Legumes for Our Land and Water

Using deferred grazing technology to increase the legume content of hill country pastures

Katherine Tozer (AgResearch), Tracy Dale (AgResearch), Steve Howarth (AgFirst), Blake Gunn (AgFirst), Maryann Staincliffe (AgResearch), Ian Tarbotton (Ballance Agri-Nutrients), Graeme Doole (AgResearch)

December 2023

Report for Our Land and Water

Client Report Number RE450/2021/05

Contents

Katherine Tozer, Tracy Dale, Steve Howarth, Blake Gunn, Maryann Staincliffe,
Ian Tarbotton, Graeme Doole

1. Executive Summary

Deferred grazing, which involves grazing exclusion from late spring until after seed-fall typically in mid-summer, is a practice used by farmers to control feed quality and rejuvenate pastures. There is some evidence that a standard deferred grazing regime can increase legume abundance in dairy pastures, but there is a lack of knowledge on how deferred grazing affects legume abundance in hill country. In this Our Land and Water project, a proof-of-concept study was established to:

1. Determine the impact of deferred grazing and legume undersowing on legume establishment success and abundance on one North Island hill country farm in Waikato.
2. Use FARMAX to gain a greater understanding of how deferred grazing affects production and profitability.
3. Estimate the environmental footprint of the scenarios modelled in FARMAX.

Our hypothesis was that we can achieve a step change in the persistence and productivity of oversown legume swards by deferred grazing of pastures for a short period over summer, by reducing grass competition and increasing legume abundance, without increasing the environmental footprint.

Two paddocks were selected on a beef and sheep farm in Lower Kaimai, Bay of Plenty, in March 2023. Pastures in both paddocks were two years old, had been sown with the same mixture of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), and had the same fertiliser history. A standard deferred grazing period was implemented in the first paddock, which involved spelling between mid-October 2022 and mid-February 2023 ('October-deferred'). The second paddock was grazed intermittently in spring 2022 and spelled between December 2022 and mid-February 2023 ('December-deferred'). A mixture of red clover and lotus was undersown in each of two paddocks, in April 2023. Red clover and lotus were selected as test legumes as they were not present at the experimental field site.The trial was established as a randomised complete block design, with four replicates of the undersowing treatments, in each of the two paddocks.

Measurements: Yield, botanical composition, perennial ryegrass tiller densities and emergence of ryegrass and legume seedlings from the soil seedbank were measured.

Undersowing effects: Undersowing was successful; the legumes germinated and seedlings were observed. However, they did not contribute to a change in the legume content in either

Katherine Tozer, Tracy Dale, Steve Howarth, Blake Gunn, Maryann Staincliffe,
Ian Tarbotton, Graeme Doole

May or July, following the April undersowing. Metabolisable energy of the pasture was also similar for both undersowing treatments (i.e. with and without undersowing), averaging 12.2 MJ/kg DM. This is to be expected given the similarities in botanical composition for both treatments.

Paddock management effects: Perennial ryegrass competition was less in the December-deferred than October-deferred treatment. The content of perennial ryegrass in total DM was lower in the December-deferred than October-deferred paddocks. The mass of perennial ryegrass tillers was also smaller in the December-deferred than October-deferred paddock, when measured in June 2023.

The lower ryegrass content was associated with a greater legume content in the December-deferred than October-deferred paddock. The content of undesirable grasses, especially Yorkshire fog (*Holcus lanatus*) and annual poa (*Poa annua*), was also greater in the December-deferred than October-deferred paddock, but the metabolisable energy content and yield in both paddocks was similar.

The seedbank was sampled in March 2023. The amount of perennial ryegrass in the seedbank was similar for both the October- and December-deferred paddocks, which inferred that the timing of grazing of the paddock in December 2022 did not prevent perennial ryegrass seed-set and seed-fall.

However, the amount of white clover in the seedbank was over 3-fold greater in the October-deferred than December-deferred paddock. The timing of grazing of the December-deferred paddock may have prevented white clover from producing seed. Possibly livestock grazed white clover in December while white clover was flowering, rather than livestock being removed prior to flowering.

While there was negligible impact of undersowing on the legume content during the establishment phase, much was learned about how the timing of deferred grazing may affect legume abundance. The pilot study inferred that grazing perennial ryegrass during its reproductive period in December reduced ryegrass dominance and increased the dominance of existing clover populations, with no impact on pasture quality, when compared to a standard deferred grazing regime. This has large implications for management given that similar benefits may accrue from a shorter deferral period. In conjunction with other current research on deferred grazing, this pilot study has raised questions for future research on deferred grazing and legume abundance. This includes: the timing of grazing exclusion and effects on perennial ryegrass and white clover flowering and seed-set, if legumes could be introduced into pastures by broadcasting into deferred pastures at the end of the deferred period, unintended impacts on undesirable grasses if implementing a December-deferred regime, and how different grazing exclusion periods may affect nutrient leaching.

2. Background

There have been numerous attempts to increase the legume content of New Zealand hill country pastures, with limited success (Kemp *et al.* 1998; Tozer and Douglas 2016). Impediments to maintaining a high legume content include climatic factors (e.g. drought stress), invertebrate damage (e.g. clover root weevil), competition from other pasture species (particularly grasses), inadequate fertility, and grazing pressure (Barker and Zhang 1988; Brock *et al.* 1989; Fajri *et al.* 1996; Hayes *et al.* 2019).

Recently, there has been increased interest in deferred grazing to rejuvenate hill-country pastures. Deferred grazing involves spelling pastures from grazing from mid-spring until the end of summer (Tozer *et al.* 2020a). This enhances the vigour of existing pasture species, as well as enabling them to reseed and produce seedlings in the following autumn (Tozer et al. 2020b).

There is some evidence that a standard deferred grazing regime can increase legume abundance. For example, deferred grazing (grazing exclusion between mid-October to late-February) increased white clover stolon density and abundance in Bay of Plenty dairy pastures (Watson et al. 1996; Harris et al. 1999). This was attributed to lower soil surface temperatures and greater soil moisture retention in the deferred pastures (Watson et al. 1996; Harris et al. 1999). In the Lower Kaimai, where the field site is located, white clover leaf area was 140% greater in deferred than grazed pastures, when measured in mid-February at the end of a standard (October-February) deferred period (P=0.056). The farm owner had also observed large increases in clover in some years in response to deferred grazing (Figure 1). However, data are missing to substantiate any benefits of deferred grazing for clover on hill-country farms and the conditions under which these may occur.

Figure 1. Red clover, white clover and lotus in deferred pastures, Mataiwhetu Station, Lower Kaimai, 13 January 2023.

In the 1950s, Eddie Suckling tested numerous combinations of targeted grazing to suppress grass growth and spelling to encourage legume populations on Te Awa, a hill-country research farm near Palmerston North (Suckling 1959). The greatest success came from intensively grazing pastures to the end of December, to weaken the resident grasses by preventing reseeding. Pastures were then spelled to allow the legumes to flower and reseed; eight weeks for white clover, and three months for red clover (*Trifolium pratense*) and bird's foot trefoil (*Lotus corniculatus*) (Suckling 1966). This period of closure fits well with many hill-country farm systems. Grazing into December and spelling thereafter coincides with the weaning of lambs and the concentrated grazing of mature ewes; pastures are generally set-stocked and intensively grazed up to this point. Its impacts on feed availability are also modest given that only 5-10% of the farm would typically be deferred in this way each year. Feed demand also decreases as lambs are sent away from the farm to be slaughtered, from mid- to late December.

Suckling (1966) also demonstrated how this strategy can increase the abundance of legumes oversown in the previous autumn (Figure 2). Therefore, thes grazing and spelling guidelines can be used in three ways – to strengthen existing legume populations, increase oversowing success, or a combination of both (Suckling 1966). Alternatively, it may be possible to intensively graze in spring to weaken grass populations, spell the pastures over summer to allow legume reseeding, graze intensively at the end of summer, and then oversow new legume seed (e.g. red clover and lotus). Suckling (1966) noted that spring grazing led to weaker grass populations in the following autumn, which would further enhance legume establishment from seed.

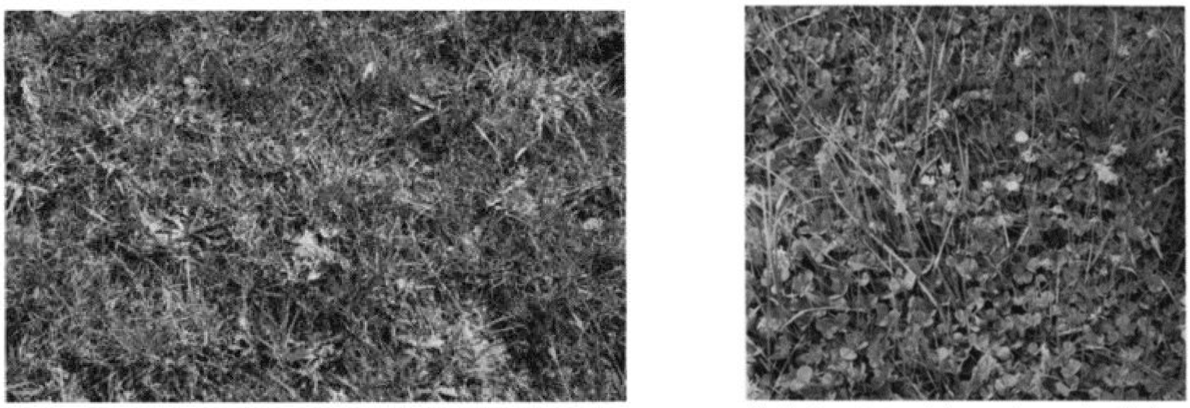

Figure 2. Unimproved, grass-dominant pasture (left) and improved pasture with a high legume content (right) at Te Awa, in the 1950s, in response to top-dressing, oversowing and targeted spring grazing and summer spelling of pastures (Suckling 1966).

Since Suckling's work in the 1950s and 1960s, there has been no research to explore the combined impact of targeted grazing in spring to reduce grass abundance and spelling to promote legume replenishment and reseeding. Research has largely focused on maintaining pastures in a green, leafy, vegetative state, and on white clover grazing management to increase stolon density and reseeding (Brock *et al.* 1989; Chapman *et al.* 1990; Brock *et al.* 2003; Widdup and Barrett 2011; Caradus *et al.* 2023).

We propose a fresh approach that builds on this previous work to help enhance the profitability, and reduce the environmental footprint of hill-country farms. In this Our Land and Water project, a proof-of-concept study was established to:

1. Determine the impact of deferred grazing management and legume undersowing on legume establishment success and abundance on one North Island hill country farm in Waikato.

2. Use FARMAX to gain a greater understanding of how deferred grazing can affect production and profitability.
3. Estimate the environmental footprint of the scenarios modelled in FARMAX.

Our hypothesis was that we can achieve a step change in the persistence and productivity of oversown legume swards by reducing grass competition and spelling pastures for a short period over summer, without increasing the environmental footprint.

3. Materials and Methods

3.1 Paddock history

The study was undertaken on Mataiwhetu Station, Lower Kaimai, Bay of Plenty which is typically considered 'summer-safe'. Rainfall in January 2023 (summer) and May 2023 (late autumn) was approximately 3-fold greater than the long-term average rainfall, while rainfall in winter and early-spring was below average (Figure 3).

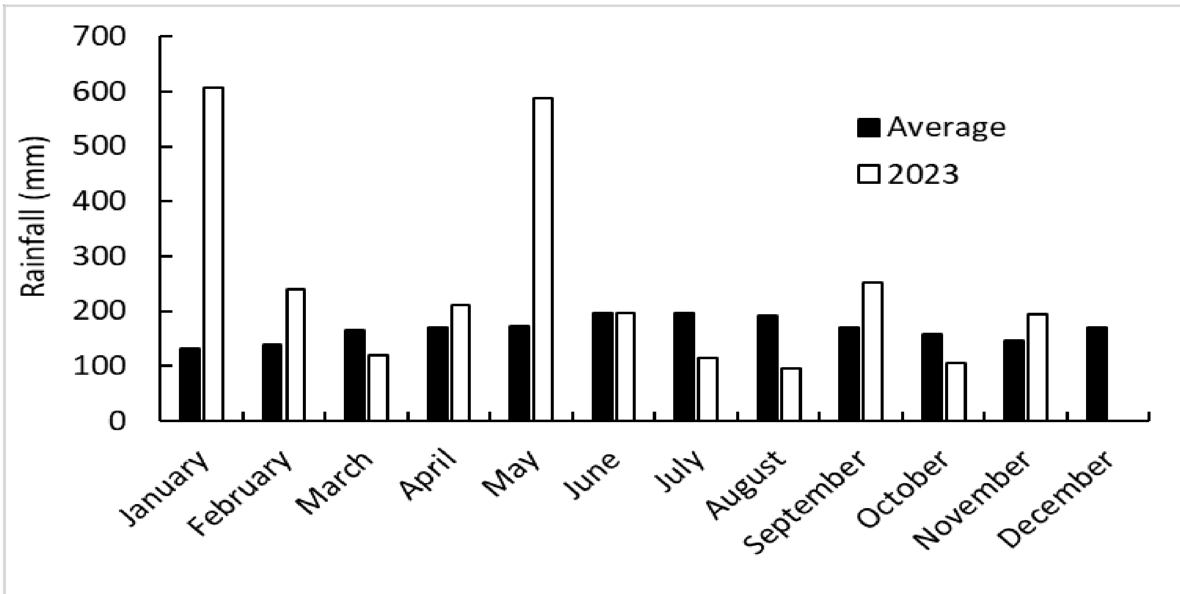

Figure 3. Long-term (1963-1923) average monthly rainfall and monthly rainfall in 2023, on Maitaiwhetu Station, Bay of Plenty, within 1 km of the field site.

The paddocks were grazed by heifers, ewes and lambs or hoggets between undersowing (see next section) and spring 2022. A standard deferred grazing period was implemented in the first paddock, which involved spelling between mid-October 2022 and mid-February 2023 ('October-deferred', Figure 4). The second paddock was grazed intermittently in spring 2022 and spelled between December 2022 and mid-February 2023 (Figure 4). During the deferred period, standing biomass of over 4000 kg DM/ha typically accumulates, and livestock typically remove approximately 50% of the available herbage at the end of the deferred period (Tozer *et al.* 2020b).

Two paddocks were selected with Kahoroa and Waihi ash soils and a similar slope that averaged 9°. The first paddock was 1.8 ha and south-facing and the second paddock was 1.0 ha and west-facing. Both paddocks were aerially sown with the same mix of perennial ryegrass and white clover in 2020 and had the same fertiliser history.

Figure 4. October-deferred paddock: a) on 28 February 2023, just after grazing the deferred pasture, and b) on 4 May, showing prolific perennial ryegrass seedling emergence from the seedbank within the strips to which glyphosate had been applied to reduce pasture competition prior to undersowing legumes. December-deferred paddock: c) on 28 February 2023, soon after grazing the deferred pasture, and d) on 4 May, showing prolific clover regrowth. Clover was not killed by the glyphosate application but regrew from existing stolons. Emergence of white clover seedlings from the seedbank was minimal. All photos are of pasture in the undersowing treatments.

Soil was sampled in April 2022 in the October-deferred and December-deferred paddocks (30 cores per paddock) and processed at Hill Labarotories, Hamilton (Table 1). No fertiliser was applied during the nine-month experimental period.

Table 1. Soil pH (1:2.5 soil:water) and nutrient status in the October-deferred (Oct-def) and December-deferred (Dec-def) paddocks for Olsen P, potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulphate sulfur (S) and molybdenum (Mo) sampled to a depth of 75 mm prior to undersowing legumes.

Paddock	pH	Olsen P (mg/L)	K (me/ 100g)	Ca (me/100g)	Mg (me/100g)	Na (me/100g)	S (mg/kg)	Mo (mg/kg)
Oct-def	5.3	45	0.49	6.6	0.95	0.11	14	0.8
Dec-def	5.3	43	0.57	8.7	1.30	0.15	16	1.0

3.2 Undersowing treatments

In each of the two experimental paddocks (October-deferred and December-deferred), undersowing treatments were arranged in a randomised complete block, with four replicates of each of the two treatments (legume undersowing, no legume undersowing). Plots were 3 m wide x 50 m long.

For the 'legume undersowing' treatment, AGPRO glyphosate 510 (0.18 L/ha, 92 g a.i/ha) was applied on 31 March 2023. The paddocks were grazed 6-8 April for 48 hrs with 150 R1 heifers. A legume mixture, comprising 8 kg/ha red clover (*Trifolium pratense*, 4 kg/ha of each of the two cultivars: Relish and Morrow) and 6 kg/ha lotus (*Lotus pedunculatus*), was drilled on 10 April, and Slugout™ (144 g a.i/ha) broadcast at a rate of 8 kg/ha on 17 April.

For the 'no legume undersowing' treatment, no herbicide was applied, no legumes were undersown and no Slugout was applied.

3.3 Grazing management after undersowing

The two paddocks were grazed during autumn and winter on three occasions. Paddocks were grazed for approximately 48 hours, by 150 R1 heifers on 18 May, 300 hoggets on 24 June, and 150 R1 heifers 28 July. Pre-grazing herbage mass was 2740 kg DM/ha and post-grazing herbage mass was 1730 kg DM/ha, averaged over all grazings and both paddocks. Paddocks were set stocked for lambing for one month as of 20 August 2023. Measurements were discontinued at this point as paddocks were grazed at different stocking densities and it was unknown how this may have affected the legume content and pasture botanical composition (7 ewes+lambs/ha in October-deferred, 10 ewes+lambs/ha in December-deferred).

3.4 Measurements

Germinability of the sown red clover and lotus seed was assessed in August 2023. One hundred seeds of each red clover cultivar and 100 lotus seeds were sown in seed trays (30 cm x 41 cm, 5 cm depth) filled with Premium Seed Mix (Daltons Ltd, Matamata). Trays were placed in a glasshouse at AgResearch, Hamilton, watered daily, and emerged seedlings counted one month after undersowing. This process was repeated for a further 200 lotus seeds, in September 2023.

The soil seedbank in each paddock was assessed in March 2023. Forty soil cores (7.0 cm diameter to a depth of 5 cm) were collected from random locations in each of the two paddocks. The soil was bulked for each paddock and sieved. Seedling trays were filled with soil to a depth of 2 cm, maintained in a glasshouse and watered daily to keep the soil moistened to field capacity. Emerged seedlings were counted and categorised as ryegrass, other grasses, white clover, red clover, lotus (*Lotus* spp.) other legumes (mainly subterranean clover (*Trifolium subterraneum*)) and broadleaf weeds. Most seedling emergence from the seedbank occurs within several weeks, using this seedbank assessment method (Rahman et al. 1995). At the same time, baseline data on perennial ryegrass tiller and seedling densities were obtained by counting the number of adult tillers, daughter tillers and seedlings in each core. White clover plants, including stolons, were also separated from the cores, and oven-dried at 65°C over ≈24 h and weighed. This enabled characterisation of the perennial ryegrass tiller density and white clover, in each paddock at the end of the deferred period, prior to undersowing legumes.

Legume seedling establishment was assessed on 20 June 2023. All legume seedlings in each of ten randomly positioned 0.09 m^2 quadrats along a 25 metre transect in each plot were counted.

Pre-grazing herbage mass and post-grazing residual herbage mass were assessed between undersowing and 20 August. A rising plate meter (RPM) was randomly positioned in 50 locations along the 25 m transect in each plot (RPM, EC-10, Jenquip, NZ, calibration equation: pasture mass = compressed pasture height x 40+500).

Botanical composition and nutrient content were assessed on 9 May and 21 July by snip sampling, in which 20 randomly selected fistfuls of pasture along the 25 m transect were cut to ground level in each plot. The samples were bulked, mixed and subsampled using the quartering method (Cayley and Bird 1996). A sub-sample was separated into perennial ryegrass, other grasses, white clover, red clover, lotus, broadleaf weed and dead vegetation components. Each component was dried at 65°C and weighed to determine its contribution to total dry matter. A second sub-sample was dried at 65°C for 48 hours, ground to a fine powder and sent to Hill Laboratories to determine the metabolizable energy content using near near-infrared spectroscopy (NIRS, Corson et al. 1999).

Ryegrass tiller density was assessed on 21 June 2023. Vegetation in five, randomly positioned 10 cm x 15 cm quadrats along the 25 m transect in each plot were harvested to ground level, bulked and weighed. A subsample (containing ≈200 entire perennial ryegrass tillers) was removed, dissected into adult and daughter perennial ryegrass tillers, perennial ryegrass seedlings and 'other vegetation'. Ryegrass tillers and seedlings were counted and all components weighed. All components were oven-dried at 65°C to a constant weight over ≈24 h, weighed, and tiller mass of perennial ryegrass estimated. The perennial ryegrass tiller and seedling numbers, and percentage of DM in the subsample and whole sample were used to estimate the number of perennial ryegrass tillers in the whole sample. This was scaled to estimate the tiller number per square meter.

All data analysis was performed in R (Version 4.2.2 (2022)). ANOVA was used to assess the main additive effects of paddock management (October-deferred and December-deferred), undersowing treatment (legume undersowing and no legume undersowing) and season (autumn and winter). It is noted that paddock management was not replicated and the statistical comparisons of the October-deferred vs. December-deferred paddocks are indicative only.

4. Results and Discussion

4.1 Undersowing

Success of undersowing

Undersowing resulted in increased legume establishment. A total of 27 lotus seedlings per m^2 and 43 red clover seedlings per m^2 were present in undersown treatments in June, and 20 lotus seedlings per m^2 and 38 red clover seedlings per m^2 were present in undersowing treatments in October. There were no lotus seedlings and negligible red clover seedlings present in the 'no undersowing' treatments.

A key aim of this study was to determine the impact of undersowing on pasture composition and productivity in the October-deferred and December-deferred paddocks. However, despite an increase in the number of seedlings in the undersown treatment, there was no effect of undersowing on the botanical composition (percentage in total DM of perennial ryegrass, other grasses, legumes, broadleaf weed or dead vegetation), in autumn or in winter 2023 (data not shown, $P>0.05$). Although the legumes germinated and seedlings were observed, they were small, and did not contribute to a change in the legume content in either May or July, following the April undersowing (Figure 5). Metabolisable energy of the pasture was also similar for both undersowing treatments, averaging 12.2 MJ ME/kg DM ($P>0.05$). This is to be expected given the similarities in botanical composition for both treatments.

Figure 5. A lotus seedling on a) 23 June, approximately 2.5 months after undersowing, and b) 31 July, approximately 3.5 months after undersowing.

Herbicide effects on resident pasture

Herbicide was applied at low, chemical topping rates to reduce the vigour of the resident pasture and improve establishment success of the legumes. The chemical topping rate is typically 5-8% of the full rate. The initial intent was to apply Paraquat as has been done in other studies to reduce competition of resident grasses and increase the success of legume introduction (Tozer *et al.* 2013). However, this was not an option due to changes in label recommendations for application to pastures. The only available chemical option was glyphosate. The glyphosate application rate for pasture suppression was discussed with agrichemical specialists. A standard chemical topping rate was used, given knowledge of its impact on pastures, albeit traditionally for spring application, when ryegrass is less sensitive to herbicide application.

Despite applying glyphosate at a low rate, the resident ryegrass was killed. This reduced the competitive effect of the existing pasture on emerging ryegrass seedlings and was the likely reason why there was a higher seedling density, with a lower mass, in the undersowing treatment ($P<0.05$. Table 2). Therefore, an unintended consequence of herbicide application was that it improved perennial ryegrass establishment from the seedbank.

Possibly even lower rates of glyphosate should be considered to suppress pasture growth prior to introducing legumes in autumn. An alternative strategy may be to broadcast legumes into deferred pastures prior to grazing the sward. If this is done, the pasture must be well-grazed and trampled to ensure good seed-soil contact and to allow light to penetrate to the base of the sward to enable seedling growth. This requires investigation.

Table 2. Effect of herbicide application and undersowing on perennial ryegrass tiller density and tiller mass, botanical composition and metabolisable energy for the oversowing and no oversowing treatments. Data were averaged over the October-deferred and December-deferred pastures. Tiller characteristics were measured in June 2023. sed: standard error of difference. ns: not significant (P>0.05).

Measurement	No undersowing	Undersowing	sed	P value
Perennial ryegrass tiller density and mass				
Adult tillers (m^2)	3010	2550	395	ns
Daughter tillers (m^2)	100	120	24	ns
Seedlings (m^2)	60	90	14	0.038
Total tillers (m^2)	3170	2760	395	ns
Tiller mass (g per tiller)	0.06	0.04	0.01	0.001

Seed germinability and purity

When tested for germinability in the glasshouse, ninety-nine percent of each of the two red clover cultivars germinated (one provided by Agricom and one by Barenbrug), and all were red clover. Ninety-nine per cent of the initial sown 'lotus' seed stock also germinated. However, of the germinated 'lotus' seeds, 51% comprised white clover and 49% comprised lotus. The repeat test yielded similar results, with 52% of the germinated seed comprising white clover and 48% lotus (Figure 6). Subsequent conversations with agronomists from Agricom and Barenbrug confirmed that contamination of lotus seed by white clover is widespread in the New Zealand seed industry and that it is difficult to produce lotus seed with a high level of purity. For this reason, companies such as Agricom and Barenbrug do not produce lotus seed. Commercial lotus seed is only available through smaller companies and may have high levels of contamination. The purchased lotus seed exceeded $60 per kilogram. With a contamination rate of approximately 50%, the purchaser is effectively paying $90 per kilogram of lotus, which is a significant financial outlay.

Figure 6. A tray of 'lotus' seed. Note the abundance of white clover seed contamination.

4.2 Paddock management

Emergence of sown seed was greater in the October-deferred than December-deferred paddock for lotus (22 vs. 5 seedlings per m^2, respectively) and red clover (32 vs. 13 seedlings per m^2 respectively) in June. It was also greater in the October-deferred than December-deferred paddock for lotus (18 vs. 2 seedlings per m^2 respectively) and red clover (32 vs. 7 seedlings per m^2 respectively) in October. This may have occurred due to the greater abundance of clover in the December-deferred than October-deferred paddock, which possibly led to increased shading of emerging clover seedlings. Shading of clover can reduce its establishment success (Brougham 1962).

As the effects of undersowing on botanical composition were minimal within the experimental period, the remainder of this report focuses on differences between the October- and December-deferred paddocks. The paddocks were selected for this study after the deferred period; baseline data were not obtainable. However, many valuable lessons have been learned from comparing soil seedbank, perennial ryegrass tiller densities, botanical composition, yield and nutritive value in the December-deferred and October-deferred paddocks. Results are presented in chronological order to provide the reader with an understanding of:

(i) changes in the botanical composition of the December- and October-deferred paddocks over the experimental duration,
(ii) implications for the timing of deferred grazing on the legume content, and

(iii) future research needs.

Effects of deferred grazing on seedbank replenishment ***<u>during</u>*** *the deferred period*

Sampling the soil seedbank in March 2023 indicated that the timing of grazing in December, in the December-deferred paddock, did not prevent replenishment of the seedbank with perennial ryegrass seed. This is because the amount of perennial ryegrass in the seedbank was similar for both the October- and December-deferred paddocks (Table 3).

There were also many perennial ryegrass seedlings present in the December-deferred pasture in March 2023, further demonstrating that substantial reseeding occurred in both paddocks (1900 vs. 2600 seedlings m^2 in December-deferred and October-deferred pastures respectively).

Conversely, the timing of grazing may have reduced replenishment of the seedbank by white clover, through removal of white clover flowers. This is inferred from the amount of legume seed that was present in the seedbank. The amount of white clover seed was over 3-fold greater in the October-deferred than December-deferred paddock (Table 3). These data highlight the importance of the closing date and the way the pasture is grazed up to the beginning of the deferred period. Set-stocking during ryegrass stem elongation and flowering phase, and removing livestock when white clover is flowering, were used by Suckling (1966) to increase legume abundance, which was different from the stock management practices implemented here.

There was a high content of broadleaf weeds in the seedbank of both paddocks, especially scrambling speedwell (*Veronica persica*) and mouse-eared chickweed (*Cerastium glomeratum*) in the October-deferred paddock, and mouse-ear chickweed and hawksbeard (*Crepis capillaris*) in the December-deferred paddock. Other seedbank and pasture surveys of dairy, sheep and beef pastures in Northland, Waikato, Bay of Plenty, Taranaki and Canterbury have showed that broadleaf weeds are prevalent in the seedbank, although broadleaf weeds are generally only a minor component of the above-ground pasture composition (Tozer et al. 2010; Tozer et al. 2011). Seeds of broadleaved species are often long-lived in the soil seedbank and may have been present for many years.

Effects of deferred grazing on pasture botanical composition ***at the end of*** *the deferred period*

Visual observations of the paddocks at the end of the deferred period in February 2023, when paddocks were selected for the OLW study, indicated that clover was abundant in the December-deferred paddock and that grass was dominant in the October-deferred paddock (Figure 7). This is substantiated by data on clover mass and perennial ryegrass tiller densities which were collected at the end of February to characterize the two paddocks. The mass of clover leaf, stem and stolon was almost 2-fold greater in the December-deferred than October-deferred paddocks (96 vs. 52 g m^2).

Figure 7. a) October-deferred paddock with a high grass content, and b) December-deferred paddock with abundant clover content, on 28 February just after deferred pastures were grazed.

Effects of deferred grazing on pasture botanical composition ***after*** *the deferred period*

There were differences between the two paddocks in terms of their perennial ryegrass populations. The seedling density was lower (P<0.01) and the mass of perennial ryegrass tillers was lower (P<0.001) in the December-deferred than October-deferred paddock, when measured in June 2023. Results were similar to those obtained in February 2023, before herbicide was applied and legumes oversown. However, there was no difference between the October-deferred and December-deferred paddocks in the density of perennial ryegrass adult tillers, daughter tillers or total number of tillers in June 2023 (P>0.05, Table 3).

The content of perennial ryegrass in total DM was also lower in the December-deferred than October-deferred paddocks in winter (P<0.001, Table 3). These differences indicate that flowering and seeding of perennial ryegrass was reduced in the December-deferred paddock to a greater extent than in the October-deferred paddock. As discussed previously, a set-stocking regime for a longer period during the ryegrass reproductive period may have reduced seedbank replenishment more effectively.

Other grasses filled the gap created by the weakened ryegrass in the December-deferred paddock. The content of other grasses, especially Yorkshire fog (*Holcus lanatus*) and annual poa (*Poa annua*), was higher in the December-deferred than October deferred paddock (Table 3, P<0.01). This is also consistent with the greater abundance of other grasses in the seedbank in the December-deferred than October deferred paddock. The reduction in perennial ryegrass content may also have allowed other less desirable grasses to gain a competitive advantage. Possible reasons for this also include paddock topography, as there were more low-lying areas in the December-deferred paddock in which Yorkshire fog was abundant. The impact of timing of deferring on pastures with a high level of undesirable grass species, such as Yorkshire fog grass, needs to be considered in future research.

There was no effect on the broadleaf weed content or content of dead vegetation, which comprised a low proportion of total DM in both May and July (Table 3, P>0.05).

The impact on the legume content was as expected, with a higher legume abundance in the December-deferred than October-deferred treatment. This was observed particularly in autumn when the content of legume (mainly white clover) in total DM averaged 18% and 10% in the December-deferred and October-deferred paddocks respectively (P<0.05, Table 3). It was also observed when dissecting samples in the laboratory that the white clover present comprised adult plants with established stolons, few seedlings were observed. Clover populations were most likely enhanced by increasing the competitive ability of resident clover by resting pastures from grazing between December and February, rather than increasing seedling establishment from the seedbank.

A high proportion of white clover seed becomes hard seeded and may remain dormant in the seedbank for several years, depending on the conditions during seed ripening (Hyde 1950). This was most likely the case for the October-deferred paddock, which had an abundant white clover seedbank. Even if white clover germinated, plants were most likely small and contributed little to the proportion of legume in total dry matter, given the size of red clover and lotus plants in this trial.

While dissections are a valuable tool to assess botanical composition in the field, some measure of clover ground cover or frequency may be needed to fully capture the clover contribution to the sward. Although snip samples were cut to ground level, white clover stolons were often partly buried and therefore not sampled. It is therefore likely that the true contribution of white clover to the sward botanical composition was underestimated.

There was no difference between the October-deferred and December-deferred paddocks in the metabolisable energy content of the pastures (12.2 MJ/kg DM averaged over both paddocks, oversowing treatments and autumn and winter assessments, $P>0.05$), or on herbage accumulation during late autumn / winter (1210 kg DM/ha between undersowing and August 2023 averaged over all treatments and both paddocks, $P>0.05$).

One potential benefit of higher legume abundance in late summer / early autumn is an increase in ewe liveweight prior to joining, which can increase ewe fecundity and the lambing percentage (see the FARMAX modelling report). Given the results of this pilot study, the impact of the timing of deferred grazing on the total legume content and its seasonal distribution warrants further research. As a result of this OLW-funded project, we are designing a new study to explore this, with site establishment planned for autumn 2024.

Farmscale and environmental impacts

This pilot study indicated that grazing perennial ryegrass during its reproductive period can reduce ryegrass competition and increase legume abundance, with no impact on pasture quality, when compared to a standard deferred grazing regime (i.e., December-deferred vs. October deferred). However, the impact on legume abundance was relatively small when considering the impact on livestock production, and there was no effect on pasture growth, during the establishment period.

The impacts at a farm-scale have been explored in FARMAX. Based on the FARMAX output, it is unlikely that there will be significant differences between deferred grazing (October-deferred or December-deferred) and standard rotational grazing for GHG emissions or N-leaching.

However, there are two impacts of deferred grazing that are not considered in FARMAX, both which may influence N-leaching. Controlled studies indicate that deferred grazing increases root mass at depth and the accumulation of water soluble carbohydrates (WSC)

(Tozer, Müller and Tarbotton 2020b). An increase in root growth, which may occur in response to deferred grazing, may increase the amount of nutrient captured in the soil profile. Further, a higher water soluble carbohydrate content of ingested forage may increase the WSC to crude protein ratio of the forage. This can lead to a change in N partitioning, less N in the urine and a reduction in N losses (Pacheco 2007). Both of these impacts of deferred grazing are speculative and have yet to be explored through modelling and field research, but warrant further investigation.

Table 3. Emergence from the soil seedbank, perennial ryegrass tiller density and tiller mass, botanical composition and metabolisable energy in the October-deferred (grazing exclusion between mid-October 2022 and mid-February 2023) and December-deferred (grazing exclusion between mid-December 2022 and mid-February 2023) paddocks. The seedbank was assessed in March 2023, prior to treatment application. Perennial ryegrass tiller populations were assessed in June 2023. sed: standard error of difference. ns: not significant (P>0.05).

Measurement	Oct-deferred	Dec-deferred	sed	P value
Emergence from the soil seedbank (m^2)				
Ryegrass	1910	1680	-	-
Other grass	3450	10790	-	-
White clover	600	160	-	-
Red clover	0	0	-	-
Lotus	40	0	-	-
Other legumes	40	0	-	-
Broadleaf weed	3490	1460	-	-
Perennial ryegrass tiller density and mass				
Adult tillers m^2	2910	2650	395	ns
Daughter tillers (m^2)	100	120	24	ns
Seedlings (m^2)	100	50	14	0.004
Total tillers (m^2)	3110	2820	395	ns
Tiller mass (g per tiller)	0.06	0.04	0.01	<0.001
Total legume content (% in total DM)				
May 2023	10	18	1.81	0.003
July 2023	2	5	1.81	0.090
Botanical composition (content in total DM averaged over autumn and winter (%))				
Perennial ryegrass	74	59	2.8	<0.001
Other grasses	6	19	2.5	<0.001
Legumes	6	11	1.3	0.003

Broadleaf weed	11	8	1.0	ns
Dead	3	2	1.0	ns
		Metabolisable energy (MJ ME/kg DM)		
Metabolisable energy	12.1	12.3	0.2	ns

*'Other legumes' comprised subterranean clover.

5. Conclusions and recommendations

While there was negligible impact of undersowing on the legume content during the establishment phase, much was learned about how the timing of deferred grazing may affect legume abundance. The pilot study indicated that grazing perennial ryegrass during its reproductive period in December reduced ryegrass dominance and increased the dominance of existing clover populations, with no impact on pasture quality, when compared to a standard deferred grazing regime. This lends support to the strategy employed by Suckling (1959) to increase legume dominance. In conjunction with other current research on deferred grazing, this OLW pilot study has raised questions for future investigation:

1. Farmers often graze deferred pastures in March. Given the need to introduce legumes early in autumn (ideally March vs. April), project team members asked if legumes could be broadcast into deferred pastures before grazing off, to enable their successful establishment in hill country. This would require that sufficient standing biomass is removed so that light can reach the germinating legume seeds and enough trampling to ensure high levels of seed-soil contact.

2. If using glyphosate to suppress pasture growth when introducing legumes in autumn, what rate is best?

3. How does snip sampling compare to other assessment methods such as estimates of basal cover or using quadrat cuts to capture the contribution of white clover to the sward botanical composition?

4. What is the best timing for resting pastures to increase the abundance of different legumes, based on their timing of flowering?

5. When compared to deferring in October, what impact does December-deferred grazing have on the content of undesirable grasses and are there some species in particular that may be increased by this practice?

6. What impacts does deferred grazing have on root growth and is this affected by the timing and extent of the deferred period? Does this have an impact on nitrogen use efficiency and N leaching losses?
7. What impacts does deferred grazing have on the WSC: CP ratio of ingested forage and does this reduce N leaching?
8. Does dry matter production and feed quality differ between an October-deferred and December-deferred pasture, deferred and undersown paddocks, and standand rotationally grazed paddocks, and if so for how long will these differences persist?
9. How can a farm system be optimized to integrate the potential benefits of both October-deferred and December-deferred deferred grazing management strategies?

6. Acknowledgements

We thank Our Land and Water and Ballance Agri-Nutrients for funding; Allen Coster and Paul Anselmi, Mataiwhetu Station, for hosting this trial and stock management of the field site; AgResearch staff Alex Ankersmit-Udy and Libby North for technical assistance, Grant Rennie and David Stevens for advice on the FARMAX modelling, and Alba Chaolumen for statistical support; Angee Nagra (Agricom) for red clover seed and agronomic advice; and Jen Corkran and Gemma Hansen (Barenbrug) for red clover seed and agronomic advice; Paul Addison (Nufarm) for technical advice on herbicide application; and Bill and Sue Garland for their input into the FARMAX modelling scenarios.

References

Barker DJ, Zhang DM (1988) The effects of paraquat spraying, seed placement, and pre-germination on the appearance and survival of white clover, cocksfoot, and ryegrass seedlings from spring oversowing in hill country. *New Zealand Journal of Experimental Agriculture* **16**, 1-9.

Brock JL, Caradus JR, Hay MJM (1989) Fifty years of white clover research in New Zealand. *Proceedings of the New Zealand Grassland Association* **50**, 25-39.

Brock JL, Hyslop MG, Widdup KL (2003) A review of red and white clovers in the dryland environment. In ‘Legumes for dryland pastures: proceedings of a New Zealand Grassland Association (Inc.) Symposium held at Lincoln University, 18-19 November, 2003.' (Ed. DJ Moot) pp. 101-108. (New Zealand Grassland Association: Wellington)

Brougham RW (962) The leaf growth of *Trifolium repens* as influenced by seasonal changes in the light environment. *Journal of Ecology* **50**, 449-459.

Caradus JR, Roldan M, Voisey C, Woodfield DR (2023) White clover (*Trifolium repens* L.) benefits in grazed pastures and potential improvements. In 'Production and utilization of legumes: progress and prospects.' (Ed. M Hasanuzzaman) pp. 1-28. (IntechOpen: London)

Cayley JWD, Bird PR (1996) Techniques for measuring pastures. 2nd edn. (Agriculture Victoria: Hamilton, VIC)

Chapman DF, Robson MJ, Snaydon RW (1990) The carbon economy of developing leaves of white clover (*Trifolium repens* L.). *Annals of Botany* **66**, 623-628. doi: 10.1093/oxfordjournals.aob.a088076

Fajri A, Swaby B, Inwood RJ, Butler JH, Carter ED (1996) Effects of time of application of herbicide on the yield and nitrogen fixation of clover in grassy pasture. In 'Agronomy - science with its sleeves rolled up: Proceedings of the 8th Australian Agronomy Conference'. pp. 247-250. (Australian Society of Agronomy: Melbourne, Australia)

Harris SL, Waugh CD, McCabe RJ, van Vught VT (1999) Effect of deferred grazing during summer on white clover content of Waikato dairy pastures, New Zealand. *New Zealand Journal of Agricultural Research* **42**, 1-7.

Hayes RC, Ara I, Badgery WB, Culvenor RA, Haling RE, Harris CA, Li GD, Norton MR, Orgill SE, Penrose B, Smith RW (2019) Prospects for improving perennial legume persistence in mixed grazed pastures of south-eastern Australia, with particular reference to white clover. *Crop and Pasture Science* **70**, 1141-1162. doi:10.1071/CP19063

Hyde E (1950) Studies on the development of white clover seed. *Proceedings of the New Zealand Grassland Association*, **12**, 101-107.

Kemp P, Barker D, Valentine I, Awan M, Nie Z (1998) Oversowing legumes into perennial pasture: can we do it better? In 'Agronomy, growing a greener future: proceedings of the Ninth Australian Agronomy Conference'. (Eds DL Michalk, Pratley JE) pp. 273-275. (Australian Society of Agronomy: Wagga Wagga)

Pacheco D, Burke J, Cosgrove G (2007) An empirical model to estimate efficiency of nitrogen utilisation in cows grazing fresh forages. In 'Proceedings of the Third Australasian Dairy Science Symposium. (Eds DF Chapman, DA Clark, KL Macmillan, DP Nation) pp. 409-416. (National Dairy Alliance: Melbourne, Australia)

Rahman A, James TK, Grbavac N, Mellsop J (1995) Evaluation of two methods for enumerating the soil weed seedbank. In 'Proceedings of the 48th New Zealand Plant Protection Conference'. pp. 175-180. (New Zealand Plant Protection Society: Wellington). doi:10.30843/nzpp.1995.48.11550

Suckling FET (1959) Pasture management trials on unploughable hill country at Te Awa. II Results for 1951-57. *New Zealand Journal of Agricultural Research* **2**, 488-543.

Suckling FET (1966) 'Hill pasture improvement.' (Newton King Group of Companies in collaboration with the New Zealand Department of Scientific and Industrial Research: New Plymouth, New Zealand)

Tozer KN, Douglas GB (2016) Pasture establishment on non-cultivable hill country: a review of the New Zealand literature. In 'Hill Country Symposium: papers from the 12 and 13 April 2016, Rotorua'. pp. 213-224. (New Zealand Grassland Association: Dunedin). doi:10.33584/rps.16.2016.3233

Tozer KN, Douglas GB, Cameron CA, Fraser TJ, Moss RA, Rennie GM, Knight TL, Muir PD (2013) Pasture establishment on non-cultivable hill country. In 'Proceedings of the New Zealand Grassland Association. pp. 215-220. (New Zealand Grassland Association: Wellington). doi:10.33584/jnzg.2013.75.2897

Tozer KN, Barker GM, Cameron CA, James TK (2010) Relationship between seedbank and aboveground botanical composition during spring. *New Zealand Plant Protection* **63**, 90-95. doi:10.30843/nzpp.2010.63.6541

Tozer KN, Cameron CA, Thom ER (2011) Weed ingress and pasture persistence in Bay of Plenty dairy farms: field observations and farmer perceptions. *New Zealand Plant Protection* **64**, 68-74. doi:10.30843/nzpp.2011.64.5964

Tozer KN, Müller K, Craven T, Tarbotton I, Coster A, Burke R, Sherlock J, Cameron C (2020a) Effect of deferred grazing during late spring and summer on pasture productivity in Waikato and Bay of Plenty hill country. *Journal of New Zealand Grasslands* **82**, 111-119. doi:10.33584/jnzg.2020.82.448

Tozer KN, Müller K, Tarbotton I (2020b) 'Deferred Grazing Handbook. ' (AgResearch Ltd: Hamilton, New Zealand) Available at https://www.agresearch.co.nz/our-research/deferred-grazing-handbook/ [Verified 20 December 2023]

Watson R, Harris S, Bell N, Neville F (1996) Deferred grazing to enhance white clover content in pastures. In 'White clover: New Zealand's competitive edge. Proceedings of a joint symposium between Agronomy Society of New Zealand and New Zealand Grassland Association, Lincoln University, New Zealand, 21-22 November, 1995'. (Ed. DR Woodfield) p. 154. (Agronomy Society of New Zealand: Christchurch). doi:10.33584/rps.6.1995.3357

Widdup K, Barrett B (2011) Achieving persistence and productivity in white clover. In 'Pasture Persistence Symposium: papers from the Pasture Persistence Symposium, 10 and 11 May 2011, Hamilton, New Zealand'. (Ed. CF Mercer) pp. 173-180. (New Zealand Grassland Association: Dunedin). doi:10.33584/rps.15.2011.3206

s