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OPTIONS AND IMPLICATIONS FOR INCORPORATING PLANTAIN MIXED PASTURES INTO A CANTERBURY DAIRY SYSTEM

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Abstract

A modelling study using DairyNZ's Whole Farm Model linked to APSIM was designed for a Canterbury dairy farm to investigate options for incorporating plantain mixed pastures into the farm system. These options included 28% of the milking platform in a 25% plantain sward, 56% of the platform in a 25% plantain sward, 28% of the platform in a 50% plantain sward, a scenario feeding plantain silage sourced from the support block to lactating cows, and a scenario with 100% of both platform and support pastures consisting of a 50% plantain mix. Scenarios were simulated for different drainage years and included economic implications, such as costs for maintaining plantain pastures, as obtained from the actual case-study farm. The modelling reflected plantain's effect on herbage quality and cow urinary nitrogen (N) concentration, but not soil processes. The 100% of pasture area in 50% plantain resulted in a 10 kg N/ha leaching reduction (16%) on the platform pasture area, which was diluted to a 5 kg N/ha (7.5%) reduction when all hectares were counted including the support and crop blocks. However, the most practical scenario for N leaching reduction was 28% of the platform in 50% plantain sward, resulting in a 1 kg N/ha (1.5%) reduction from all hectares counted. This scenario achieved an annual plantain intake of around 11% of the diet, which was not enough to impact on urinary N amount and concentration and, therefore, affect N leaching. Reasons for the low impact on N leaching included the amount of supplements fed on this farm (≥20% of total annual diet) combined with the area covered by mixed pastures and the proportion plantain in the swards diluting the effect of plantain, and the herbage quality for plantain mixed pastures showing relatively small differences in crude protein and dry matter content compared with the standard pastures. Plantain silage carted from the support block to the milking platform had no effect on N leaching. Milk production and profitability were not negatively affected by any of the plantain scenarios.

Key Words: Urinary nitrogen, Nitrate leaching, Feed composition, Plantain silage

Introduction

The use of modern cultivars of plantain (*Plantago lanceolata* L.) is increasing as the species is being recognised for its enhanced tolerance and greater productivity under dry conditions (relative to ryegrass), potential environmental benefits, and versatility of use in livestock production systems. It can be sown both as a special-purpose crop or in a mixture with grass, legumes and other herbs (Vibart et al., 2016). While the animal production response to diets containing plantain has been relatively well studied (Bryant et al., 2020), it is not well understood how best to incorporate plantain into farming systems for maximum environmental impact, while being practical and with minimal negative economic repercussions.

Ruapuna Farms Ltd (-43.859, 171.296) is located near the town of Mayfield, in the Canterbury region. It is a monitor farm for the Forages for Reduced Nitrate Leaching (FRNL) programme that has the aim of reducing nitrogen (N) leaching by 20% whilst maintaining or increasing production and profit. The farmer was keen to implement the FRNL principles that so far have shown potential to reduce N leaching. In this regard they were looking at implementing plantain mixed pastures on part of their farm. The farm imports 20-30% of its feed. The farm receives an average annual rainfall of 900 mm on stony silt loam soils that are free draining. Overseer® predicted a relatively high N leaching of 78 kg/ha for all hectares counted; platform and the nearby support block. The farm falls in the Lower Hinds/Hekeao Plains area for environmental footprint regulations and according to Environment Canterbury N leaching will have to be reduced substantially within the next few years (15% by 2025; 25% by 2030).

The objective of this study was to explore different options for plantain mixed pastures in terms of area of the farm planted, plantain proportion in the mixed sward, and harvesting ryegrass-plantain silage on the support block and feeding it to lactating cows on the platform. Different modelling tools were used to predict the impact of these options on annual production, profitability and N leaching (all hectares counted) for three different climate years.

Methods

Base and alternative scenarios

The Base scenario (the reference system) represented the 2017-18 farming season for Ruapuna Farms (platform and support). The main features of the dairy system were a fully irrigated milking platform (375 ha) stocked at 3.8 crossbred cows/ha (1404 peak milking cows and 1480 wintered); standard ryegrass-clover pastures with 270 kg N/ha of fertiliser applied annually on the platform and 140 kg N/ha on the support block (244 ha); supplements eaten of around 900 kg DM/cow/year consisted of bought-in palm kernel expeller and molasses, with barley grain, fodder beet bulb, and pasture silage made on the support block and brought to the milking platform; milk production of 470 kg MS/cow and 1747 kg MS/ha. Eight hectares of the milking platform was cropped in fodder beet, grazed by cows between April and May, followed by an oats catch crop sown in June, harvested in November (approx. 6 t DM/ha) and then sown into new pasture. Cropping on the support block consisted of 70 ha in fodder beet (approx. 25 t DM/ha) of which 54 ha was fed to wintering mature cows and heifers, 14 ha to young stock, and 2 ha harvested (lifted) and carted to the platform (costing $0.07/kg DM) where it was fed to lactating cows. Following the fodder beet, the 70 ha block was sown into barley on 15 September, harvested on 20 February (approx. 9 t DM grain/ha; 4 t DM straw/ha), followed by new pasture.

The first alternative scenario (PLT1) included 105 hectares of the platform (28%) sown in plantain mixed pastures. It was assumed that this block was established over time so that the most recently drilled areas would include up to 50% plantain in the sward, while the oldest parts would have <5% plantain in the sward (Dodd et al., 2017). For the purpose of this exercise we assumed an average sward composition of 25% plantain for the 105-ha mixed pasture. The feed composition by month was derived from a trial conducted by Martin et al. (2017) in the Canterbury region (Table 1). Since there is no climate-driven model in the DairyNZ Whole Farm Model (WFM) for plantain mixed pastures, user-defined monthly growth rates were assumed for these pastures. Following guidance from the Ruapuna farm owner (Grant Early, pers. comm., 2018), the growth rates of standard and mixed pastures were similar for this farm.

Table 1. Average annual feed compositions assumed for the different pasture mixes and silages used in the simulations. RGC = standard ryegrass clover.

	DM%	CP%	ADF%	NDF%	Ash%	RUP%	SC%	ST%	Fat%	Lign%	Sol Prot %	Insol Prot %
0%-plantain[1]	18.9	19.2	22.7	40.0	9.6	29.7	23.3	2.1	4.5	2.6	13.4	11.3
25%-plantain[1]	18.1	18.1	21.9	37.8	10.9	32.9	25.6	2.1	4.1	2.9	12.2	11.9
50%-plantain[1]	16.7	17.9	20.6	33.7	12.3	35.9	28.8	2.2	3.7	3.3	10.8	12.6
RGC silage[2]	25.0	14.8	32.6	50.6	8.0	13.4	5.0	1.0	3.5	5.0	8.0	6.7
Plantain silage[3]	31.3	14.4	36.1	50.3	10.7	27.6	11.0	1.2	3.3	4.7	8.1	10.4

[1]From Martin et al. (2017)
[2]WFM default
[3]From Bariroh et al. (2018)

In the second alternative scenario (PLT2) the area of the platform in 25% plantain mixed pasture was increased from 28 to 56% with the same assumptions about yield and feed composition as in PLT1. In the third alternative scenario (PLT3) the proportion of the platform in mixed pasture was kept at 28%, but the plantain proportion in the sward was increased to 50% by over-sowing plantain seed at an assumed cost of $150/ha. Monthly growth rates for 50% plantain were assumed to be the same as for 25% plantain, but feed composition was different following data from Martin et al. (2017) (Table 1).

The fourth scenario (PLT4) was an attempt to evaluate the strategy of shifting plantain, in the form of silage, from the support block to the milking platform for feeding to lactating cows and reducing urinary N and leaching. This scenario was developed by taking PLT3 and adding changes to the cropping policy on the support block. Instead of a fodder beet to barley to standard pasture rotation on the 70 ha crop block, the standard pasture was replaced by a short rotation ryegrass-plantain mixture with an 18-month life cycle. It was assumed that this pasture grew at the same rate as the standard pasture on the support block. Feed composition was the same as 50%-plantain. Surplus from this pasture was harvested as “plantain-silage”, with feed composition following data from Bariroh et al. (2018) for a 50% plantain/50% ryegrass silage mix. The plantain silage was carted to the platform where it was fed to lactating cows in autumn.

The fifth scenario (PLT5) explored the system implications if 100% of platform and support block pastures consisted of a mixed pasture with around 50% plantain as a proportion in the sward. Extra costs for maintaining the high proportion of plantain were accounted for.

Table 2. Main differences between Base and alternative scenarios PLT1, PLT2, PLT3, PLT4 and PLT5.

	Base	**PLT1**	**PLT2**	**PLT3**	**PLT4**	**PLT5**
Plantain-mixed pasture (% of platform)	0	28	56	28	28	100
Plantain in the sward (%)	NA	25	25	50	50	50
Plantain silage sourced from support block	no	no	no	no	yes	no

Models and assumptions

DairyNZ's Whole Farm Model (WFM) was used to predict the economic and environmental impact of incorporating plantain-mixed pastures into the Ruapuna Farms system. The WFM was used in conjunction with two other linked software packages: (1) the Urine Patch Framework (UPF) that applies the urine excreted per grazing event, as predicted by the Molly cow model for individual animals, and (2) the Agriculture Production System Simulator (APSIM) that simulates water, N and carbon dynamics and predicts N leaching from urine and non-urine patches. Nitrate leaching from pasture paddocks was predicted using the WFM-UPF-APSIM models in combination as explained by Beukes et al. (2011). The potential of plantain to inhibit the nitrification process in the soil was not modelled. Leaching from the crop paddocks was predicted using only the APSIM model. For these simulations urinary N depositions as predicted by WFM (amounts and timing) were applied to grazed crops using APSIM management rules. Management rules were also used to simulate other events, faecal N return, N fertiliser, irrigation, sowing and harvesting policies. Because there was no fodder beet model available in APSIM when this work was carried out, the APSIM maize model was used as a proxy for fodder beet, with the assumption that maize would yield the same and take the same amount of N from the soil as a fodder beet crop. APSIM's oats and barley crop models were used for the paddocks where these crops were part of the rotation.

The Base scenario was set up for the 2017-2018 season with economic input from Ruapuna Farms (Grant Early, pers. comm., 2018) and a milk price of $5.10/kg milksolids. Cropping costs were assumed to be $2700/ha for fodder beet, and $1800/ha and $800/ha for barley and oats, respectively.

The WFM-UPF-APSIM model combination has the capability to simulate the performance of the same system under different climate years. This model combination was initialised with an Eyre soil for both platform and support blocks and simulated for 2017-2018 with average annual drainage (352 mm), for 2014-2015 with low drainage (114 mm), and for 2012-2013 with high drainage (434 mm).

Results and Discussion

The results in Table 3 present three factors determining the N leaching from a dairy system with plantain, 1) the total amount of urinary N (UN) per annum deposited on the pasture block, 2) the concentration of this UN, and 3) the N leaching from the pasture block, which is normally the largest in terms of area in hectares. The data show that the changes in total UN deposited onto platform pasture paddocks from Base to PLT scenarios are not large e.g. the maximum reduction is from Base to the 100% scenario, PLT5, amounting to 23 kg N/ha. The change from Base to PLT3 was 11 kg N/ha. These small changes in the main driver of N leaching can be explained by looking at the proportion of plantain the cows actually ingested in the different scenarios. In Base scenario this was zero because of zero mixed pastures in the system. For the PLT scenarios it can be assumed that 20% of the cows' diet consists of supplements, therefore only 80% comes from pasture. So, in PLT1 the amount of plantain in the diet on an annual basis can be calculated as 0.8 pasture in diet × 0.28 proportion of platform in mixed pasture × 0.25 proportion of plantain in the mixed sward = 5.6%. This relatively small proportion of the diet resulted in 6 kg N/ha less UN deposited, together with a small decrease in UN concentration, and a N leaching reduction of 1 kg N/ha.

Table 3. Predicted urine deposition on platform pasture paddocks for Base and plantain mixed pasture scenarios (PLT) for the 2017-2018 farm season. Nitrate leaching was predicted by WFM-UPF-APSIM model combinations.

Scenario	Urinary N (kg/ha)	Urine volume (L/ha)	Urinary N conc (g/L)	N leaching (kg/ha)
Base	186	27482	6.77	61
PLT1	180	27804	6.47	60
PLT2	178	28276	6.30	60
PLT3	175	28205	6.20	58
PLT4	179	28501	6.28	58
PLT5	163	30294	5.38	51

Following the same argument both PLT2 and PLT3 scenarios had a plantain intake of 11.2%. It is important to note that both these scenarios resulted in further reductions in UN deposited and UN concentration from PLT1, but PLT3 had a stronger effect on N leaching reduction than PLT2 (Table 3). This is because a 50% plantain mix (PLT3) has a larger effect on UN even though it occupied a smaller proportion of the platform (28%) than the 25% plantain in PLT2 (56% of platform). This finding aligns with data from a plantain feeding trial (Elena Minnee, pers. comm., 2019) where the 15% plantain in the diet had no effect on UN excreted compared to the 45% plantain diet that substantially reduced UN amount and concentration. This finding, that a smaller area of mixed pasture with high plantain content is better for N leaching reduction than a larger area with a lower plantain content, is also confirmed by an unpublished Bayesian modelling exercise (Alvaro Romera, pers. comm., 2018).

Because N leaching from the milking platform pasture area is by far the largest component of N leaching from all hectares counted, it is important to understand why this study only showed small reductions in N leaching due to plantain mixed pastures. The first point is that this monitor farm at Ruapuna, is a high-input farm in terms of supplement usage (system 4), resulting in 80% of the cows' diet based on pasture. This reduces the leverage that management has for manipulating the pasture component of the diet. The second point is that the effect of plantain on N leaching either gets diluted by the low plantain content of the mixed pasture (PLT1 and 2), or by the large proportion of the platform without plantain mixed pastures (PLT3 and 4). The third explanation for the relatively small reductions in N leaching is the feed compositions used in this study. The difference between standard ryegrass-clover (0% plantain) and the plantain mixes (Table 1) were smaller compared to differences reported in previous Canterbury studies (Nobilly et al., 2013) in terms of the important measures like crude protein and DM%.

Two previous studies have shown the importance of a reduced UN amount and, especially, UN concentration in reducing N leaching from pastures (Beukes et al., 2014; Romera et al., 2017). The small reduction in UN concentration of 0.57 g/L from Base to PLT3 resulted in a modest decrease in N leaching of 3 kg/ha. In contrast, the hypothetical scenario PLT5 had approximately 40% plantain in the diet ($0.8 \times 1.0 \times 0.5$) and showed a reduction in UN concentration from Base of 1.4 g/L, resulting in a substantial decrease in N leaching of 10 kg N/ha (16%).

The results for PLT4 show that harvesting plantain silage on the support block and feeding it in autumn to lactating cows on the platform did not result in a further reduction in N leaching compared to PLT3 (Table 3). The plantain silage fed in autumn replaced PKE, barley grain and oats silage with CP% of 18, 12 and 10, respectively. It means that on average the CP content of the replaced supplements was lower than the plantain silage of 14.4%. However, the DM% of the plantain silage was lower than the replaced supplements resulting in a slight increase in urine volume. The total effect of plantain silage on UN amount and concentration was too small to affect the N leaching from the pasture block.

Although plantain pastures had minimal effect on milk production, operating profit of the PLT scenarios trended higher compared with Base (Table 4). The main reason for this was more pasture silage made on the platform in the PLT scenarios because of stronger spring and summer growth, which resulted in less supplement bought in and lower farm working expenses. This could be a model artefact of the user-defined growth rates for the plantain mixed pastures and should not be generalised because pasture growth rates for plantain mixed pastures can be affected by many factors.

Of the practical scenarios evaluated, farm-scale N leaching was only reduced in the PLT3 scenario compared to Base, but the reduction was only 1 kg N/ha (1.5%). The main reasons for this small reduction are explained above. The only point to add when all hectares are counted is that N leaching from crop blocks dilutes the effect of plantain on the pasture block. Leaching reduction for PLT3 compared with Base was 3 kg N/ha for the pasture block, but only 1 kg N/ha when all hectares were counted. Similarly, the substantial reduction in N leaching from pastures in PLT5 of 16% was reduced to only 7.5% when all hectares were included (Table 4).

Table 4. Predicted milk production, operating profit and nitrogen leaching for the Base and five alternative scenarios, PLT1, PLT2, PLT3, PLT4, and PLT5, for the Ruapuna case study farm. The results for each scenario include all hectares counted (platform and support block) and are averaged over three climate years. Percentage change from Base is in brackets.

Scenario	**Milk production (kg MS/ha)**	**Operating profit ($/ha)**	**N leaching (kg/ha)**
Base	1061	867	67
PLT1	1059 (-0.2)	934 (7.8)	67 (0.0)
PLT2	1055 (-0.6)	952 (9.8)	68 (1.5)
PLT3	1049 (-1.1)	951 (9.7)	66 (-1.5)
PLT4	1051 (-0.9)	927 (6.9)	67 (0.0)
PLT5	1042 (-1.8)	1021 (17.8)	62 (-7.5)

Conclusions

This study could not provide evidence that incorporating plantain pastures and plantain silage into the Ruapuna Farms system would reduce N leaching from all hectares counted, or would increase production and profit with any level of confidence. However, it did confirm the important drivers that determine if plantain mixed pastures will be effective in reducing N leaching or not; 1) the proportion of pasture in the cows' diet, 2) the area of the farm in plantain mixed pastures and the proportion of plantain in the sward where a smaller area with a higher proportion is better, 3) the feed composition of plantain mixes in terms of CP%, CP composition and DM% should be different enough from the standard pasture it replaces to make a substantial impact on urinary N amount and concentration. A hypothetical scenario indicated that a plantain intake of around 40% could reduce N leaching from pastures by 16%, which was diluted to 7.5% when all hectares, including crop blocks, were counted. Plantain mixed pastures did not appear to affect milk production and operating profit.

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References

Bariroh NR, Bryant RH, Black AD, 2018. Plantain quality under variable management practices. Journal of New Zealand Grasslands 80:119-124.

Beukes PC, Chikazhe T, Edwards JP, 2018. Exploring options to reduce nitrogen leaching while maintaining profitability within a Canterbury farm business comprising several distinct enterprises. Journal of New Zealand Grasslands 80:191-194.

Beukes PC, Edwards P, Coltman T, 2017. Modelling options to increase milk production while reducing N leaching for an irrigated dairy farm in Canterbury. Journal of New Zealand Grasslands 79:147-152.

Beukes PC, Gregorini P, Romera AJ, Woodward SL, Khaembah EN, Chapman DF, Nobilly F, Bryant RH, Edwards GR, Clark DA, 2014. The potential of diverse pastures to reduce nitrogen leaching on New Zealand dairy farms. Animal Production Science 54:1971-1979.

Beukes PC, Romera AJ, Gregorini P, Clark DA, Chapman DF, 2011. Using a whole farm model linked to the APSIM suite to predict production, profit and N leaching for next generation dairy systems in the Canterbury region of New Zealand. Proceedings of the 19th International Congress on Modelling and Simulation, Perth, Australia, 12-16 December 2011. http://mssanz.org.au/modsim2011

Bryant RH, Snow VO, Shorten PR, Welten BG, 2020. Can alternative forages substantially reduce N leaching? findings from a review and associated modelling. New Zealand Journal of Agricultural Research 63:3-28.

Dodd MB, Dalley DE, Elliott D, Wims CM, 2017. Establishment year productivity, botanical composition and nutritive value of grass/Lucerne/plantain dairy pasture mixtures. Journal of New Zealand Grasslands 79:229-235.

Martin K, Edwards G, Bryant R, Hodge M, Moir J, Chapman D, Cameron K, 2017. Herbage dry-matter yield and nitrogen concentration of grass, legume and herb species grown at different nitrogen-fertiliser rates under irrigation. Animal Production Science 57:1283-1288.

Nobilly F, Bryant RH, McKenzie BA, Edwards GR, 2013. Productivity of rotationally grazed simple and diverse pasture mixtures under irrigation in Canterbury. Proceedings of the New Zealand Grassland Association 75:165-171.

Romera AJ, Doole GJ, Beukes PC, Mason N, Mudge PL, 2017. The role and value of diverse sward mixtures in dairy farm systems of New Zealand: An exploratory assessment. Agricultural Systems 152:18-26.

Vibart RE, Vogeler I, Dodd M, Koolaard J, 2016. Simple versus diverse temperate pastures: Aspects of soil-plant-animal interrelationships central to nitrogen leaching losses. Agronomy Journal 108:2174-2188.