Performance of plantain pastures on Tararua dairy farms

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Abstract
Based on the published benefits of narrow-leaved plantain for reducing nitrogen leaching losses in grazed pasture systems, dairy farmers in the Tararua District implemented a development programme to increase plantain in the diet of cows. To address key establishment and management questions posed by dairy farmers, an associated pasture monitoring programme commenced in autumn 2019. The inclusion of plantain at levels of >30% of harvested dry matter (autumn-measured) in perennial ryegrass/white clover pastures significantly improved annual herbage accumulation (+12%). Herbage accumulation of pure plantain and plantain-white clover pastures was not significantly different from established perennial ryegrass/white clover pastures. Forage quality was high in all pasture that included plantain and decreased only slightly in swards with high plantain content. In grass-based pastures, the greatest plantain content after a year was achieved when sown in a new pasture mix in autumn. However, the plantain content of all pastures declined with time regardless of establishment method and was typically <10% after two years. Dairy farmers can have confidence that the use of plantain in pastures will be unlikely to result in a reduction in forage quantity or quality, but the need to find ways to maintain plantain content over time remains, in order to realise the benefits for forage supply and N leaching.

Keywords: forage quality, herbage accumulation, pasture management, persistence, *Plantago lanceolata*

Introduction
Plantago lanceolata L., known as narrow leaf plantain or ribgrass, is a herb species that can be found naturally in many pastures and has had a long history of use as a forage plant in grasslands throughout the temperate world (Stewart 1996). First commercialised in New Zealand over 20 years ago, plantain was initially used for sheep, beef cattle and deer as its rich mineral components made it highly palatable to grazing animals (Stewart 1996). Plantain pastures can provide benefits during lactation for ewes through improved intake, reduced faecal egg output (Judson et al., 2009) and for lamb finishing (Moorhead et al., 2002; Kemp et al., 2013). Plantain can be sown both as a special-purpose monoculture crop or in a mixture with grasses, legumes or other herbs (Vibart et al., 2016). Successful establishment can be limited by strong competition from other species (Hildebrandt and Schulz 1987). There are now seven cultivars on the New Zealand market (Stewart et al., 2022).

More recent studies, notably with the cultivars Tonic and Agritonic (Ecotain), have revealed the ability of plantain to reduce nitrate leaching from grazed pastures (Bryant et al., 2017, Bryant et al., 2020, Dodd et al., 2018). A key mechanism is reduced urinary N concentration by increased urine volume and altered N partitioning in the cow (Carlton et al., 2019; Judson et al., 2018; Navarrete et al., 2022). Nitrate leaching through groundwater into streams and waterways is an increasing environmental concern throughout New Zealand. Regional Councils have introduced restrictions that require agricultural land to limit leaching losses to improve water quality. An important consideration in the efficacy of plantain for affecting N flows is ensuring that it constitutes more than 30% of the animal dry matter intake (Minneé et al., 2020). While this can be achieved in different ways at a farm systems level, it does imply the need for a similar level where grazed pastures are the majority of intake.

In the Tararua District (lower North Island, New Zealand), while most dairy farms are relatively low input systems from a supplementary feed and fertiliser perspective, the combination of high rainfall and free draining soils makes dealing with leaching difficult. The use of plantain offers farmers a means of reducing nitrate losses in grazed systems with a relatively simple adjustment to forage composition, compared to other options which may be capital intensive or involve agrichemical application. However, dairy farmers in the region identified some key technical questions to address before embarking on a substantial programme of pasture renewal, to meet the dietary intake threshold. In 2018, DairyNZ launched a programme in the district to address these questions, which included a paddock-scale monitoring programme amongst early adopters.

The questions were:

Q1. What is the effect on seasonal forage supply of including plantain in perennial ryegrass/white clover-based mixtures?

Q2. What is the seasonal and annual herbage

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accumulation (HA) of plantain and plantain/clover swards compared with established ryegrass/white clover swards?

Q3. What is the effect on feed quality of pasture types that include plantain (pure plantain, plantain/clover, ryegrass/clover/plantain), compared with established ryegrass/white clover pastures?

Q4. Which establishment methods result in the greatest persistence of plantain within perennial ryegrass/white clover pastures? This question also included a comparison of three methods of persistence assessment, based on cover, plant population and dry matter harvest, in order to establish a simple practical method of persistence assessment.

This paper reports on four years of data collection and analysis from the monitoring programme, designed to answer these questions. It is important to note that the nature of the monitoring programme does not constitute a conventional field experimental design with tight management rules.

Materials and Methods

A total of 87 paddocks across 11 dairy farms, between 40.0693 S and 40.6758 S latitude in the Tararua District of New Zealand, were monitored between 2019-2022. All paddocks were established by the farmers at their discretion using a range of establishment techniques, the details of which were recorded (timing, establishment method, sowing rates, fertiliser inputs). The paddocks were divided into two groups, designed to address questions 1-3 (Group 1) and question 4 (Group 2). Group 1 (17 paddocks, five farms: H, M, A, D and F) included assessments of HA, pasture quality, plantain proportion and plantain plant population, in split-paddock or adjacent-paddock comparisons across six dairy farms. Group 2 (Five Group 1 paddocks plus 62 additional paddocks across six additional farms) included spring and autumn botanical sampling, visual plantain proportion and plantain plant populations.

Herbage accumulation

To address Question 1 regarding the inclusion of plantain in perennial ryegrass-based swards, four split-paddock comparisons were established on two farms. The pastures were sown in March 2019 with 18 kg/ha perennial ryegrass cv. Base and 4 kg/ha white clover, with or without 4 kg plantain cv. Ecotain (Farm H); and in October 2019 with 25 kg/ha perennial ryegrass cv. Bealey and 2 kg/ha white clover , with or without 4 kg/ha plantain cv. Ecotain (Farm M). To address Question 2 regarding sward type comparisons, ten adjacent-paddock comparisons were undertaken on Farms A, D and F, each of which included a comparison with a conventional perennial ryegrass-white clover pasture established well before 2018.

For both Q1 and Q2 data sets, following establishment of the sward treatment differences, HA on the paddocks was measured with cage harvests. Four cages of 400 mm × 500 mm size were placed in representative parts of the pasture following grazing and the herbage visually assessed for plantain content (% of standing herbage) and harvested within four days of the next grazing event. Each cage was then re-positioned in a different site for the next grazing round and pre-trimmed to 2 cm. Herbage was cut from both part-paddocks on the same date, using electric shears to cut the whole caged area to 2 cm height. Harvested herbage was weighed wet, subsampled and the subsample dried at 80°C for 48 hours to determine dry matter yield. Herbage accumulation was summed by Forage Value Index (FVI) season for the Lower North Island (DairyNZ 2022): Spring = July-October (123 days); Summer = November-January (92 days); Autumn = February-April (89 days); Winter = May-June (61 days). Where harvest dates did not fall on the first or last day of a season, the mean HA rate of the overlapping period was applied to the shorter period between the harvest date and the start or end of the season.

For the Q1 data set, the seasonal HA totals from Autumn 2019 to spring 2021 were analysed by repeated measures analysis of variance in Genstat v21 (VSN International 2021) with pasture type, season and their interaction as fixed effects, and paddock as a random effect. For the Q2 data set, a two-tailed paired t-test of the seasonal HA totals over three years (autumn 2019 to autumn 2022) was used to determine whether there was a non-zero difference in HA between the plantain pasture types and the ryegrass/clover pastures.

Forage quality

To address Question 3 regarding the effect of sward type on forage quality, a further 200 g subsample from all cage-harvested material was sent fresh to Hill Laboratories (Hamilton, NZ) for analysis of dry matter (DM, %), crude protein (CP, %DM), digestibility of organic matter (DOMD, %DM) and metabolisable energy (MJME/kgDM). A total of 465 samples were included in a Genstat analysis of variance, with sward type as one treatment factor (either pure plantain, ryegrass/clover/plantain, plantain/clover or ryegrass/clover) and sample FVI season as a second factor, including the interaction as a fixed effect.

Persistence

To address Question 4 regarding the effect of establishment methods on plantain persistence in grass-based swards, pastures from both Group 1 and 2 were visually assessed in spring and autumn each year for plantain content (% cover of standing herbage), plantain proportion of dry matter and plantain plant population density. For visual scoring, in each paddock or split-paddock 30 quadrat frames (0.20 m^2) between 5-10 m apart were placed along a representative transect and visually assessed for plantain cover as a proportion of total vegetative cover, to the nearest 10% (Dodd et al*.,* 2019). For proportion of dry matter, 30 snip samples (0.025 m^2 cut to 2 cm height) between 5-10 m apart along a representative transect were taken from each paddock, bulked and a ~400-piece subsample taken for botanical dissection of plantain from the herbage. The plantain and combined other species botanical portions were weighed after drying at 80°C for 48 hours. For the population counts, in each paddock or split-paddock 20 quadrat frames (0.20 m^2) between 10-15 m apart were placed along a representative transect and plantain plant numbers tallied in each. Only the visual estimates were continued for a given paddock when two consecutive seasonal visual assessments of plantain cover were less than 10%.

Persistence measures were compared for consistency by correlation analysis in Genstat, to link them to the goal of maintaining plantain as a high proportion of dry matter available to livestock. Treatment effects of establishment season (FVI autumn, spring and summer), establishment method (direct drilling as new pasture, cultivation as new pasture, oversowing and undersowing into existing pasture) and plantain sowing rate (range 2-12 kg/ha) on plantain content in the first autumn after sowing were analysed in an analysis of variance (including first-order interaction terms and Farm as a blocking term). The interaction between each of these main effects and the effect of age since sowing was analysed in a general linear model to determine the effect of establishment practice on persistence.

Results and Discussion

Q1: Effect of plantain inclusion on herbage accumulation

Including plantain in a perennial ryegrass/white clover pasture significantly increased total HA ($p<0.05$, Table 1). Quantitatively, this effect was greatest in summer and autumn, although the treatment × season effect was not significant ($p>0.05$). The average seasonal differences in HA were 669 kg DM/ha in summer and 501 kg DM/ha in autumn, and the annual total HA difference was 1620 kg DM/ha. This effect is consistent with the findings of Dodd et al*.,* (2017) in Waikato grass-based pastures, where plantain inclusion led to significant increases in DM yield in the summer, early and late spring periods. Addition of sown species beyond simple grass-clover mixes has also been shown to benefit HA in the meta-analysis of Vibart et al*.,* (2016) and is commonly attributed to resource-use complementarity (Black et al*.,* 2017). On average, plantain cover in these swards was 33% in autumn and 14% in spring, thus meeting the nominal threshold for effects on urinary N in autumn.

Q2: Comparison of plantain swards with ryegrass/clover for herbage accumulation

There was no significant difference in mean seasonal HA between perennial ryegrass/white clover swards and pure plantain crops on Farm F (Table 2: mean

Table 1 Mean seasonal and annual herbage accumulation (kgDM/ha) for perennial ryegrass/clover in Tararua dairy pastures with and without plantain. Different letters indicate significant treatment effects between pasture types at the 5% level. SED within season = 353.

Sward Type	Spring	Summer	Autumn	Winter	Total
Ryegrass/clover	3775 a	5027 a	2528 a	1675 a	13005 a
Ryegrass/clover/plantain	4034 a	5696 a	3029 a	1866 a	14625 b
Percentage difference	7	13	20	11	12

Table 2 Mean seasonal and annual herbage accumulation (kg DM/ha) for plantain-based Tararua dairy pastures compared to perennial ryegrass/clover pastures. No significant effects found.

Farm	Sward Type	Spring	Summer	Autumn	Winter	Total
F	Ryegrass/clover	4190	4080	2480	1510	12260
F	Plantain	3300	5270	2120	1140	11830
	Difference (%)	-21	29	-14	-25	-4
A	Ryegrass/clover	4120	3490	2610	1640	11860
A	Plantain/clover	4220	4700	3770	1670	14360
	Difference (%)	2	35	44	2	21

difference = 146 kgDM/ha, SEM = 261, p = 0.58). This was also the case for perennial ryegrass/white clover swards vs. plantain/clover swards on Farm A (Table 2: mean difference = 422 kgDM/ha, SEM = 299, p = 0.18). The lack of a statistical effect of pasture type on HA appears to be due to high within-seasonal variation across the three years. However, the relative mean differences in seasonal HA do suggest a shift in the seasonal pattern toward increased summer forage supply for pure plantain and increased summer-autumn forage supply for plantain/clover pastures. This pattern is consistent with the growth pattern of summer dominance observed in other seasonal forage supply studies of plantain (Minneé et al., 2013) and plantain/clover (Navarrete 2015) swards.

Q3. Effect of sward type on pasture quality

Both sward type and season had a significant effect on ME, CP% and DM% (Table 3, p<0.01). Metabolisable energy was greater in the ryegrass/plantain/clover and ryegrass/clover sward types than the pure plantain and plantain/clover sward types. Crude protein % was greatest in the ryegrass/clover sward and least in the plantain sward. Dry matter content was greater in the ryegrass/clover and plantain/clover swards than the ryegrass/plantain/clover and pure plantain swards.

The interaction between sward type and season was only significant for DM% (p<0.01), attributable to relatively low DM% of the ryegrass/clover/plantain sward in summer and autumn. Overall, the differences in quality were small and all pastures were at the high end of typical feed quality ranges (Lambert and Litherland 2000). Only in summer and autumn was the decline in ME (<1 MJ ME/kgDM), CP (1-2%) and DM (2-4%) potentially of concern, for the pure plantain swards containing the highest plantain content.

Q4. Effect of establishment method on persistence of plantain

The comparison of the two visual methods of plantain assessment in mixed swards (quadrats and plant populations) against the snip sample method showed that the visual quadrat method was well correlated (r = 0.92), though tended to under-estimate plantain content at levels >60%. Plant population counts were less useful (r=0.70) with a distinct curvilinear relationship, i.e. higher plant population variance at high plantain levels. For example, paddocks with 30% plantain ranged between 2-21 plants/m^2, and at 60% ranged between 20 and 180 plants/m^2. This probably reflects size-density compensation dynamics in older swards.

Based on the analysis of visual cover measurements in grass-based pastures, the effects of both establishment method and sowing season were significant (p<0.01, Table 4). New pastures established by direct drilling or cultivation reached 35-36% plantain cover, while broadcast and under-sown pastures only reached 14-16%. Autumn-sown pastures had more than double the plantain cover of spring and summer-sown pastures. The interaction between establishment method and sowing season was not significant. Sowing rate did not have a significant effect on cover (p>0.05), possibly due to most paddocks being sown with 2-4 kg/ha of plantain. These results support earlier observations by Bryant et al., (2019) of sowing plantain within new pasture mixes being the most successful method of establishment.

In grass-based pastures, plantain cover declined significantly with pasture age (p<0.05, Figure 1), but

Table 3 Effect of sward type and season on metabolizable energy (MJ ME/kgDM) content, crude protein content (CP%) and dry matter content (DM%) of Tararua dairy pastures. Different letters indicate significant main treatment effects at the 5% level. SED = 0.24 (ME), 1.3 (CP), 0.62 (DM).

Quality trait	Sward Type	Spring	Summer	Autumn	Winter	Mean
MJ ME	Ryegrass/clover	12.0	11.3	10.9	11.6	11.4 a
	Ryegrass/clover/plantain	12.1	11.4	11.1	11.6	11.5 a
	Plantain/clover	11.8	10.7	10.5	11.6	11.0 b
	Pure plantain	11.9	10.6	10.7	11.7	11.1 b
CP%	Ryegrass/clover	23.3	19.8	22.2	28.1	22.3 ab
	Ryegrass/clover/plantain	22.3	22.1	23.3	28.9	23.2 a
	Plantain/clover	22.5	20.0	20.3	25.5	21.3 bc
	Pure plantain	19.7	19.5	20.7	23.1	20.3 c
DM%	Ryegrass/clover	15.4	18.0	22.0	13.5	17.8 a
	Ryegrass/clover/plantain	14.4	15.1	18.0	10.7	15.2 b
	Plantain/clover	14.0	18.1	21.7	12.3	17.2 a
	Pure plantain	13.4	16.3	14.6	12.5	14.5 b

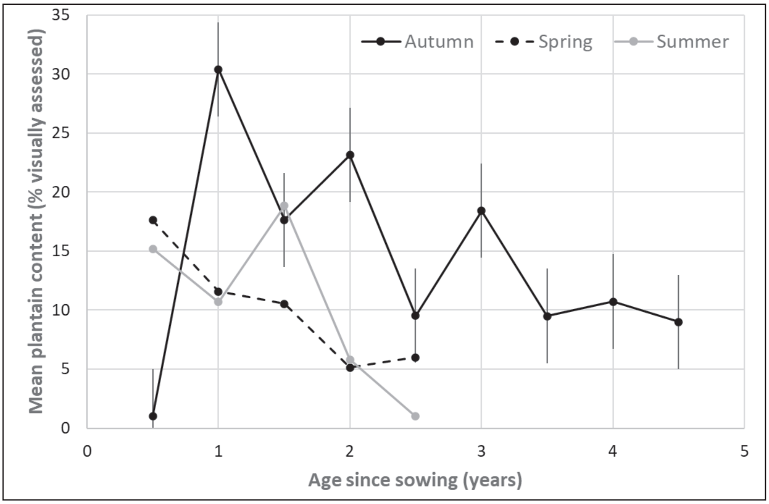

Figure 1 Mean plantain cover (% visually assessed) of 67 paddocks on Tararua dairy farms by age since sowing for three sowing seasons. Bars represent average SED.

there was no interaction with establishment method or season of establishment. Essentially this means that those swards wherein plantain established well in the first year, declined at the same rate as those that did not. Achieving the greatest plantain levels in older pastures was dependent on good initial establishment. Only three paddocks showed plantain levels >30% after 3 years. This result echoes the nationwide paddock survey of Dodd et al., (2019). At present paddocks will need to be refreshed to maintain plantain proportion at levels considered to be effective for mitigating nitrogen leaching (>30%, Minneé et al., 2013). It remains to be seen whether the lower levels of establishment of plantain into existing swards via broadcasting or under-sowing (Table 4) will be sufficient to achieve this. Ongoing work within the DairyNZ Tararua project will test this.

An alternative option for achieving sufficient plantain levels at the farm scale is to combine mixed pastures with small areas of higher plantain content, such as plantain/clover pastures or pure plantain crops. A whole-farm visual cover assessment on Farm F (18% of area in plantain crop, remainder in grass-based mixed pasture) indicated that plantain made up 26% of home-grown forage supply in late autumn and 27% in spring. By contrast Farm H had achieved 12% in late autumn, relying only on grass-based mixed pastures of various ages since re-grassing with mixes including plantain.

Conclusions

Q1&2: The herbage accumulation data should give dairy farmers confidence that the use of plantain in perennial ryegrass/clover swards, or as plantain/clover swards, will not be to the detriment of pasture supply. In the Tararua, there was an improvement in home-grown forage supply by including planting in perennial ryegrass-based pastures.

Q3: The pasture quality data should give dairy farmers confidence that the use of plantain in ryegrass/clover swards, or as plantain/clover swards, will not result in a substantive loss in forage quality. The use of pure plantain does appear to lead to a slight loss in summer forage quality, relative to perennial ryegrass/white clover swards.

Q4: In terms of establishment practice, the best results for plantain within perennial ryegrass/white clover swards were achieved by cultivation or drilling with new grass in autumn in the Tararua District. The threshold sowing rate for achieving a high plantain proportion (>30%) is still not clear. Plantain proportion in all paddocks declined over time, with few paddocks

Table 4 Effect of establishment method and season of establishment on plantain content (%) of Tararua dairy pastures in the autumn after establishment. Different letters indicate significant main treatment effects at the 5% level. SED = 9%.

Establishment method	Spring	Summer	Autumn	Mean
Direct-drilled new pasture	23	17	40	35 a
Cultivated new pasture	33	-	37	36 a
Under-sown	3	15	14	16 b
Broadcast	7	10	9	14 b
Mean	10 b	11 b	26 a	

exceeding 30% plantain cover after 3 years. This was not mitigated by establishment practice.

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