Plantain dominated in mown mixed swards, but produced less than the original ryegrass-dominant sward

Ray A. MOSS[1]*, David R. SCOBIE[1], Alasdair D.L. NOBLE[1], Anna L. TAYLOR[1] and Robyn A. DYNES[1]
[1]*AgResearch, Lincoln Research Centre, Private Bag 4749, Christchurch, New Zealand*
*Corresponding author: ray.moss@agresearch.co.nz

Abstract
This trial determined the effect of compost on mixed species pasture. Existing (five year old) perennial ryegrass provided the control. A mixture of perennial ryegrass, white clover and plantain was sown into sprayed-out treatment plots, giving five replicates of six treatments. One treatment was direct drilled another was cultivated and drilled. The remaining three were spread with compost (50, 100 or 150 t/ha wet weight) and cultivated. Plots were mown at 35 d intervals for two years with clippings returned to the sward. Although grass established well at 500 plants/m^2 plantain quickly came to dominate in all renewed plots, at 55-61% of DM in year 1 and 57-79% of DM in year 2. Grass contributed 29-35% of DM in year 1 and 10-30% in year 2, with clover 5-8% in year 1 and 10-14% in year 2. Grass dominated control plots (73 and 82% DM, respectively), while clover contributed more DM in absence of plantain (22% and 17%). Compost did not affect production. Cultivation gave a slight advantage over direct drilling, but new swards produced <50% the total DM of the control ($P<0.05$). Substantial investment was involved, so rewards need to be considerable to recoup costs.

Keywords: Compost, *Plantago lanceolata*, *Lolium perenne*, *Trifolium repens*, pasture renewal techniques

Introduction
The environmental consequences of increased agricultural intensity have necessitated the search for technologies to mitigate losses such as nitrate leaching. Solutions could include the application of compost to improve soil organic matter and supply nutrients over a prolonged period (Horrocks et al., 2016). Alternatively, feeding lower protein diets (Huhtanen et al., 2008) or changing pasture species to plantain (*Plantago lanceolata*) (Box et al., 2017) could be used to decrease urinary nitrogen deposition or spread urine more widely.

Dodd et al. (2019) found that the proportion of plantain in pastures declines rapidly after sowing in New Zealand. Very few paddocks had more than 20% of available dry matter as plantain three years after sowing. Likewise in Uruguay, plantain populations declined rapidly under grazing (Ayala et al., 2011). At less than 20% of the diet, plantain has no detectable effect on urinary nitrogen concentration (Bryant et al., 2017; Minneé et al., 2017) and may not reduce nitrate leaching from pastures. Maintaining more than 30% of the diet of the dairy cow as plantain can be challenging in pasture-fed circumstances.

Application of compost has been a useful alternative source of nutrients in cropping systems (Horrocks et al., 2013; Horrocks et al., 2016). Although compost has been used in pastoral systems, it has generally been spread on forage cropping phases of grazing systems rather than on broadacre pastures. The following experiment was designed to test the hypothesis that where heterogeneity in pasture production was high, compost applied to perennial pastures at modest rates could stimulate pasture production and affect species composition following pasture renewal.

Materials and Methods
Establishment
In March 2018, a five-year-old spray irrigated dairy pasture that was dominated by perennial ryegrass (*Lolium perenne*) on the Rakaia Island in Central Canterbury (-43.880, 172.212), was selected for renewal. For details of the location, climate and soils see Taylor et al. (2021). Thirty plots, measuring 5 m x 6 m, were established on this area and the six treatments described in Table 1 were applied. Treatments were replicated five times. The control plots were mown on 16 March 2018, with clippings discarded, one day before all other treatment areas received herbicide. All plots except the control (A), which remained in original pasture, were sprayed with Glyphosate360 herbicide at 4l/ha on 17 March 2018. The experimental area was fenced to prevent cattle access for the duration of the experiment.

Compost, (Meadow Mushrooms Ltd., Canterbury, comprised of 37% dry matter, 2.58% total nitrogen, 0.72% total phosphorus, 1.79% total potassium and 2.51% total sulphur), was applied to treatments D, E and F plots at three different rates (Table 1) 14 days after herbicide treatment. Compost was spread by hand according to treatment allocation. Compost was applied by wet weight but was 37% DM. Treatments C - F plots were cultivated 6 d after compost application. Cultivation consisted of three passes of a rototiller with

a crumbler attached to incorporate the compost within the top 150mm of soil.

Sowing of treatments B - F occurred on 20 April, 34 d after herbicide application. The seed mix consisted of perennial ryegrass (*Lolium perenne* L.), white clover (*Trifolium repens* L.) and plantain (*Plantago lanceolata* L.) at 21, 3, and 2 kg/ha respectively. It was sown using a direct drill followed by a Cambridge roller.

Pasture management

Pastures were irrigated *via* a centre pivot system controlled by the farm manager. The plots were not grazed post-February 2018 but were mowed with a rotary lawn mower cutting at 30 mm above ground level with harvests taken at an average of 35 d intervals (range 25 to 42) during the spring, summer and autumn periods. The first measurement on this treatment was made on 26 June 2018. All plots were mown simultaneously at intervals from 11 September, aligned with grazing rotation of this paddock on farm. Clippings were discarded from the first two mowings and subsequently clippings were returned to the plot.

Pasture production and sward species composition

Pasture growth was assessed over two years, post-establishment, using a rising plate meter (Farmtracker: Farmworks Ltd, Fielding) to estimate sward height pre- and post-mowing, using a regression equation to determine herbage-mass (kgDM/ha). The regression equation used for the control plot, which consisted predominantly of ryegrass (Figure 1), was that of Litherland et al. (2008). Plantain became the main component of all other swards (Figure 1), rendering the grass-based equation inappropriate. Consequently, a series of pasture cuts was undertaken on the plantain containing plots to generate a plantain-based regression equation. This involved obtaining the average of three separate and not overlapping rising plate meter values from within a 0.25 m^2 quadrat, cutting the herbage to ground level followed by washing to remove extraneous matter, drying and weighing. This generated a regression equation Mass (kgDM/ha) =12.004 height (cm) + 1420.7 (R^2=0.669), which was applied to the sward height values from the plantain containing plots. The rate of pasture growth (ROG) was calculated using the total dry matter produced over the measurement period divided by the number of days to which the measurement period related. A herbage sample was cut at 30 mm above ground level prior to each mowing event for species composition. This involved botanical dissection of the sample into plantain, grasses and clovers and oven drying of botanical components (60° for 48 h) to determine dry mass.

Statistical analysis

An analysis of variance was carried out for the annual total dry matter (DM) and the pasture species composition. Total dry matter yield and percent botanical composition were the response variables and treatment, species and year were explanatory variables along with their interactions. The models were simplified by removing non-significant interactions and variables. Residuals were inspected visually for violation of normality assumptions and were considered adequate.

Results

Ryegrass established successfully in all renewed plots with an overall mean of 509 seedlings/m^2 at d 67 post-sowing. Despite this success, the proportion of both grass and clover relative to plantain declined soon after establishment (Figure 1). During the first season it became clear that the proportion of plantain was high at the expense of other components in all the plots where the pasture mix had been sown. Botanical composition did not differ significantly across any of the treatments B-F. This prevailed in year 2. Clover was a major component of the total amount of dry matter in the original sward, with strong seasonal variation throughout the two years of this study. The clover content of the renewed plots was the smaller component of total dry matter in these swards during the establishment year (Table 2). The proportion of clover increased in the new swards during year two

Table 1 List of treatments and corresponding treatment reference letter

Reference	Treatment
A	no compost, no cultivation, no herbicide, original pasture
B	no compost, no cultivation, plus herbicide, pasture renewed
C	no compost, cultivated, plus herbicide, pasture renewed
D	50 t/ha compost*, cultivated plus herbicide, pasture renewed
E	100 t/ha compost*, cultivated, plus herbicide, pasture renewed
F	150 t/ha compost*, cultivated, plus herbicide pasture renewed

* wet weight

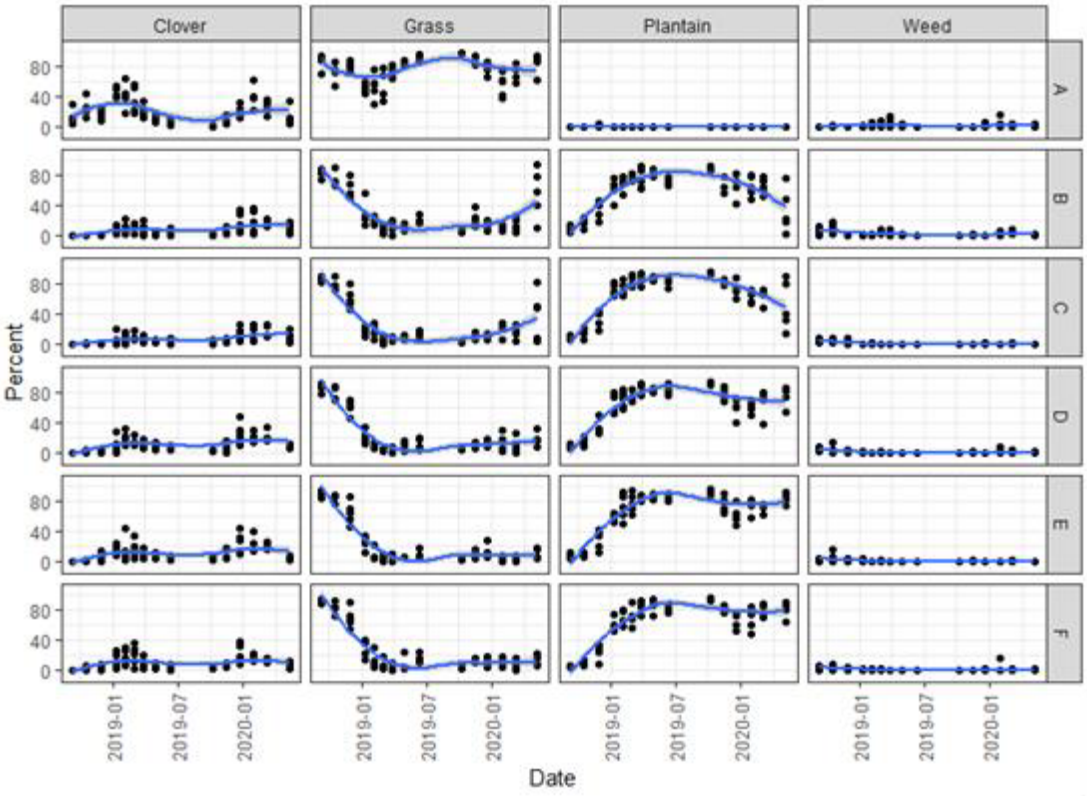

Figure 1 Seasonal and temporal changes in the proportion of grass, plantain and clover of all treatments from two years following sowing of treatments B, C, D, E and F.

while it declined slightly in the original sward such that the difference became non-significant (Table 2). Weed ingress was negligible (Figure 1).

The original five-year-old pasture produced an average of 17.9 t DM/ha/year, which was significantly more than all renewed swards (P<0.05) and twice as much as those renewed in the absence of cultivation (treatment B, Table 3). This latter treatment was also less productive than those established with cultivation, although this was only statistically significantly different from the highest rate of compost application (treatment F).

The seasonality of pasture production followed a

Table 2 Species composition (% dry matter basis) during the two years post-establishment of a mixed plantain/ryegrass/white clover sward when irrigated and managed under a mowing regime with and without varying levels of compost and/or cultivation. Means within columns with different letters differ significantly P<0.05

	Year 1			Year 2		
	grass	plantain	clover	Grass	plantain	clover
A	73[a]	0[a]	24[a]	82[a]	0[a]	17[a]
B	35[b]	56[b]	5[b]	30[b]	57[b]	11[a]
C	33[b]	61[b]	5[b]	23[b]	67[b]	10[a]
D	32[b]	58[b]	9[b]	16[b]	70[b]	14[a]
E	33[b]	57[b]	9[b]	12[b]	74[b]	13[a]
F	35[b]	55[b]	8[b]	10[b]	79[b]	10[a]
SE	14.7	9.0	13.3	8.3	3.7	4.9
P value	0.046	<0.0001	0.0002	<0.0001	<0.0001	0.697

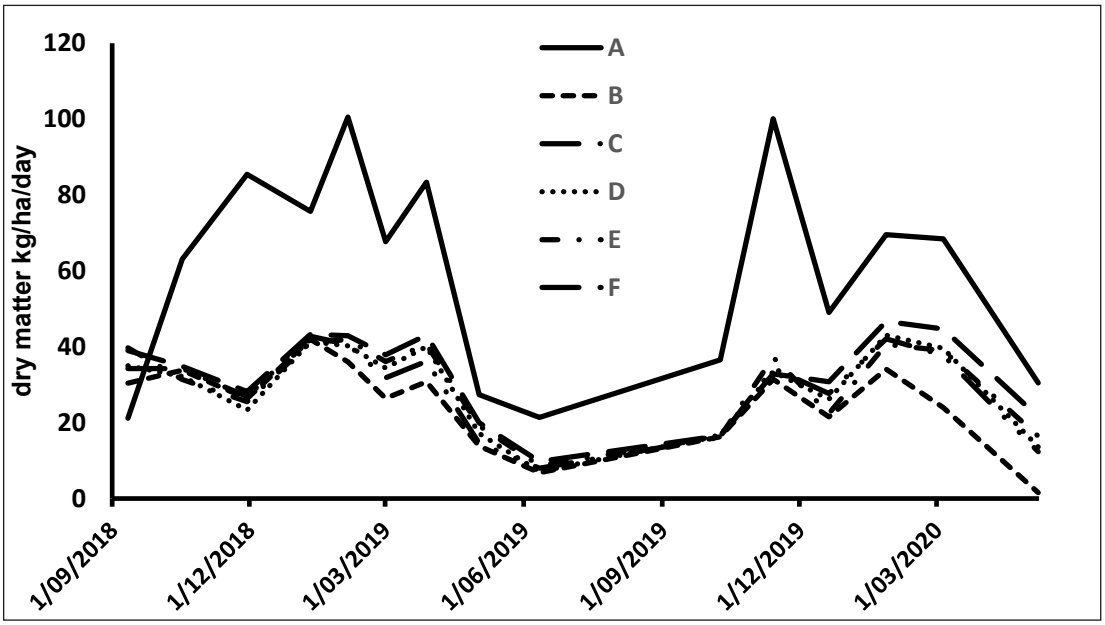

Figure 2 Comparing the seasonal growth rates of ryegrass dominant pasture from five to seven years old (treatment A, solid line) with newly established ryegrass/plantain/clover swards up to two years old (broken lines), when managed under irrigation and mowing.

similar trend for all treatments, except for the original grass dominant pasture which reached greater extremes between summer and winter growth rates (Figure 2.) The original pasture exhibited greater production on all occasions, except at the initial measurement.

Discussion

Mowing a mixed sward at around 35 d intervals gave plantain an advantage in the environment observed here. This is one of very few cases where plantain became dominant rather than a declining proportion of the sward (Dodd et al., 2019). Under grazing, the proportion of plantain in the sward declined in favour of grass in other reports (Ayala et al., 2011; Dodd et al., 2019). Equivalent results to those currently observed were evident in similar pasture mixtures measured by Myint et al. (2021), where plantain dominated in the first two years, but ryegrass came to dominate the sward in years 3 and 4 in pastures grazed by sheep. The addition of nitrogen fertiliser increased the proportion of ryegrass in Myint et al. (2021), particularly at the expense of clover, but plantain maintained a dominant portion of the young sward in the first two years. Mowing used here or rotational grazing (Myint et al. 2021) may precipitate different results to set stocking. Plantain became dominant in the sward from mowing alone and perhaps more so than reported by Myint et al. (2021).

Table 3 Pasture production during the two years post-establishment of a mixed plantain/ryegrass/white clover sward when irrigated and managed under a mowing regime (t DM/ha). Means within columns with different letters differ significantly P<0.05.

	Year 1	Year 2	Years 1 + 2
A	19.0^{a}	17.8^{a}	36.9^{a}
B	9.6^{c}	6.6^{c}	16.2^{c}
C	10.4^{bc}	8.4^{bc}	18.9^{bc}
D	10.4^{bc}	8.5^{bc}	18.9^{bc}
E	11.1^{bc}	8.4^{bc}	19.5^{bc}
F	11.6^{b}	9.5^{b}	21.0^{b}
SE	0.53	0.80	1.18
P value	<0.0001	<0.0001	<0.0001

The experiment reported here was designed to examine the effect of compost on this dairy farm. There was little benefit of compost on total dry matter production between the treatments applied here. Perhaps the soil used here was already more than adequate for pasture growth, though 150 tonne of wet compost was a considerable amount. This had the potential nutrient content to supply 1430 kg/ha N, 400 P, 990 K and 1390 S depending on the rate of breakdown and release from organic matter. Horrocks et al. (2016) had used similar amounts by wet weight in cropping systems and observed increasing yields with increasing compost. They also found the effect of compost persisted for three to four years in cropping soils. In the second year

of results here there appeared to be a trend towards more plantain and less grass with increasing amounts of compost (Table 2 and Figure 1). Considering only treatments C, D, E and F in year two (Table 2), there was a significant relationship ($P<0.001$) between plantain content and amount of compost ($R^2=0.861$). The opposite was evident for grass. Whether compost exacerbated the disadvantage to grass or promoted plantain is not clear from this design.

Cultivation significantly increased production of renewed pasture ahead of direct drilling. Around one tonne of additional dry matter was recorded on cultivated plots with no compost compared to direct drilled plots in the first year, and more than two tonnes in the following year. The cost of that cultivation and the effect on environmental outcomes should be considered, particularly when the existing five-year old pasture persisted for two more years and produced more dry matter than any other treatment. Total dry matter production was half that of the original grass pasture which remained uncultivated, received no compost or herbicide. Indeed, given the cost of pasture renewal with spraying and cultivation, a disappointing result was achieved here in terms of pasture production. The benefits from pasture quality for milk production and benefits of species to the environment would need to be considerable to recoup this sacrifice, but again this could be applied on part of the farm.

Initial sowing rates were 10 times higher for grass than plantain (21 *vs*. 2 kg) and though there was adequate establishment of grass seedlings, plantain dominated from soon after establishment. Since the seed weight of plantain and ryegrass are both around 2 grams per thousand seeds, by number of seedlings per square metre the grass would have been expected to dominate. Establishment of clover was likewise satisfactory, though again the total number of seeds in 2 kg of clover seed (0.7 g per thousand seeds) would dramatically outnumber that in 2 kg of plantain, without considering the potential contribution of volunteer clover, and yet plantain composed the majority of the sward (note that only grass seedlings were counted at establishment). Myint et al. (2021) claimed that equivalent proportions of seed gave the best balance of species in the sward yet with dramatic differences here, contributions of the species were similar to their observations by year two. Mowing might be used to maintain plantain crops that can be fed to cows on ryegrass-based pastures by 'cut and carry' or particularly stockpiled and carried forward into autumn and winter as silage (Bariroh et al., 2018).

Conclusions

This system promoted an abundance of plantain in the sward albeit, with half the production of the existing sward, so what opportunity does this create for systems where 30% plantain in diet will promote lower nitrate leaching? A system which advantages plantain may be useful given that its proportion in the sward should be greater than 30% to reduce urinary nitrogen loading and associated leaching to meet environmental goals. However annual production of less than half the total amount of dry matter produced per hectare from plantain swards would have consequences for stocking rate. With modified management, plantain swards have the potential for reducing environmental impacts but there is a trade off in production, and consequential costs.

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