Plantain helping farmers to achieve environmental targets

Once considered a weed, a modern plantain *(Plantago lanceolata L.)* cultivar is showing promise for reducing nitrate leaching and greenhouse gas emissions.



Elena Minnée, post-doctoral scientist, DairyNZ
Cecile de Klein, principal scientist, AgResearch
Dawn Dalley, senior scientist, DairyNZ

KEY POINTS

Compared to cows fed ryegrass/white clover diets, when plantain exceeded 30 percent of the diet:

- urine volume increased and urine nitrogen (N) concentration decreased, reducing N loading and N leaching risk from urine patches
- total daily N excreted in urine was reduced as more dietary N was partitioned to milk and faeces
- the amount of drinking water consumed was reduced, so care must be taken when medicating drinking water and feeding plantain.

Nitrous oxide (N_2O) emissions from individual urine patches was also reduced by increasing the percentage of plantain in the sward and in the diet. The latter is most likely due to a reduction in the N content of the urine.

The link between plantain, nitrogen, and the environment

Why it's important

Regional councils are committed to establishing targets for fresh water quality that must be implemented by 2025 under the National Policy for Freshwater Management Statement. Also, as signatories to the 2016 Paris Agreement, the New Zealand Government has committed to reducing greenhouse gas (GHG) emissions to 30 percent below 2005 levels by 2030. Further, the proposed Zero Carbon Bill aims to set more stringent long-term GHG reduction targets. To achieve these water and GHG targets, reductions in nutrient and GHG emissions are required from all sectors of the economy.

In agricultural systems, nitrogen (N) loss from the soil contributes to freshwater pollution. The main source of N loss is from urine excreted by livestock during grazing. The high N loading rates in urine patches (about 600 kilograms of N per hectare or ~ 600kg N/ha[1]) exceed plant requirements, with surplus N susceptible to leaching below the root zone and subsequently into fresh water. N in urine deposits can also be lost to the atmosphere as nitrous oxide (N_2O). While N_2O makes up only about 10 percent of New Zealand's agricultural GHG emissions[2], it is a potent GHG with significant global warming potential.

What we're doing

The DairyNZ-led Forages for Reduced Nitrate Leaching Programme (FRNL) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) have focused on developing proven, adoptable mitigation options for farmers to minimise the environmental effects of farming. Emerging from this work, and supported by associated projects, is evidence to suggest the concentration of N in cattle urine is reduced when the plantain cultivar *Ceres Tonic* is included in the diet[3, 4, 5].

Reducing urinary N concentration reduces the N surplus in urine deposits, thus reducing the risk of N leaching and N_2O emissions. What is not well understood are the mechanisms responsible for reduced urine N concentration, how much plantain is required in the diet to achieve this, and what the effects of lower urine N concentration has on N_2O emissions. To address these questions, DairyNZ and AgResearch carried out two detailed experiments, jointly funded by the Ministry of Business, Innovation and Employment (MBIE) and NZAGRC, from January to June 2018.

Plantain studies

Nitrogen partitioning and excretion

To evaluate the effect of plantain in the diet of dairy cows on urine N, cows were housed in metabolism stalls at DairyNZ's Lye Farm in Hamilton. The stalls allowed us to measure how much N

was eaten and where that N went (to milk, or excreted in dung and urine), which we can't do in outdoor grazing trials.

Cows in late lactation were offered one of four diets and could eat as much as they chose to. These diets contained 0, 15, 30 or 45 percent fresh plantain (with the balance as ryegrass/white clover pasture). This was because previous research suggested reduced urine N concentration would be achieved within this range, and agronomic studies also suggest it is feasible to achieve these levels of plantain in ryegrass-based swards.

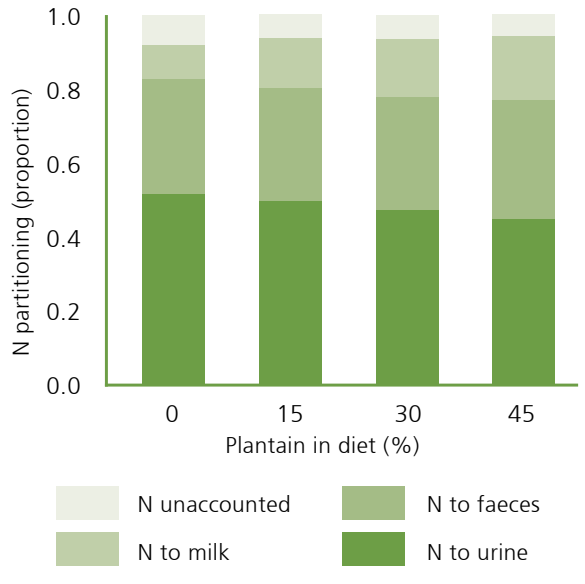
Dietary N intake is determined by the N content of feed and how much is eaten. In this experiment, the N content of plantain was much less than ryegrass: 2.2 grams versus 3.7 grams per 100 grams of dry matter (g DM). However, because cows consuming diets including plantain ate more DM *(Table 1)*, total N intake (g/cow/day) was similar across the diets.

Generally, N excreted to urine (g per day) is highly correlated with N intake[6], so at similar N intakes, similar amounts of urinary N were expected. However, cows offered diets with 45 percent plantain excreted 25 percent less N/cow/day in urine than cows consuming pasture. Examining where N went indicated that as the percentage of plantain in the diet increased, cows partitioned more N to milk and faeces and less to urine *(Figure 1)*.

Table 1: Effects of increasing plantain in cows' diet

	% plantain in diet				
	0	15	30	45	Significance
Total DM intake (kg DM/cow/d)	14.8	16.5	16.8	17.4	$P < 0.05$
N intake (g/cow/day)	553	575	529	525	NS
N excreted in urine (g/cow/d)	268	268	237	202	$P < 0.05$
Milk solids (kg/cow/d)	0.96	1.14	1.16	1.24	$P < 0.05$

Figure 1: Dietary nitrogen partitioning in relation to % of plantain in cows' diet

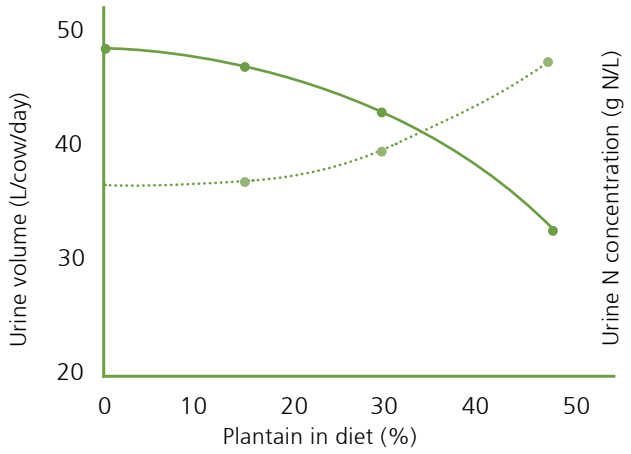


These differences in N partitioning between diets may be explained by differences in the forms of N in ryegrass and plantain. N in feed can be categorised in three groups: soluble non-protein N, rumen-degradable protein N (RDP) and rumen-undegradable protein N (RUP). Plantain contains less soluble and more rumen-undegradable N than ryegrass. Soluble N is very quickly degraded to ammonia in the rumen. When the production of ammonia exceeds what can be used immediately by rumen microbia, it is absorbed into the blood and excreted as N in urine[7].

Therefore, forages with high proportions of soluble N are not desirable. Further, because N is rarely a limiting nutrient in pasture-based farming, an increased proportion of RUP in plantain is not a concern. Rather, RUP will pass through the digestive tract and be metabolised or excreted as faeces[6]. Greater partitioning of excreted N to faeces, rather than urine, is desirable, as faecal N is less susceptible to leaching and conversion to N_2O[8].

N concentration in urine declined in diets containing more than 15 percent plantain, with a steep decline observed when plantain content was 30 percent and above *(Figure 2)*. Differences in N partitioning explain part of this decline, but there is evidence that when fed at high levels (≥ 30 percent in diet) plantain reduced urine N concentration via increased urine volume (i.e., a 'dilution effect'). Cows consuming 45 percent plantain produced around 10 litres (L) more urine per day (~ 30 percent; *Figure 2*) through slightly larger and more frequent

Figure 2: Urine N and volume in relation to increasing plantain in cows' diet



Total daily urine volume (·····) and mean daily urine nitrogen (N) (——) concentration from dairy cows fed increasing percentage of plantain in the diet.

urination events than cows consuming pasture only.

The mechanism driving increased urine volume (diuresis) is still uncertain. The low DM content of plantain (~ 9.5 percent) may cause diuresis simply through the consumption of large amounts of water in the plantain[9, 10]. Alternatively, plantain contains bioactive compounds that may induce an osmotic diuresis[11]. Both diuretic mechanisms work to inhibit water reabsorption, but further research is required to determine to what extent each is responsible for increased urine volume of cows fed plantain.

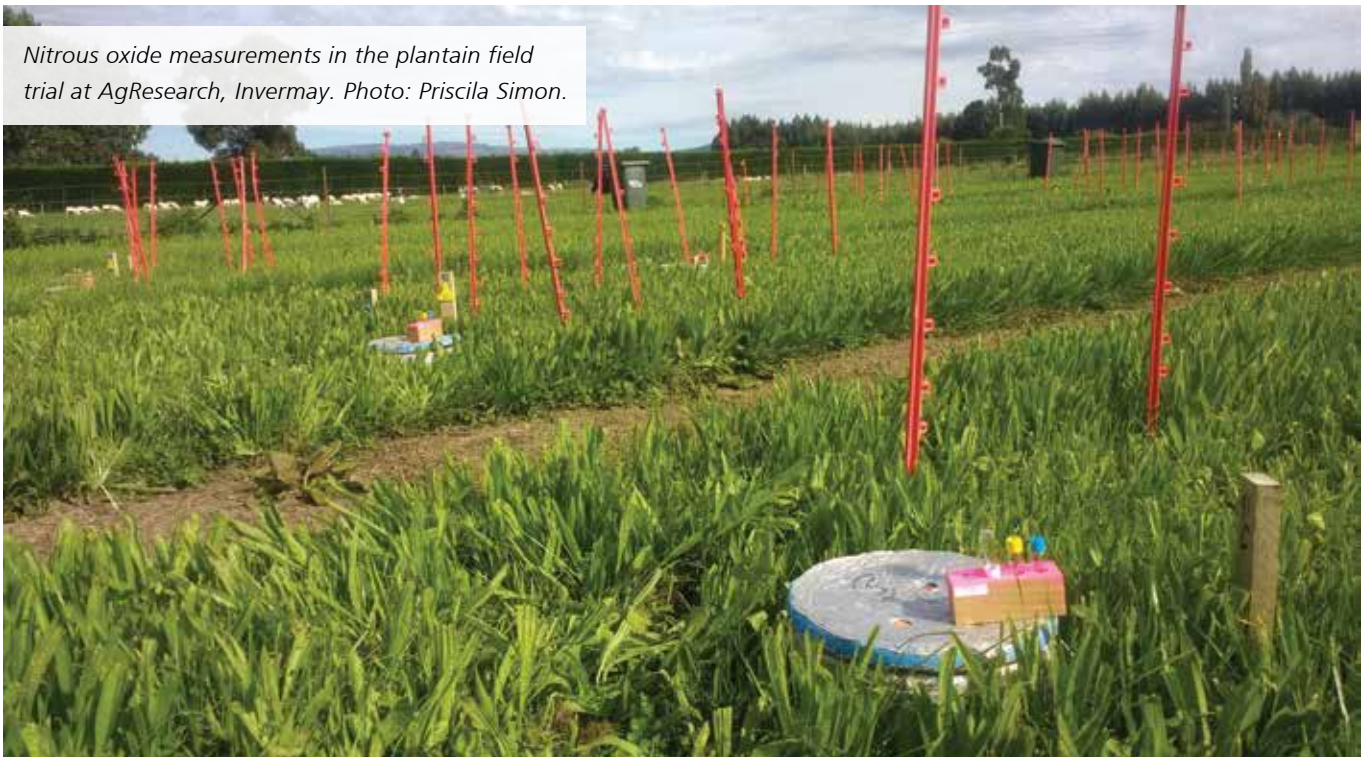
Greater urine volumes of cows on high plantain diets was not a result of greater consumption of drinking water. Cows tended to drink less water from the trough as the amount of plantain in the diet increased. Total water consumed, i.e. in feed plus drinking water, was greatest in cows fed 45 percent plantain, despite these animals drinking virtually nothing from the trough. Assessment of the blood showed no evidence of dehydration from high plantain diets.

The reduction in water consumed from the trough in systems incorporating plantain into pastures is an important consideration for farmers who deliver medication or minerals to cows via drinking water.

Nitrous oxide (N_2O)

The effect of plantain in the diet on N_2O emissions from urine was explored using urine collected from cows in the metabolism stall experiment. The urine was used in a field trial at AgResearch Invermay.

Urine collected from cows on a 0, 15, 30 and 45 percent plantain diet was gently poured onto plots with the corresponding percentage of plantain in the sward (i.e., 0 percent urine/0 percent sward, 15 percent urine/15 percent sward, etc.). N_2O emissions were measured using a standard chamber technique (*see example in photo below*). Cumulative N_2O emissions from 30 and 45 percent treatments were about 50 percent lower than the cumulative emissions from the 0 and 15



Nitrous oxide measurements in the plantain field trial at AgResearch, Invermay. Photo: Priscila Simon.

percent treatments. This is most likely due to a reduction in the urinary N concentration achieved by increasing proportions of plantain in the diet.

But is there also a direct plantain plant effect on N_2O emissions?

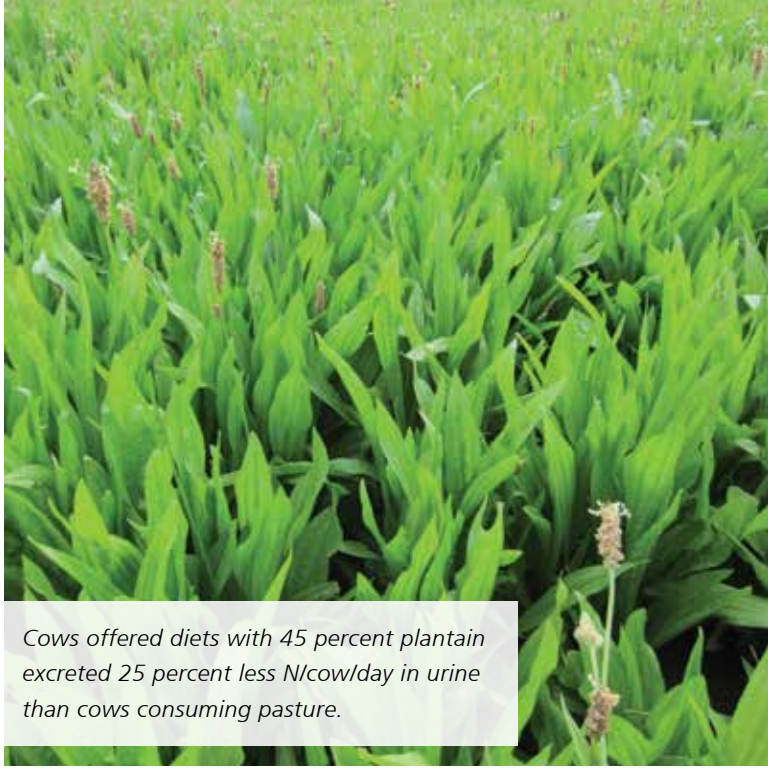
To start answering that question, we did a second experiment, where we applied the same type of urine (collected from cows on diets of 0 percent plantain) to plots with increasing plantain content in the sward (0, 30, 60 and 100 percent plantain).

Preliminary results show that N_2O emissions progressively reduced with the percentage of plantain in the sward, with emissions from the 100 percent plantain swards being about 40 percent lower than from the 0 percent plantain swards. As these plots received the same type and rate of urine, these results suggest a 'plant' effect of plantain on N_2O emissions.

Right now, NZAGRC is conducting further investigations to better understand how plantain can reduce N_2O emissions, as well as its potential for maintaining soil carbon stocks and reducing methane emissions from cows fed diets containing plantain. Keep an eye out for the results on the NZAGRC website.

More information

- The Forages for Reduced Nitrate Leaching Programme (FRNL) has principal funding from MBIE. The programme is 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** and find out more about plantain at **dairynz.co.nz/plantain**



Cows offered diets with 45 percent plantain excreted 25 percent less N/cow/day in urine than cows consuming pasture.

- You might also like to check the Tararua Plantain Project, which capitalises on research findings from the FRNL programme. See **dairynz.co.nz/Tararua**
- The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) is funded by the Ministry for Primary Industries (MPI) via its Primary Growth Partnership Fund and is a partnership (non-financial) of nine New Zealand research organisations: AgResearch, DairyNZ, Manaaki Whenua, Lincoln University, Massey University, National Institute of Water and Atmospheric Research (NIWA), Pastoral Greenhouse Gas Research Consortium (PGgRc), Plant & Food Research and Scion. Learn more about NZAGRC at **nzagrc.org.nz**

REFERENCES:

1. Selbie, D., L. E. Buckthought, and M. A. Shepherd. 2015. The challenge of the urine patch for managing nitrogen in grazed pasture systems. Advances in Agronomy 129:229-292.
2. Ministry for the Environment. 2017. New Zealand's Greenhouse Gas Inventory 1990-2015. Page xxv. New Zealand Government. Publication number ME 1309. ISSN: 1179-223X (electronic).
3. 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.
4. Minnée, E. M. K., G. C. Waghorn, J. M. Lee, and C. E. F. Clark. 2017. Including chicory or plantain in a perennial ryegrass/white clover-based diet of dairy cattle in late lactation: Feed intake, milk production and rumen digestion. Animal Feed Science and Technology 227:52-61.
5. Cheng, L., H. G. Judson, R. H. Bryant, H. Mowat, L. Guinot, H. Hague, S. Taylor, and G. R. Edwards. 2017. The effect of feeding cut plantain and perennial ryegrass-white clover pasture on dairy heifer feed and water intake, apparent nutrient digestibility and nitrogen excretion in urine. Animal Feed Science and Technology 229:43-46.
6. Kebreab, E., J. France, D. E. Beever, and A.R. Castillo. 2001. Nitrogen pollution by dairy cows and its mitigation by dietary manipulation. Nutrient Cycling in Agroecosystems 60:275-285.
7. Pacheco, D., and G. C. Waghorn. 2008. Dietary nitrogen – definitions, digestion, excretion, and consequences of excess for grazing ruminants. Proceedings of the New Zealand Grassland Association 70:107-116.
8. Chadwick, D. R., L. M. Cardenas, M. S. Dhanoa, N. Donovan, T. Misselbrook, J. R. Williams, R. E. Thorman, K. L. McGeough, C. J. Watson, M. Bell, S. G. Anthony, and R. M. Rees. 2018. The contribution of cattle urine and dung to nitrous oxide emissions: Quantification of country specific emission factors and implications for national inventories. The Science of the Total Environment 635:607-617.
9. O'Connell, C. A., H. G. Judson, and G. K. Barrell. 2016. Sustained diuretic effect of plantain when ingested by sheep. Proceedings of the New Zealand Society of Animal Production 76:14-17.
10. Atherton, J. C., M. A. Hai, and S. Thomas. 1968. Effects of water diuresis and osmotic (mannitol) diuresis on urinary solute excretion by the conscious rat. The Journal of physiology 197:395-410.
11. Tamura, Y., T. Yoshida, K. Rikimaru, M. Imanari, S. Fujimura, M. Al-Mamum, and H. Sano. 2010. Bioactivity and practical use of plantain *(Plantago lanceolata)*. Proceedings of the New Zealand Grassland Association 72:257-261.