Effect of modern red clover & nitrogen fertiliser on yield, quality and botanical composition of a hybrid ryegrass sward

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Abstract

The advantages to pasture quality and quantity using red clover in New Zealand farm systems is becoming more recognised. The performance of tetraploid hybrid ryegrass, with and without red clover, and with and without nitrogen fertiliser (276 kg N/ha/annum) was compared with a pure red clover stand in three replicated plot experiments, established in 2019 in the Manawatu, Canterbury and Southland provinces of New Zealand. This paper presents the combined multi-site analysis of treatment, season, and year, comparing dry matter (DM) production, composition and feed quality under a cutting regime for 3 years. Adding both red clover and fertiliser to hybrid ryegrass increased total dry matter production, metabolizable energy and crude protein concentration of the pasture. Hybrid ryegrass without fertiliser yielded 24,660 kg DM/ha over three years, while the addition of red clover or nitrogen fertiliser separately increased total yield ($p<0.001$) by 18,180 and 14,850 kg DM/ha respectively. When combined, yield was increased ($p<0.001$) by 23,340 kg DM/ha. Fertiliser use and season had a significant effect ($p<0.001$) on the red clover percentage of the pasture. While fertiliser use decreased the percentage contribution of the clover to total yield, total yield was increased from additional grass growth particularly in late spring and summer and additional red clover growth in summer. The addition of red clover in pasture significantly increased overall and seasonal production regardless of fertiliser practice. Maintaining fertiliser contributed to a balanced feed curve with high total production and benefiting the autumn-winter production phase.

Keywords: red clover, legumes, lolium hybridium, nitrogen

Introduction

Nitrogen fertiliser and legumes have played a significant part in the recent development of New Zealand agriculture (Barr 1995, Caradus et al. 2021, Journeaux et al. 2019, Moot 2023). Much of the understanding stems from research predominantly on ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) mixed pastures (Gray 2023). However, the interaction between nitrogen (N) fertiliser and modern red clover (*Trifolium pratense*) genetics is lacking research in a New Zealand context (Gray 2023). An extensive review paper by Gray (2023) highlighted the many studies investigating the interaction between the application of N fertiliser and the proportion and production of white clover but failed to identify research examining red clover as the legume.

Red clover use in pastures declined due to persistence issues (Harris and Hoglund 1977, Brougham 1959, Brougham 1960, Cosgrove and Brougham 1985, Hume et al. 1995), often linked to grazing management (Cosgrove and Brougham 1985). However, with the improved persistence, production and lower formononetin levels of modern red clover cultivars (Ford and Barrett 2011), the potential value it can add to cut and carry silage (O'Kiely et al. 2006, Clavin et al. 2016), or grazed systems (Black et al. 2009, Smith et al. 2022) is significant. Red clover has a deep tap root, the ability to fix atmospheric nitrogen, and provides moderate drought tolerance and high yields (Brown et al. 2003). In addition, red clover offers an increase in feed quality when used in a mixed grass/legume pasture, especially during summer, where maintaining pasture quality can be challenging (Ryan-Salter and Black 2012).

With the inflating cost of imported feed on farm, home-grown feed systems are still the cornerstone of efficient New Zealand feed systems (Caradus et al. 2021, DairyNZ 2019). In July 2021, the government introduced a 190 kg N/ha cap for applying synthetic nitrogen fertiliser for land grazed by livestock under the Essential Freshwater package (Ministry for the Environment 2023). This has increased interest in alternative ways to increase pasture growth and quality, by increasing legume competitiveness with high performance ryegrasses. Conserved feed remains an important part of New Zealand farming systems, with the need for high quality feed resulting in favouring the production of high-quality pasture silage over traditional hay production (Murray 1960, DairyNZ 2023).

Red clover has higher yields in late spring and summer, but lower winter growth (Keenan et al. 2023).

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It has a more erect growth than white clover increasing its competitive ability when sown with grasses (Black et al. 2009). These characteristics make it suitable for cut and carry, and silage-based systems. Cutting systems are typically on longer rounds and more lax than a typical dairy rotation and don't have the same selective grazing pressures of a set-stocked sheep pasture, which red clover can prefer (Cosgrove and Brougham 1985, Black et al. 2009). This leads to the question of whether red clover will be a suitable companion and able to compete and contribute to yield when mixed with hybrid ryegrass (*Lolium hybridium*), especially those used in a cut and carry system.

This research hypothesises that red clover will increase both herbage production and feed quality when combined with hybrid ryegrass. We also hypothesise that red clover production in a mixed pasture will continue to contribute significantly when N fertiliser is added.

Materials and Methods

Site description and design

A four-replicate randomised complete block experiment was established in 2019 at three sites (Manawatu sown 15/3/2019; Canterbury sown 21/2/2019; Southland sown 23/12/2019; Table 1). This paper tests the effects of adding red clover (cultivar Relish) and nitrogen fertiliser on the yield, quality, and botanical composition of a tetraploid hybrid ryegrass pasture sward (cultivar Mohaka AR37). Each experiment ran for 3 years. This project assessed five treatments:

1. Hybrid ryegrass without fertiliser (H)
2. Hybrid ryegrass with fertiliser (H+F)
3. Hybrid ryegrass + red clover without fertiliser (H+RC)
4. Hybrid ryegrass + red clover with fertiliser (H+RC+F)
5. Red clover without fertiliser (RC)

Each site had 200 kg/ha DAP broadcast by a hand spinner at the time of drilling, after which no fertiliser was applied to the sites except for the two with fertiliser treatments. The fertiliser treatments (+F) were applied by hand to the individual plots of the +F treatments and consisted of six applications of 46 kg N/ha, totally 276 kg N/ha per year. Applications included one of 128 kg/ha SustainN Ammo 36N (36% Nitrogen; 9% Sulphur) in September, followed by four applications of 100 kg/ha Urea (46% Nitrogen) from October to February and an autumn application of 263 kg/ha di-ammonium phosphate (DAP; 17.6% Nitrogen; 20% Phosphate; 1% Sulphur). The rate was considered as mid to high input for grazed systems averaged across the three regions (Chapman et al. 2018b), but with consideration for the cut and carry forage system.

The straight tetraploid hybrid ryegrass treatments (H+F and H) were sown at 28 kg/ha; the red clover mixes (H+RC and H+RC+F) were sown at 20 kg/ha tetraploid hybrid ryegrass and 8 kg/ha red clover, the straight red clover (RC) treatment was sown at 10 kg/ha. Bare, untreated seed was used for all treatments. Plot size was 1.5m wide and ranged from 4.5m long to 5.5m long, depending on location. The sites were drilled using a plot cone disc drill, with a randomised complete block layout, into a cultivated stale seedbed. Sites were chosen that had prior been in a crop (not a grass-to-grass rotation) and not taken for hay in recent years while in pasture.

At the start of the experiment, a baseline soil test was taken at each site to identify the key nutrient status of pH, OlsenP, potentially available nitrogen (PAN), and anaerobically mineralizable nitrogen (AMN) (Table 1). Annual soil testing was carried out, with eight cores collected from each treatment to 150mm prior to autumn fertiliser application. All soil testing was analysed by Hill Laboratories.

Weed control was as required to keep weed burdens lower than 5%. Weeds were mainly broadleaf, removing any legume out of straight grass treatments and any grass out of the straight clover plots. Some hand-rogueing was done for harder to control weeds such a dock (*Rumex obtusifolius*) and catsear (*Hypochaeris radicata*).

For the Canterbury site, regular irrigation scheduling occurred throughout the spring/summer period, with 10mm being applied every 2.5-3 days as required.

Measurements

Plots were assessed for plant establishment eight weeks after planting by a visual row integrity score from 1 – 9. Successful establishment was achieved at all sites and treatments and defined by an average of 90% or greater of the sown species. All sites were managed using a cut and carry system. Yield measurements were taken when the average yield was approximately 3,000 kg DM/ha across the trial or within 40 days of the previous measurement over the summer period (whichever occurred first). The measurement period was from the first winter post establishment (June) and ran for 3 years. A 45 cm rotary mower strip was cut the length of each plot to an approximately 1,500 kg DM/ha residual or around 4 cm mower height. The cut samples were weighed for fresh weight. Sub-samples were taken to determine dry matter percentage and oven dried at 90 degrees for at least 48 hours or until dry. Remaining herbage was removed using a mower. Quality and botanical samples were taken four times per year, approximately in the middle of every season (winter, spring, summer and autumn). Representative

Table 1 Site description and starting soil tests (to 150mm depth) from the three trial site locations: Manawatu; Canterbury and Southland. Long term mean (LTM = 1991-2020), during trial 2019-2021. Source: NIWA

			Manawatu	Canterbury	Southland
Site description			Rainfed	Irrigated	Rainfed
Latitude: Longitude			40.08S, 175.6E	42.71S, 172.893E	45.851S, 168.658E
Rainfall (mm/ annum)	LTM (1991-2020)		940	584	919
	During trial: 2019		813	410	516
	2020		560	506	886
	2021		1166	468	725
Av. Daily air temperature (°C) LTM		July	8.8	5.6	4.8
		January	18	17	14.5
Soil Type			Mafic Brown	Orthic Recent	Yellow Ultic
Starting Soil test					
	pH		5.7	6.0	5.5
	OlsenP (mg/L)		29	37	25
	Potentially Available Nitrogen(kg/ha)		160	134	177
	Anaerobically Mineralizable Nitrogen (μg/g)		96	87	139

samples of two 30cm rows per plot, were cut with hand shears to the same height as the mower residual. Quality samples were bagged and sent directly for analysis by Hill Laboratories, mixed pasture plant analysis by NIR. Botanical samples were hand separated into sown species and weeds, oven dried at 90 degrees for at least 48 hours or until dry and weighed to determine the contribution to yield of the various categories.

Statistical analysis

Each site was analysed both individually and as a multi-site analysis looking at the effect of treatment on yield, quality and botanical composition tested by ANOVA (Genstat 22nd edition). Significant means were separated by Fisher's protected least significant difference (LSD) at the 5% level. Treatments, Years, Seasons (winter, early spring, late spring, summer, and autumn), Sites and their interactions were considered as fixed effects. The five seasons were defined using that of the Dairy NZ Forage value index (Chapman et al. 2012). This paper presents the combined overall multisite analysis of treatment, season, and year.

Results and Discussion

Regional average annual yields

The air temperature at all sites was between 0.5-0.8 degrees greater than the annual long term mean (LTM; Table 1). Manawatu had two drier and one wetter than average year. Canterbury and Southland were both drier than the LTM rainfall for the period of the trial, although the impact of the dry for Canterbury was buffered by the site being irrigated. Further site by treatment and season interactions are not included in this paper.

The highest average total yield was achieved at the Canterbury site, followed by the Manawatu and Southland with an average total yield of 15280, 13380 and 10190 kg DM/ha/year ($p<0.001$; Table 2). The highest yield at all sites was from the H+RC+F treatment, and the lowest the H treatment. At the Manawatu site adding red clover (H+RC) increased yield by more than adding N fertiliser alone (H+F) (Table 2) and was similar in yield to adding both red clover and nitrogen fertiliser (H+RC+F). Manawatu experienced two prolonged summer dry periods where fertiliser would likely have minimal impact. For Canterbury, adding N fertiliser and red clover (H+RC+F) created a significant benefit over the separate addition of either red clover or fertiliser ($p<0.001$; H+RC and H+F). In Southland, the addition red clover and fertiliser separately (H+RC and H+F) or together (H+RC+F) were non-significantly different. The monoculture of red clover (RC) yielded significantly ($p<0.001$) more than the hybrid ryegrass monoculture (H) at all sites, and non-significantly different from H+RC and H+F treatment at all sites.

Seasonal and yearly yield treatment effects

The use of red clover and or nitrogen fertiliser was effective at significantly increasing the seasonal (Figure 2) and annual dry matter production (Figure 1 and Table 3; $p<0.001$) compared to the monoculture hybrid ryegrass (H). The addition of red clover and nitrogen fertiliser (H+RC+F) resulted in the highest average

Table 2 Total annual yield (kg DM/ha), mean of 3 years for Manawatu, Canterbury, Southland.

Treatment	Manawatu	Canterbury	Southland
H + RC + F	16560[a]	19190[a]	12260[a]
H + RC	15460[ab]	16200[b]	11170[ab]
H + F	12190[c]	16010[b]	11300[ab]
H	8670[d]	10030[c]	5970[c]
RC	14000[bc]	14980[b]	10250[b]
Mean	13380	15280	10190
sig	***	***	***
LSD	1950	1380	1718

Letters that are the same are not significantly different within their individual site (column). LSD = Fisher's protected least significant difference test. *** = p < 0.001

Table 3 Mean seasonal and annual yield (kg DM/ha) from three years across three locations

Treatment	Winter	Early spring	Late spring	Summer	Autumn	Annual
H + RC + F	1196[a]	1776[a]	4548[a]	5987[a]	2471[a]	16000[a]
H + RC	932[b]	1779[a]	3738[b]	5837[a]	1974[c]	14280[b]
H + F	1156[a]	1400[b]	3763[b]	4631[b]	2195[b]	13170[c]
H	828[c]	998[c]	1944[c]	3057[c]	1385[d]	8220[d]
RC	380[d]	1523[b]	3847[b]	5877[a]	1431[d]	13080[c]
Mean	898	1495	3568	5078	1891	12950
sig	***	***	***	***	***	***
LSD	100	125	290	475	183	980

Letters that are the same are not significantly different within their Season (column). LSD = Fisher's protected least significant difference test. *** = p < 0.001

total yield (16,000 kg DM/ha/ annum; Table 3), across all three individual years of measurement (Figure 1), and significantly more than all other treatments in late spring and autumn (Table 3, Figure 2).

From the multi-site analysis, the highest producing treatment (H+RC+F) produced 7,780 kg DM/ha/ annum more than the lowest producing treatment (H) per year. Over the three-year period, this difference accumulates to 23,340 kg DM, approximately doubling yield.

Nitrogen fertiliser addition increased dry matter production by 4,950 kg DM/ha/ annum (Table 3; $p<0.001$) when red clover was excluded. This is an average response rate of 18:1 per unit of N applied. This response is at the high end of the range summarised by Gray (2023).

The findings from Ball and Field (1985) that a grass/clover pasture could produce herbage DM yield equivalent to a ryegrass monoculture pasture that received 300-600 kg/ha/year of N fertiliser, could seem feasible when comparing our results and looking at the performance of H+F, which had the 276 kg of nitrogen fertiliser per hectare per year, compared to the H+RC. H+RC produced significantly more total yield for year 2 and 3 (Figure 1) and the mean total yield of 3 years (Table 3) with no additional fertiliser after drilling. Including red clover in the pasture sward (without the inclusion of nitrogen fertiliser) increased yield by 6,060 kg DM/ha/annum, or 73%, for the H+RC treatment compared to the H treatment. Ryan-Salter et al. (2012) measured a 41% advantage in a one-year trial in Canterbury, when red clover was included with Italian ryegrass. When examining the comparable data from year 1 (Figure 1), the measured 4.7 t DM/ha was similar to the 4 t DM/ha advantage measured by Ryan-Salter et al. (2012).

Adding nitrogen fertiliser and red clover (H+RC+F) increased total yield by a further 1,720 kg DM/ha/ annum above the H+RC mix. For this mixed pasture, there was a response rate of 6.5:1 per unit of N applied, which was lower than the response of using N fertiliser alone. This lower apparent N response rate from a grass/clover mix rather than a grass monoculture is consistent to findings from a Canterbury trial (Chapman et al. 2018c) where grass monoculture plus fertiliser

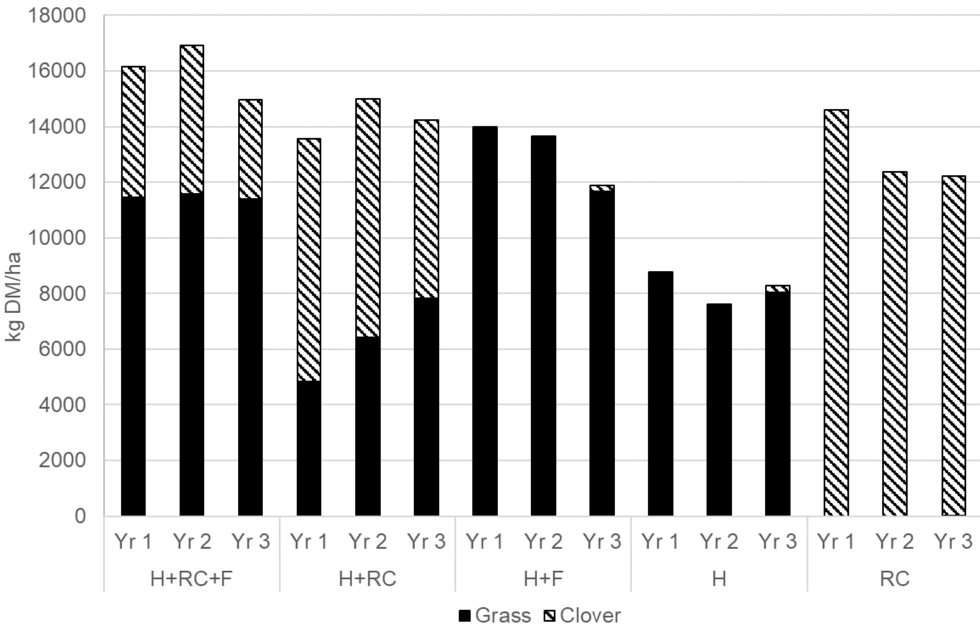

Figure 1 Multi-site treatment annual total yields (Year 1, 2 and 3) and botanical breakdown of clover and grass contributions to yield (solid black = sown grass yield and dashed black = clover yield). Least significant difference (LSD) for total yield = 906.

treatments responded at 18.9 kg DM/kg N compared with 6.2 kg DM/kg N in grass/clover mixtures. A multi-site analysis (Chapman et al. 2018a) calculated that compared to a grass monoculture, a grass/clover mix produced an additional 2400 kg DM/ha/annum in the low-N treatment and an additional 1200 kg DM/ ha/ annum in the high-N treatment. This demonstrates the buffering ability of the species mix compared to N application to a monoculture. When compared with the ryegrass/white clover results of Chapman et al. (2018a) the added production provided by red clover of over 6000 kg DM/ha/annum was much greater in the current study.

An international literature review of the management of white and red clover (Black et al. 2009) found that nitrogen fertilizer had little impact on the production of a red clover monoculture, although may increase the weed grass component and reduce the red clover content of the stand (Frame et al. 1976). It has also been reported that the effect of applying N fertiliser to grass/ red clover mixes on the legume component is similar to that for grass/white clover swards (O'Kiely et al. 2006). Gray (2023) reported that generally, the application of N fertiliser reduced the proportion of white clover in grass/clover pastures (Lambert et al. 2012, Chapman et al. 2018a). However, Smith et al. (2000) did not see a reduction of clover from the addition of 50 kg N/ha in autumn or spring, although those nitrogen applications were much smaller than these reported here.

The addition of fertiliser (H+RC+F) reduced the red clover content as a percentage contribution to the yield compared to the H+RC treatment (Figure 1). This was from an increase in the competitiveness of the grass. Grass yield remained constant over the three years in the H+RC+F treatment, while annual yield fluctuations were due to changing clover yields, increasing from year 1 to year 2 and then decreasing in year 3 (Figure 1). The grass contribution in the H+RC treatment showed a different trend, increasing from year 1 to year 3, while clover yields slightly declined. Morton and Stevens (2023) reported reductions of white clover in the pasture sward with high amounts of N fertiliser. White clover was 15% for the control, dropped to 2% when 200 kg N/ha/year or more was applied. In our experiment, with the addition of N fertiliser, while legume yield did decline, the competitive nature of red clover meant that the actual amount of legume was still substantial, and these amounts may still pose bloat risks in cattle systems.

The two monocultures without fertiliser (H and RC) show the productivity differences of the species when without fertiliser inputs. The total yield of red clover declined from year 1 to year 2, then stabilised for year 3 (Figure 1). The straight hybrid ryegrass with no fertiliser (H) was consistently the lowest yielding treatment, and the annual total yield was not significantly different

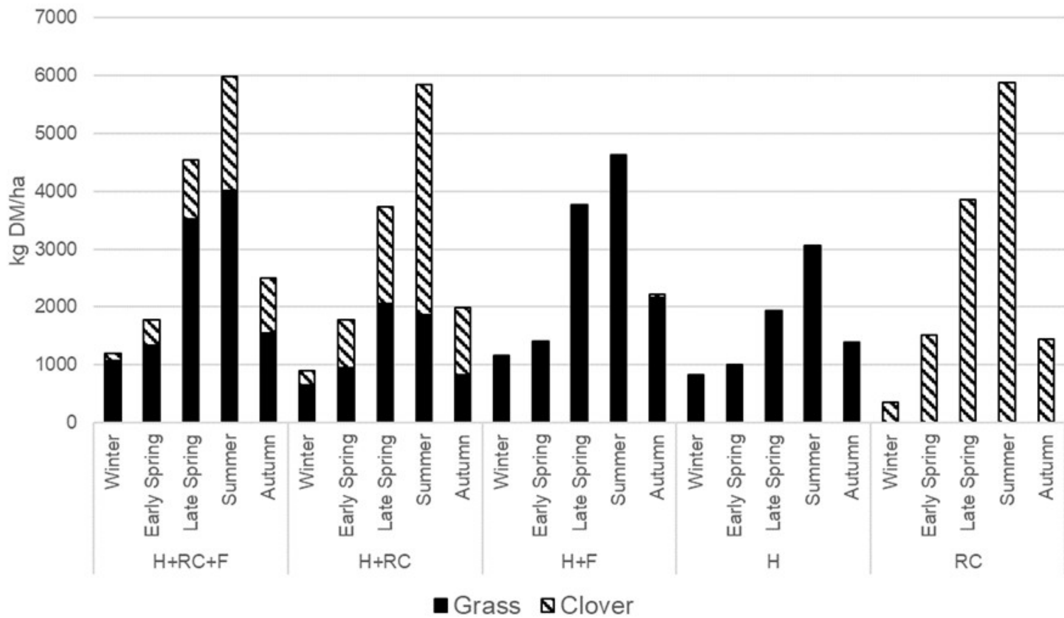

Figure 2 Multi-site seasonal yields and botanical contribution of clover and grass to total yields averaged from three years of data (solid black = sown grass yield and dashed black = clover yield). Least significant difference (LSD) for total yield = 996.

between years (Figure 1). The seasonal growth of the red clover monoculture (RC) was similar to that reported by Keenan et al. (2023) with increasing growth in spring to peak in summer, before declining in autumn to near no growth in winter. The straight grass monoculture without fertiliser (H) follows the expected growth curve (Easton et al. 1997), similar to the H+F treatment but with lower seasonal totals (Figure 2). The red clover monoculture and including red clover in the grass mix increased the summer benefit over the grass monoculture (H and H+F). Ryan-Salter and Black (2012) suggested possible explanations of the ability of red clover to source both soil mineral N and fixed N (Harris 2001), the complementary growth between the two species (Harris 2001), greater access to soil moisture (Brown et al. 2003) more efficient water use (Moot et al. 2008), and greater light capture (Black, et al. 2009). Our results can support some of these possible mechanisms. The ability of red clover to source nitrogen and the complementary growth between species is shown in that with or without fertiliser, treatments with red clover grew more total yield than their equivalent without red clover (Table 3). There is superiority of red clover growth during summer (Table 3, Figure 2), so this could demonstrate the suggested greater access to soil moisture and water use efficiency.

The results under grazed systems could be different, although the improvement in red clover persistence shown by Ford and Barrett (2011) has been observed in this study. Not only has the RC monoculture treatment performed strongly for all 3 years in each location but the proportions of red clover in the pasture sward have remained strong in year 3. While the use of this type of cut and carry system in a farm sense is more typical for silage systems, the timing for the measurements also could be in keeping with approximate grazing rounds. Our methodology had a harvest protocol more typical to rotationally grazed pasture, than what can often be seen in northern hemisphere silage systems where cut and carry silage cuts typically take around 4 or 5 large harvests per year (Black et al. 2009, Clavin et al. 2016). Our sites had 9 harvests per year on average, with cover aiming for an average 3000 kg DM/ha or 40 days over summer, whichever came first. This methodology meant there were not excessively long periods where the clover could be shaded, with yield measurements taken when the average yield was approximately 3,000 kg DM/ha across the trial or within 40 days of the previous measurement over the summer period (whichever occurred first).

Farmers considering adding a modern red clover cultivar as a legume for hybrid ryegrass pastures could have yield and quality and seasonal growth benefits, but it would also be important to consider strategic use of fertiliser to maintain a balanced pasture composition. Farmers also need to have awareness of the lower growth phases in winter for colder regions, and potential suppression of winter ryegrass growth in legume dominated pastures. Stevens and McCorkindale (2002) found that pasture yields could be reduced in

Table 4 Seasonal metabolizable energy (ME MJ/kg DM), crude protein (CP g/100 g DM), nitrogen percentage (N g/100 g DM) and dry matter (DM) production (kg DM/ha) of the treatments. Means with different superscripts within a season column are significantly different.

Season	Treatment	ME	CP (g/100g DM)	N (g/100g DM)	DM harvested[1] (kg DM/ha)
Winter	**H**	10.8	19.6	3.0	570
	H + F	10.6	20.5	3.2	1240
	H + RC	10.7	27.2	4.2	980
	H + RC + F	10.6	23.8	3.7	1440
	RC	-	-	-	-
	Tmt sig	NS	NS	NS	NS
	LSD	11.6	30.6	4.7	1160
Spring	**H**	10.8^{c}	17.1^{c}	2.6^{c}	820^{b}
	H + F	11.2^{b}	18.1^{c}	2.7^{c}	1440^{a}
	H + RC	11.2^{b}	23.5^{b}	3.6^{b}	1740^{a}
	H + RC + F	11.3^{b}	22.2^{b}	3.4^{b}	1900^{a}
	RC	11.5^{a}	30.2^{a}	4.6^{a}	1610^{a}
	Tmt sig	***	***	***	**
	LSD	0.21	2.1	0.33	480
Summer	**H**	10.4	16.0^{c}	3.0^{b}	980^{b}
	H + F	10.5	17.5^{c}	3.4^{b}	1610^{ab}
	H + RC	10.6	23.3^{a}	4.0^{a}	2290^{a}
	H + RC + F	10.6	20.8^{b}	4.0^{a}	2250^{a}
	RC	10.8	25.0^{a}	4.4^{a}	2280^{a}
	Tmt sig	NS	***	***	**
	LSD	0.38	1.9	0.36	650
Autumn	**H**	10.3^{b}	19.7^{b}	2.5^{c}	920^{c}
	H + F	10.6^{ab}	22.4^{b}	2.5^{c}	1370^{b}
	H + RC	10.6^{ab}	26.4^{a}	3.6^{a}	1370^{b}
	H + RC + F	10.8^{a}	26.2^{a}	3.1^{b}	1650^{a}
	RC	10.8^{a}	28.7^{a}	3.8^{a}	1110^{c}
	Tmt sig	*	***	***	***
	LSD	0.44	3.0	0.44	250

[1]Dry matter harvested corresponds to the direct harvest the samples were taken from, not for the entire season.

the presence of high Caucasian clover yields. While modern red clover genetics such as the cultivar "Relish" used in this work have been heavily tested, bred and evaluated under grazing by a range of stock classes (Ford and Barrett 2011), other cultivars could perform differently, and have different formononetin content which could also impact animal performance. Additional work may be needed as some report that the competitive advantage of red clover in grass mixes over white clover can be lost in grazed systems (Black et al. 2009), and mainly when grazing in winter where crown damage and subsequent fungal infection could occur (Hay and Ryan 1989).

Forage Quality

Adding red clover or nitrogen fertiliser to a hybrid ryegrass sward improved pasture quality. The proportion of red clover in the sward increased crude protein percentage (CP%), in all seasons except for winter (Table 4), when growth of red clover was minimal (Figure 2; Table 3).

In the spring and autumn, metabolizable energy (ME) significantly increased by adding red clover and/or nitrogen fertiliser compared to grass alone (Table 4). However, red clover is also needed to increase the CP% of the pasture as the addition of nitrogen fertiliser increased grass growth rather than CP%. This trend is followed through into the summer and autumn with CP% significantly higher in all treatments containing red clover compared to treatments without red clover when looking at CP%. Summer metabolizable energy concentration did not significantly increase when nitrogen fertiliser or red clover was added (Table 4).

The high CP% values with the clover treatments (Table 4) are of note because they are also some of the highest yielding treatments. Ryan-Salter and Black (2012) showed examples of the high forage quality from an Italian ryegrass/red clover mixed pasture (17.5% CP and 11.3 MJ/ kg DM ME) over a 12-month period, with the CP 1-2% higher ($p<0.001$) than an Italian ryegrass monoculture. Our experiment showed that while total herbage was highest in the H+RC+F treatment, this treatment did have lower clover than the treatment without fertiliser (H+RC), but still could be considered optimal for total production, and maintained forage quality in most seasons and annually.

Soil fertility

This type of cut and carry trial design is known to deplete soil nutrients. To provide some general comment and discussion to ensure the treatments and yields presented in this paper are interpreted correctly, bulked samples used to monitor soil fertility are presented but not statistically analysed. For general farm practices withholding fertiliser is not recommended. While some large yields have been achieved from adding red clover to a hybrid ryegrass, it is important to understand the impact of having a cut and carry system when replacement nutrient wasn't applied. A final soil test was taken from each treatment at each site and the reduction in soil fertility from the treatments that received no fertiliser was large.

Average soil pH of the sites at the beginning of the experiments was 5.7. After three years pH change varied by +/- 0.2 units across all 3 sites and treatments. Average OlsenP was 30 mg/L at the beginning of the experiments, with a change that ranged from a 1 unit increase in the H+RC+F treatment to a 13.7 unit decrease in the H+RC treatment. The largest reduction that was observed was the H+RC treatment, where the mean starting pH was 5.7 and the OlsenP was 30 (Table 1). By the end of 3 years the pH had increased to 5.8 and the OlsenP had dropped to 16.3 in this treatment. This highlights the nutrient loss when large amounts of forage are harvested, which needs to be replaced to maintain soil fertility. It must be noted that +F treatments received phosphorus fertiliser as DAP at the autumn N application, explaining the lack of OlsenP reduction in those treatments.

Table 5 Change in pH & OlsenP for each treatment (mean of 3 sites)

Treatment	Av. pH change	Av. OlsenP change
H	↑ 0.2	↓ 7.7
H+F	↓ 0.2	↑ 7.3
H+RC	↑ 0.1	↓ 13.7
H+RC+F	↓ 0.1	↑ 1
RC	↓ 0.1	↓ 10.5

Conclusion

The inclusion of modern red clover genetics, such as the cultivar Relish, to a hybrid ryegrass pasture significantly increased annual and seasonal productivity and quality compared to hybrid ryegrass alone. Addition of nitrogen fertiliser significantly affected the proportions of red clover in a hybrid ryegrass pasture. However, even in a system that is utilising large amounts of nitrogen fertiliser (in this study 276kgN/ha/ annum), addition of red clover can increase both yield and quality in the pasture sward. It has also reinforced that using nitrogen fertiliser in pasture systems, regardless of the presence of legumes, can increase both nutritional value and quantity of pastures. Farmers need to understand what they are aiming for in their pasture mix when deciding to use red clover and fertiliser in their grass mix. There could be the chance that the pasture mix could become legume dominant, which may result in grass suppression, changing the balance of seasonal production.

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