Multi-year performance of white clover (*Trifolium repens* L.) oversown into eastern North Island hill country

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Abstract

Animal performance on summer-dry North Island hill country is limited by the quantity and quality of pasture produced. This is determined largely by the amount of legume grown. A major challenge is to successfully establish and retain a substantive legume content in swards on steep slopes. This can be achieved by 1) the selection of the most appropriate legume for different slopes, aspects and soil type combinations; and 2) the utilization of successful establishment and management techniques developed in the 1980s. We demonstrate this through the re-establishment of white clover on two large southerly aspect paddocks on Tangihanga Station, Gisborne, where resident white clover abundance had diminished to <15% in autumn. Resident pasture was controlled by hard cattle grazing and a contact herbicide that supressed the dominant low-fertility grasses. White clover seed was broadcast at 6 kg/ha and then trampled with a large mob of sheep. We followed white clover persistence and animal performance over the subsequent 5 years of rotational cattle grazing with heifers and steers, compared with resident pastures in adjacent unsown paddocks. White clover abundance increased to 25–40% in sown versus remaining at 7–17% in unsown paddocks. This increased white clover herbage content, stocking rates and per head growth rates, with overall annual liveweight gain increasing by 67–169%. The cost of establishment was ca. $220/ha and was recovered in 1 year. Therefore, oversowing white clover, coupled with appropriate grazing management, was a cost-effective method of increasing animal production that has wide-spread applicability to large areas of similar south-facing slopes in summer-dry east coast regions of the North Island.

Keywords cattle, establishment, Gisborne, legume, persistence

Background

Livestock performance on approximately 4 million hectares of summer-dry North Island hill country pastures is limited by soil fertility and the challenge of establishing and retaining a strong legume content (herein % of available herbage) in swards on steep slopes. This is particularly true for perennial legumes such as white clover on warmer and drier northerly aspects (Lambert 1976; Chapman and Macfarlane 1985). Most legume species are susceptible to the unfavourable soil and climatic conditions in this environment, i.e., low phosphorus (P) fertility, low soil pH soils and the impact of selective grazing by sheep and frequent summer moisture deficits of 1–2 months duration (Dodd and Sheath 2003). Consequently, the proportion of legume persisting in grass-dominant swards that contributes to both feed quality and nitrogen fixation is typically only 5–15% (Korte and Quilter 1990; Dodd et al. 2019).

A major challenge is one of adaptation. Selecting legume species adapted to the range of slope, aspect and soil type combinations in this topographically diverse environment can overcome this limitation (Chapman and Macfarlane 1985). For example, winter-annual species such as subterranean clover (*Trifolium subterraneum* L.) survive the summer moisture stress as a seed and are useful on warm north-facing slopes in east coast summer-dry regions (Olykan et al. 2019). The range of these species available as commercial cultivars has broadened somewhat in recent decades (Stewart et al. 2022). Annual legumes are less suited to south-facing slopes where cooler temperatures mitigate moisture deficits, though can still be found in microsites. On these landscape units, perennial legumes have greater potential to contribute to forage supply and quality, with the two main options being white clover (*T. repens* L.) and red clover (*T. pratense* L.), although red clover is intolerant of the close regular grazing pressure typical in sheep-dominant systems (Lambert et al. 1986).

A second major challenge is successful establishment. In steep terrain where mechanical drills are not usable, seed must be broadcast (oversown), and have ongoing contact with soil moisture for germination. The dense grass-dominant swards that characterise these environments can hold seed off the soil surface and therefore prevent germination. Resident pasture plants also compete strongly with germinating seeds for soil water, nutrients and light. Some form of sward disturbance is necessary to create space for seedling establishment. Macfarlane and Bonish (1986) report

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that the greatest establishment success results from a combination of inoculant pelleting, P fertiliser application, pre-sowing grazing, selective herbicide use and post-sowing animal treading.

A third major challenge is one of persistence. Forage legumes are well-adapted to grazing through vegetative (stolons) and reproductive (seeds) means, but their typically greater palatability than resident species and higher feed quality means they can be preferentially grazed, particularly by sheep (Nolan et al. 2001). Long-term declines following white clover introduction are commonly observed (Dodd et al. 2001; Fraser et al. 2016). Ultimately, poor persistence results from the combination of multiple stresses (fertility, moisture) and disturbances (grazing, pests) across these hill country environments.

These issues have been addressed through years of New Zealand pastoral research, with well-recognised establishment and management techniques developed in the 1980s (e.g., Charlton and Giddens 1983, Rhodes and Clare 1983, Macfarlane and Bonish 1986). However, these seem to have been neglected in contemporary times. This study aims to demonstrate the relevance and effectiveness using these techniques in a targeted approach to legume introduction within a commercial farm system. Previous modelling has demonstrated the potential benefits of such an approach (Dodd et al. 2019) and this work aimed to validate that in the paddock. Specifically, we targeted the re-establishment of white clover on south aspects and rolling to-steep slopes where it would be well adapted, but existing legume content was low.

Approach

Four adjacent paddocks of 14–23 ha on Tangihanga Station, 20 km northwest of Gisborne (38.55°S, 177.88°E), were selected for a demonstration of white clover establishment and management at a paddock scale. At the site, the elevation ranged between 40 and120 m above sea level, mean annual maximum air temperature was 19°C, mean annual minimum air temperature was 9°C and mean annual rainfall was 1121 mm (NIWA, https://cliflo.niwa.co.nz/). The long-term mean rainfall minus potential evapo-transpiration (deficit) was 76 mm in December, 85 mm in January and 50 mm in February. The paddocks had 5–11 ha of southerly aspect and a range of slope classes from flat to steep. Soil tests had been undertaken on the southerly aspects of individual paddocks in November 2018 with the following means and standard errors of means (SEMs): Olsen P 16.4±1.4 mg/L, sulphate-S 9.8±2 mg/kg, pH 5.8±0.1, Quicktest K 6.8±1.2, Quicktest Ca 7.6±2.5 and Quicktest Mg 23.1±3.8. Resident pasture was surveyed in 2016 and comprised typically <1% legumes, 20–30% perennial ryegrass (*Lolium perenne* L.), 40–50% other grasses, <1% dicot weeds, 5–10% bare ground and 20–25% dead matter (Dodd et al. 2019).

Prior to oversowing on two of the paddocks, 40 permanent transects of 20 m length downslope were marked out in the four paddocks and the altitude of the upper and lower ends recorded with a geographic positioning system (GPS). Transects were assigned a slope class: rolling (8–15°, six transects), easy (16–25°, 24 transects) and steep (>25°, 10 transects). Each transect was used to assess the abundance of white clover by point analysis of presence/absence at 40 locations along a chain laid on the transect (i.e., every 0.5 m).

The time of sowing was selected as autumn, to minimise competition from resident grasses and moisture stress on developing seedlings (Charlton and Giddens 1983). Following the results of Macfarlane and Bonish (1986), the white clover introduction consisted of hard grazing with cattle to a residual of ~1200 kg dry matter (DM)/ha in April 2019, followed by aerial spray application of 1 L/ha of paraquat (250 g/L a.i. in 100 L/ha of water) to suppress grass regrowth. The paddocks were aerially oversown by helicopter with 6 kg/ha of white clover seed cv. Demand on 10 May 2019 and a mob of 900 ewes was used to trample in the seed, by mustering repeatedly across the paddocks with at least 10 passes. The cost of this establishment operation was $224/ha (detailed in Dodd et al. 2019).

In October 2019, and each May and October of the following 5 years, white clover abundance was re-measured on the same transects. In October each year, a bulk herbage sample was taken along each transect by harvesting 10–12 snip samples. These bulk samples were hand-dissected into white clover, perennial ryegrass, other grasses, other legumes and weeds, dried for 48 hours at 60°C and each component weighed to determine botanical composition by herbage mass. Pasture herbage mass at the time of spring sampling was measured with 20 readings along the transect using a capacitance probe and the standard calibration equation (herbage mass in kg DM/ha = 0.48C – 301, where C is capacitance reading, Grassmaster Pro, Novel Ways Ltd, https://www.novel.co.nz/). White clover herbage mass was calculated from % white clover in the separate herbage sample/100 × pasture herbage mass (kg DM/ha).

The paddocks were each divided into three blocks with temporary electric fences and management of the paddocks consisted solely of rotational grazing through the blocks, with mobs of either heifers (2019–2020), steers (2020–2021) or steers and lambs (2021–2023). Either steers or heifers were weighed going into the paddocks, twice each month in winter and monthly in spring, until leaving in early December (22–70 head depending on paddock and season). Lambs were

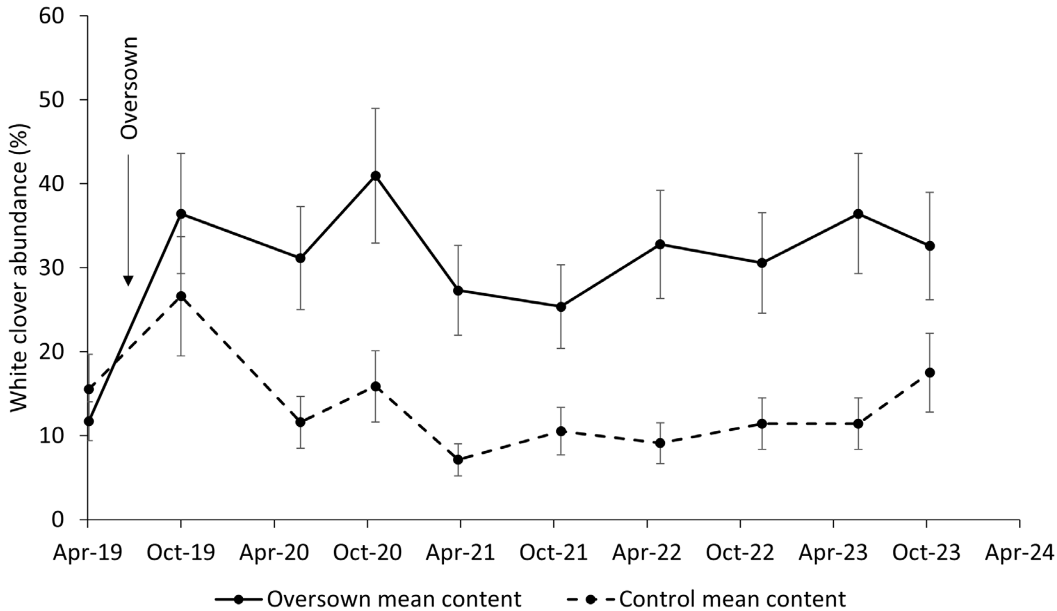

Figure 1 Mean white clover abundance (% by point analysis) in oversown and unsown (control) paddocks before and after sowing in May 2019. Bars represent standard errors of means.

weighed going into the paddocks in mid-December and on leaving in early March (80–460 head depending on paddock and season). An average per head liveweight was used for liveweight change calculations. For each paddock the total liveweight gain (LWG, kg) of each mob was calculated for the periods they were grazing on that paddock within each growing season (July–June).

Livestock revenue values were obtained from schedule prices received at the meat processor in October (heifers and steers), December (steers) and March (lambs) each year. These were converted to $/kg LWG assuming carcase dressing out values of 52% for cattle and 42% for sheep.

The oversowing operation was repeated with the same process on two additional adjacent paddocks in May 2022. In each of these paddocks, six identical fixed transects were established on south aspects. They were assessed for white clover abundance using the same method, prior to oversowing and in October and May of the subsequent 2 years.

The abundance (spring and autumn) and percent composition (spring) data were analysed in a repeated measures analysis of variance in Genstat statistical software (VSN International) https://vsni.co.uk/software/genstat/, including treatment (oversown/unsown), slope (mean slope of each transect) and time as main effects.

Results and Discussion

Oversowing increased mean white clover abundance at a paddock level from 10–15% in autumn 2019 to over 36% by the following spring and over 31% by the following autumn. The unsown paddocks also had increased white clover abundance in spring but maintained a similarly low abundance by the following autumn (12%, Figure 1). This differential persisted for the entire 5-year data record. The main effect of the oversowing treatment and its interaction over time were both significant ($P<0.01$).

The data on botanical composition in spring also showed an increase in white clover content of pasture herbage mass after oversowing, although the absolute % content amounts indicated were substantively lower than seen in the abundance data (Figure 2). The proportion of white clover in harvested herbage ranged from 8–16% over 4 years but was always significantly greater than in the unsown paddocks, at 2–5%. This quite large discrepancy in estimating white clover content raises legitimate questions about how to best estimate clover diet content in these complex mixed species pastures. The point-abundance values are likely over-estimates because of the structure of the white clover plant, presenting a large flat surface to the canopy. But it is also worth considering that the harvested mass values are potentially under-estimates of intake because of selective grazing by livestock. Diet selection studies suggest that cattle will consume 60–70% clover (Chapman et al. 1995) in contrast to the

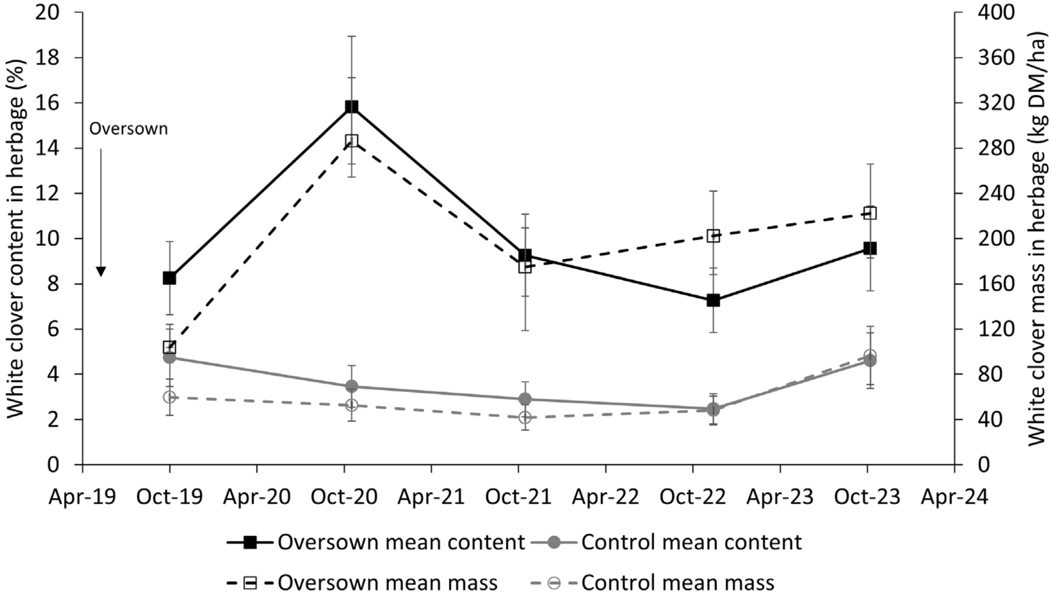

Figure 2 Mean white clover content, (% in cut herbage); and white clover mass (kg DM/ha in cut herbage), of oversown and unsown (control) paddocks in spring annually (October 2019 to October 2023) after sowing in May 2019. Bars represent standard errors of means.

sward content values of <20%.

The second oversowing of the additional two paddocks in 2022 resulted in an increase in white clover abundance from 12±2% (May 2022) to 51±4% (May 2023) for one paddock and from 15±5% (May 2022) to 53±4% (May 2023) for the other paddock, which demonstrates the repeatability of the establishment method across different years. In 2019, rainfall in May was 9 mm and mean daily temperature 13.5°C, while in 2022 rainfall in May was 56 mm and mean daily temperature 14°C.

The increase in abundance after the 2019 oversowing was evident across all the three main slope classes (Table 1). Prior to sowing, abundance was lower on steep slopes (ca. 9%), which persisted throughout on the unsown paddocks. However, abundance on oversown slopes ranged from 26–37% even on the steep slope class. Observations indicated that on the steep slope class, the additional white clover tended to occur on low slope microsites (e.g., tracks). This result demonstrates the effectiveness of the establishment method in lifting white clover abundance in difficult terrain.

The grazing management has likely also been critical in the successful maintenance of white clover after establishment. Rotational grazing within cattle-dominant systems has been shown to favour legume abundance (Lambert et al. 1986) through avoiding highly selective and/or hard grazing at critical times. This maintains a level of sward disturbance that checks the ability of grasses to out-compete white clover. In contrast, summer spelling of pastures without removal of rank growth before the end of summer can suppress clover content (Korte and Quilter 1990). It is important to note that poor white clover persistence using similar establishment methods was observed in the same region under sheep set-stocked in spring (Fraser et al. 2016).

The effect of increased white clover content and available dry matter (Figures 1 and 2) on livestock performance was quantified by the animal numbers and the difference in LWG between mobs on oversown and control paddocks. In the oversown paddocks there were 0.4–0.8 head/ha more heifers and steers in winter and spring, and 9–14 head/ha more lambs in summer in the oversown than resident pastures. Furthermore, LWG on oversown paddocks was 0.3–0.6 kg/head/day greater for heifers and steers in winter and 100–130 g/head/day greater for lambs in summer. This led to an overall mean LWG advantage for the oversown paddocks of 118 kg/ha in winter, 190 kg/ha in spring and 269 kg/ha in summer (Table 2). The total LWG advantage each year ranged between 67–169%. If the mean LWG (121%) was scaled up to the whole farm, based on the relevant slope/aspect proportion of the Tangihanga Station (23% in rolling to steep south, west and east aspects) the system-level increase would be 28%, only slightly less than that indicated previously in the modelling (32%, Dodd et al. 2019).

The livestock response is to be expected from a higher quality diet with greater white clover content (Chapman et al. 2017) but seems out of proportion to the estimated

Table 1 Mean white clover abundance (% by point analysis) by slope class in paddocks oversown or unsown with white clover. SED = standard error of difference.

		Pre-sowing		Post-sowing		
Slope class	Treatment	Autumn 2019	Autumn 2020	Autumn 2021	Autumn 2022	Autumn 2023
Rolling	Oversown	14.2	20.0	28.3	47.5	27.5
	Unsown	16.3	11.3	10.0	17.5	18.8
Easy	Oversown	12.2	32.4	27.5	31.9	37.9
	Unsown	19.6	15.7	8.6	11.1	13.2
Steep	Oversown	9.2	33.3	26.3	27.9	36.7
	Unsown	9.5	6.0	4.0	3.0	6.0
SED		7.0	8.0	8.5	11.7	11.1

Table 2 Liveweight gain advantage for oversown versus unsown paddocks for livestock mobs rotationally grazed in each season over 4 years. SEM = standard error of the mean

	Period		
Year	1 May–1 Oct	1 Oct–15 Dec	15 Dec–1 Mar
2019-20	98 (R2H[1])	116 (R2H)	
2020-21	153 (R2S[2])	218 (R2S)	
2021-22	110 (R2S)	207 (R2S)	205 (L[3])
2022-23	110 (R2S)	221 (R2S)	332 (L)
Mean±SEM	118±12	190±25	269±63

[1] R2H = rising 2-year heifers, [2] R2S = rising 2-year steers, [3] L = lambs

difference in white clover content of the herbage based on snip sampling (Figure 2). The single-measure and timing of the herbage sampling is likely to have failed to capture the longer-term effect on animal nutrition, but the relativity in white clover content between sown and unsown paddocks may be a better indicator (i.e., two to four-fold difference in clover herbage mass in sown paddocks, depending on year). More frequent snip sampling, focussed on grazing breaks immediately prior to grazing and during the grazing period would probably have given a more accurate measure of both sward and diet white clover content. For this study, demonstrating a significant difference in sward composition was considered sufficient evidence, given that animal performance was the most critical metric.

There were no additional livestock costs associated with the mobs in the oversown paddocks, hence the financial advantage is based on the difference in revenue received for the extra liveweight grown. Mean livestock values over the 4 years were $2.60/kg LW for heifers, $2.67/kg LW for steers and $2.90/kg LW for sheep. Therefore, the liveweight advantage resulted in additional revenue to the oversown paddocks of between $420–1960/ha/year, depending on year. This result is of a similar magnitude to that estimated by Rendel et al. (2017) using the AgInform® model in a Whanganui hill country farm system ($800–1600/ha/year). In the Tangihanga case, the initial cost of establishment was more than repaid in the first year alone.

It is also relevant to note that historically these paddocks had received approximately 46 kg N/ha/year in fertiliser, which was omitted during the period of the experiment, for an additional cost saving of $112/ha/year. This further enhances the value proposition of the white clover addition, although it is not possible to reliably estimate its contribution to N fixation in this case, as we have no robust calculation for the extra mass of white clover grown over a full year.

Conclusions

White clover can be successfully established and maintained in steep summer-dry hill country by attention to several key factors: 1) matching the species to the site – for white clover the south aspects which retain moisture through the summer-dry; 2) control of resident grasses prior to sowing with hard grazing and herbicide; 3) sowing in autumn (for warm North Island sites) once soil moisture has recovered after the summer-dry period; 4) trampling of seed after sowing with mob stocking; 5) control of resident grasses after sowing by maintaining moderate pasture covers; and 6) avoiding close continuous grazing by sheep to minimise selective grazing and promote persistence. This method is robust to being used in years with slightly different seasonal conditions. The resulting increase in white clover content of these pastures had a positive and lasting impact on liveweight gains and profitability, ensuring a highly favourable return on the initial investment.

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REFERENCES
Chapman DF, Macfarlane MJ. 1985. Chapter 3 in: Burgess RE and Brock JL (Eds). *Using Herbage Cultivars. Grassland Research and Practice Series 3*: 25-29. https://doi.org/10.33584/rps.3.1985.3318

Chapman DF, Mackay AD, Devantier BP, Costall DA, Budding PJ. 2017. The relative strengths of phosphate fertiliser application and white clover cultivar introduction for hill pasture improvement. *Journal of New Zealand Grasslands 79*: 19-26. https://doi.org/10.33584/jnzg.2017.79.544

Chapman DF, Parsons AJ, Schwinning S 1995. Management of clover in grazed pastures: expectations, limitations and opportunities. In: Woodfield DR (Ed). *White clover: New Zealand's competitive edge. Grassland Research and Practice Series 6*: 55-64. https://doi.org/10.33584/rps.6.1995

Charlton JFL, Giddens NG. 1983. Establishment of hill country white clover selections from oversowing. *Proceedings of the New Zealand Grassland Association 44*: 149-155. https://doi.org/10.33584/jnzg.1983.44.1618

Dodd MB, Tozer KT, Vogeler I, Greenfeld R, Stevens DR, Rhodes T, Quilter S. 2019. Quantifying the value proposition for white clover persistence on a New Zealand summer-dry hill-country farm. *Journal of New Zealand Grasslands 82*: 199-210. https://doi.org/10.33584/jnzg.2020.82.2973

Dodd MB, Sheath GW. 2003. Persistence: the key to legume performance in summer-dry hill country. In: Moot DJ (Ed). *Legumes for Dryland Pastures. Grassland Research and Practise Series 11*: 7380. https://doi.org/10.33584/rps.11.2003.2993

Dodd MB, Sheath GW, Wedderburn ME. Tarbotton IS. 2001. Long-term performance of white clover cultivars oversown into summer-dry hill country. *Proceedings of the New Zealand Grassland Association 63*: 8589.https://doi.org/10.33584/jnzg.2001.63.2435

Fraser TJ, Stevens DR, Scholfield RW, Nelson BJ, Nelson AJ, Shortland SM. 2016. Improved forages to enhance hill country sheep production. In: Thom, ER (Ed.). *Hill Country Symposium. Grassland Research and Practice Series No.16*: 225232. https://doi.org/10.33584/rps.16.2016

Korte CJ, Quilter SJ. 1990 Effects of summer grazing and fertiliser on the clover content of hill country swards in the Gisborne region. *Proceedings of the New Zealand Grassland Association 51*: 113-118. https://doi.org/10.33584/jnzg.1990.51.1927

Lambert MG (1976) Th einfluence of aspect on pasture environment. *Proceedings of the New Zealand Grassland Association 38*: 78-86. https://doi.org/10.33584/jnzg.1976.38.1472

Lambert MG, Clark DA, Grant DA, Costall DA. 1986. Influence of fertiliser and grazing management on North Island moist hill country 3. Performance of introduced and resident legumes. *New Zealand Journal of Agricultural Research 29*: 11-21. https://doi.org/10.1080/00288233.1986.10417969

Macfarlane MJ, Bonish PM. 1986. Oversowing white clover into cleared and unimproved north island hill country - the role of management, fertiliser, inoculation, pelleting and resident rhizobia. *Proceedings of the New Zealand Grassland Association 47*: 43-51. https://doi.org/10.33584/jnzg.1986.47.1746

Nolan T, Connolly J, Wachendorf M. 2001. Mixed grazing and climatic determinants of white clover (*Trifolium repens* L.) content in a permanent pasture. *Annals of Botany 88*: 713-724. https://doi.org/10.1006/anbo.2001.1493

Olykan ST, Lucas RJ, Nicholson DJ, Doscher C, Moot DJ (2019) Maximising the subterranean clover content on a summer-dry Wairarapa hill-country farm through grazing management. *Journal of New Zealand Grasslands 81*: 91-100. https://doi.org/10.33584/jnzg.2019.81.391

Rendel JM, Mackay AD. Smale PN. (2017) The value of legumes to a Whanganui hill country farm. *Journal of New Zealand Grasslands 79*: 35-41. https://doi.org/10.33584/jnzg.2017.79.555

Rhodes PJ, Clare RJ 1983. Legume oversowing on hill country in Marlborough. *Proceedings of the New Zealand Grassland Association 44*: 142-148. https://doi.org/10.33584/jnzg.1983.44.1617

Stewart A, Kerr G, Rowarth J, Stevens D. 2022. *Pasture and forage plants for New Zealand. Grassland Research and Practice Series No.8*. 5th Ed. New Zealand Grassland Assoc