Journal 108(6):2174–2188.
2. Woodward, S.L., G.C. Waghorn, M.A. Bryant and A. Benton. 2012. Can diverse pasture mixtures reduce nitrogen losses? Proceedings of the 5th Australasian Dairy Science Symposium pp 462–463.
3. Woodward, S.L., C.D. Waugh, C.G. Roach, D. Fynn, and J. Phillips. 2013. Are diverse species mixtures better pastures for dairy farming? Proceedings of the New Zealand Grassland Association 75:79–84.
4. Totty, V.K., S.L. Greenwood, R.H. Bryant, and G.R. Edwards. 2013. Nitrogen partitioning and milk production of dairy cows grazing simple and diverse pastures. Journal of Dairy Science 96:141–149.
5. Edwards, G.R., R.H. Bryant, N. Smith, H. Hague, S. Taylor, A. Ferris and L. Farrell. 2015. Milk production and urination behaviour of dairy cows grazing diverse and simple pastures. Proceedings of the New Zealand Society of Animal Production 75:79–83.
6. Bryant, R.H., M.E. Miller, S.L. Greenwood, G.R. Edwards. 2017. Milk yield and nitrogen excretion of dairy cows grazing binary and multispecies pastures. Grass and Forage Science DOI: 10.1111/gfs.12274.
7. Box, L.A., G.R. Edwards, and R.H. Bryant. 2016. Milk production and urinary nitrogen excretion of dairy cows grazing perennial ryegrass-white clover and pure plantain pastures. Proceedings of the New Zealand Society of Animal Production 76:18–21.
8. Gregorini, P., P.C. Beukes, D. Dalley and A.J. Romera. 2016. Screening for diets that reduce urinary nitrogen excretion and methane emissions while maintaining or increasing production by dairy cows. Science of the Total Environment 551:32-41
9. Betteridge, K., D.A. Costall, F.Y. Li, D. Luo, and S. Ganesh. 2013. Why we need to know what and where cows are urinating – a urine sensor to improve nitrogen models. Proceedings of the New Zealand Grassland Association 75:119–124.
10. O'Connell, C.A. 2015. An investigation of the diuretic activity of plantain following its ingestion by sheep. BSc(Hons) dissertation. Lincoln University. https://researcharchive.lincoln.ac.nz/handle/10182/6802
11. Li, F.Y., K. Betteridge, R. Cichota, C.J. Hoogendoorn, B.H. Jolly. 2012. Effects of nitrogen load variation in animal urination events on nitrogen leaching from grazed pasture. Agriculture, Ecosystems and Environment 159:81–89.