

Comparison of a herbal ley with a ryegrass-white clover pasture and pure ryegrass sward receiving fertiliser nitrogen

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Abstract

This paper compares a herbal ley (of particular interest to farmers involved in the 'organic' branch of agriculture) with a conventional pasture (ryegrass-white clover) and a more intensive system (pure ryegrass receiving 400 kg fertiliser N/ha/yr) in a study lasting 2 years. The herbal ley seeds mixture was prepared following the pioneering ideas of Robert Elliot in his "Clifton Park" mixture, which basically included a group of 'non-aggressive' grasses, forage legumes and herbs. Pasture production (average of 2 years) from Herbal ley was 15 t DM/ha/yr, representing approximately 90% of the yield from the intensively managed pure ryegrass pasture receiving 400 kg N/ha/yr and some 2530% more than from ryegrass-clover. A major feature of the herbal ley was substantial production during late spring and summer, when chicory (the most dominant herb), and red clover and white clover made a major contribution to herbage yield. In winter the total yield was similar to that from the grass-clover pasture. Legume content was 23 and 3% (averaged over the year) for Grass-clover and Herbal ley pastures respectively. In spite of this difference, symbiotic N fixation was similar. So fixation efficiency on a legume yield basis was 50.3 and 3.16 kg N fixed/t legume DM harvested, respectively. These results could reflect a different pattern of utilisation of soil N, as a consequence of the different botanical composition of the swards.

In summary, the performance of the herbal ley offers the promise of an alternative, 'specialist' pasture and would be highly beneficial if quality feed is required in summer.

Keywords herbal ley, biological fertility, nitrogen, symbiotic nitrogen fixation, pasture mixtures

Introduction

Herbage production from developed grassland in temperate regions has largely followed two different

approaches. One represents the age-old philosophy of grassland systems based on forage legumes (principally white clover) as the main source of the inputs of nitrogen (N) required to sustain pasture production. The other reflects a relatively recent technology, now well established in European and American grasslands, in which production is based largely on perennial grasses with large fertiliser applications, particularly N, and intensive management practices to support high levels of livestock production. In recent years, with increasing interest in organic agriculture, the old practice of including forage herbs in pastures has emerged as an appealing variant to current approaches.

In this study different swards representing the three approaches outlined above were established. During 2 years, their agronomic performance (periodically mob-stocked by sheep) was assessed in terms of pasture production, dynamics of botanical composition, and N flux through the herbage yield. An effort was also made to understand better the efficiency of N utilisation by the three systems from either fertiliser N or symbiotic N fixation.

Materials and Methods

This study was carried out at DSIR Grasslands, Palmerston North, from January 1989 to May 1991 on a Manawatu sandy loam soil (recent alluvial).

The experiment consisted of three treatments: (Table 1)

1. Perennial ryegrass-white clover pasture (conventional NZ system).
2. Herbal ley pasture (modified 'Clifton Park' mixture; Foster 1988).
3. Perennial ryegrass+N400 pasture (pure grass sward receiving 400 kg N/ha/yr as urea split into 8 dressings).

The experimental swards were sown in autumn 1989, treatments were replicated 4 times and arranged in a randomised, complete block design. The area of each plot was 200 m².

Table 1 Pasture seeds mixtures and rates of sowing for the Grass-clover, Herbal ley and Grass+N400.

Species / Cultivars		kg / ha	
(1) GRASS-CLOVER SYSTEM			
<i>Trifolium repens</i> L.	'Grasslands Huia '	3	(white clover)
<i>Lolium perenne</i> L.	'Grasslands Nul'	5	(perennial ryegrass)
<i>Lolium perenne</i> L.	'Yatsyn'	5	(perennial ryegrass)
<i>Lolium (perenne x multiflorum) x perenne</i>	'Grasslands Marsden '	10	(perennial ryegrass)
	Total	23	
(2) HERBAL LEY SYSTEM (Modified Clifton Park mixture)			
<i>Dactylis glomerata</i> L.	'Grasslands Kara'	3	(cocksfoot)
<i>Holcus lanatus</i> L.	'Massey Basyn '	2	(Yorkshire fog)
<i>Festuca pratensis</i> Huds.	'Aber S 53'	1	(meadow fescue)
<i>Phalaris aquatica</i> L.	'Grasslands Maru '	2	(phalaris)
<i>Festuca arundinacea</i> Shreb.	'Grasslands Roa'	3	(tall fescue)
<i>Poa trivialis</i> L.		0.5	(rough-s. meadow grass)
<i>Bromus willdenowii</i> Kunth.	'Grasslands Matua'	5	(prairie grass)
<i>Lolium perenne x multiflorum</i>	'Grasslands Manawa'	2	(short rot. ryegrass)
<i>Lolium multiflorum</i> Lam.	'Grasslands Tama '	2	(tetraploid ryegrass)
<i>Cynosururus cristatus</i> L.		1	(crested dogstail)
<i>Phleum pratense</i> L.	'Grasslands Kahu'	2	(timothy)
<i>Trifolium repens</i> L.	'Grasslands Tahora'		(white clover)
<i>Trifolium repens</i> L.	'Grasslands Hula'	1	(white clover)
<i>Trifolium repens</i> L.	'Grasslands Pitau'	1	(white clover)
<i>Trifolium pratense</i> L.	'Grasslands Pawera '	1	(red clover)
<i>Trifolium pratense</i> L.	'Grasslands Hamua'	1	(red clover)
<i>Lotus corniculatus</i> L.	'G32'	1	
<i>Lotus pedunculatus</i> Cav.	'Grasslands Maku'	2	
<i>Cornilla varia</i>	' G34 '	1	(crown vetch)
<i>Medicago sativa</i> L.	'Grasslands Oranga'	1	(lucerne)
<i>Hedysarum coronarium</i>	'Aokau'	2	(sulla)
<i>Cichorium intybus</i>	'Grasslands Puna'	1	(chicory)
<i>Sanguisorba minor</i>		3	(sheep's burnet)
<i>Plantago lanceolata</i>		1	(ribgrass)
<i>Achillea mille folium</i>		0.5	(yarrow)
<i>Onobrychis viciifolia</i>	' Fakir '	6	(sainfoin)
	Total	47	
(3) GRASS + N400 SYSTEM			
<i>Lolium perenne</i> L.	'Grasslands Nui'	5	(perennial ryegrass)
<i>Lolium perenne</i> L.	'Yatsyn'	5	(perennial ryegrass)
<i>Lolium (perenne x multiflorum) x perenne</i>	'Grasslands Marsden '	10	(perennial ryegrass)
	Total	20	

Herbal ley pasture was managed following the guidelines of the New Zealand Biological Producers' Council (Anon. 1988) for organic agriculture. In practical terms this approach avoids the use of soluble fertilisers and prohibits the use of chemical pesticides. The fertiliser policy (other than N for the **Grass+N400** treatment) was similar for the whole experimental area. Nutrient status of the soil was periodically checked using MAF 'Quick test'.

The plots were grazed by sheep, 9 times in 1989 and 10 times in 1990. The frequency of defoliations varied with seasonal changes in pasture growth rates, and the stocking rate fluctuated between 380 and 600 **su/ha**, according to the treatment and the period of the year.

At each grazing utilised **herbage** yield was measured under cage **enclosures** within the plots. One subsample per plot was drawn for the determination of dry matter and botanical composition, and chemical analyses.

To preclude sward failure through atypically dry conditions, supplemental irrigation was applied (especially during the establishment year) to equate the water receipt with average rainfall for that month. Water stress was not removed by this irrigation policy over the summer period.

The rate of symbiotic nitrogen fixation (**sNf**) was determined by a modification of the acetylene reduction assay used by Hardy *et al.* (1968). Details of the modifications are in **Hoglund & Brock** (1978).

Results and Discussion

Herbage yield and botanical composition

Herbage accumulation followed a typical pattern, reflecting high rates of growth in spring and early summer (Figure 1). Grass-clover and Herbal ley showed similar rates of **herbage** accumulation during the cooler, moist periods of the year, while **Grass+N400** was **characterised** by a large yield advantage from August to the end of October (Table 2 and Figure 1). Late spring-early summer (November in particular) of 1989 was dry and soil moisture content restricted plant growth, affecting more severely the Herbal ley and Grass-clover than the **Grass+N400** system. This probably reflects the sensitivity of the legume component to restriction in soil moisture (Hart 1987), especially during the establishment year. During this period there is also usually a **decline in grass** production as a result of the physiological stage, 'post-flowering dormancy' (Robson et al. 1989). When fertiliser N was **withheld during the period January to March 1989**, the yield of **Grass+N400** pasture declined to a similar level as in the other two systems (Figure 1), demonstrating the poor residual effect of fertiliser N as well as the strong dependency of this intensive system on continuing inputs of fertiliser N.

The annual **herbage** production (Table 2) was about 11.7, 15.2 and 16.9 t DM/ha for Grass-clover, Herbal ley and **Grass+N400** pastures. The pattern of growth of the Herbal ley differed from that of the Grass-clover and **Grass+N400** pastures. Its production

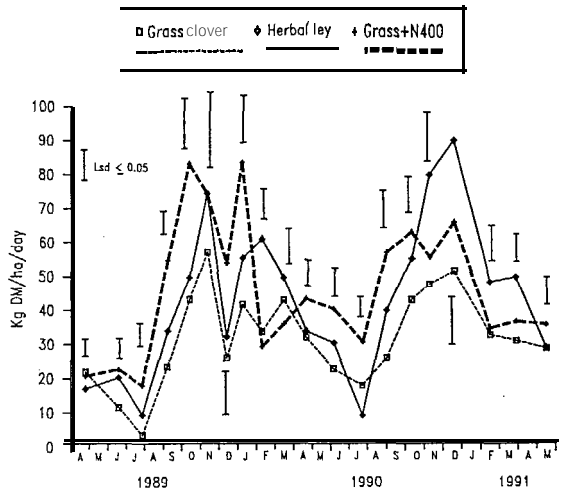


Figure 1 Herbage accumulation rate

was at a maximum in the late spring-summer period, rivalling or even exceeding that from **Grass+N400** in the second year from October 1990 to April 1991. Most of this enhanced production was due to the rapid rate of growth of legumes (principally white clover and red clover) and chicory (Figure 2).

The principal components of the Herbal ley all participated in variable proportions through the year. Of the herbs, chicory was the most important species, being the major contributor to total yield in some periods of the year. The contribution from other herbs was small, with only plantain and **yarrow** obvious at certain periods of the year, but always < 5% of the total yield. White clover

Table 2 Total herbage and legume yields, and total herbage N yield (average 1989-90 and 1990-91).

		Grass-clover	Herbal ley	Grass + N400	Lsd (0.05)
		kg/ha			
Winter	Total herbage	1501	1705	3132	399
	Legume	170	406
	Total N yield	55	63	123	11
Spring	Total herbage	3607	5202	5926	612
	Legume	756	1615
	Total N yield	92	152	180	36
Summer	Total herbage	3349	5107	4362	1031
	Legume	955	1676	..	**
	Total N yield	105	162	127	30
Autumn	Total herbage	3033	3367	3529	576
	Legume	645	636	..	ns
	Total N yield	97	112	120	10
YEAR	Total herbage	11686	15231	16971	1406
	Legume	2726	4735
	Total N yield	349	491	548	46

(Winter: J-J-A; Spring: S-O-N; Summer: D-J-F; Autumn: M-A-M)

(** Significant differences at $P < 0.01$)

and red clover were the main legumes, white clover predominating over red clover in winter and spring, while the proportion of red clover increased over the mid-summer. White clover contributed about 20% and red clover 11% to annual **herbage** DM yield. Lotus and lucerne were present only at very low proportions, contributing less than 1% to the total DM yield. The legume content of Grass-clover pasture fluctuated between 15 and 25% according to the season and its contribution to total yield was always lower than in the Herbal ley, averaging 23% (Table 2).

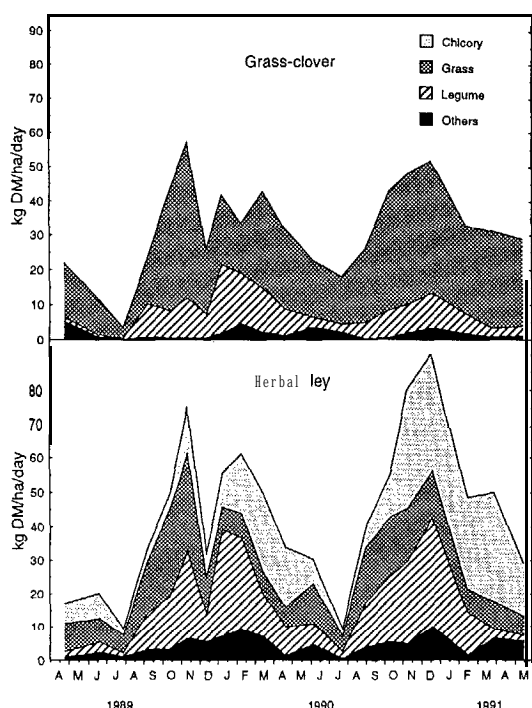


Figure 2 Dynamics of pasture composition

Herbage N yield

Nitrogen yield in the Grass-clover was generally significantly lower than that from both the **Grass+N400** and Herbal ley both seasonally and annually (Table 2). Herbal ley provided a notable turnover of N through harvested **herbage** (491 kg N/ha), almost as much as from **Grass+N400**. In general the values for the **Grass-clover** and **Grass+N400** are lower than those reported by Ball *et al.* (1978) in the same area; but the N yields from Grass-clover are higher than typical values for mixed pasture not receiving fertiliser N in NW Europe. For instance, in The Netherlands N yield fluctuates in most cases between 100 and 250 kg N/ha (van der Meer *et al.*

1986), and in southern England it is about 295 kg N/ha (Whitehead 1970).

Symbiotic N fixation

The general pattern of **sNf** (Figure 3) was similar to that found at this location by **Hoglund et al.** (1979). Higher activity occurred in early spring, in response to the increasing temperature, appropriate soil moisture content and a strong of legumes growth. In summer, although temperature and legume content were satisfactory, soil moisture was **too low** to promote **a more** intense activity. Later, in autumn, **soilmoisture** improved and temperature was still adequate, but the legume content of the sward had declined (see Table 2). Further, **Hoglund & Brock** (1978) reported that **clovers** appear to make extensive use of soil mineral N during summer-autumn. So, under the conditions of this experiment, only in 2 or 3 months was it possible to observe an intense fixation of atmospheric N.

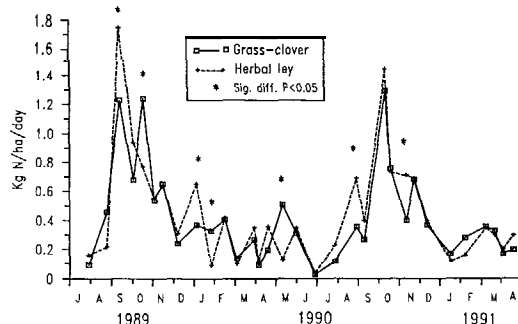


Figure 3 Changes in symbiotic N fixation

Total **sNf** in the first year was similar for both the Grass-clover and Herbal ley at 150 and 156 kg N/ha, respectively (Table 3). These values are within the range found by **Hoglund & Brock** (1978) in a developed grass-clover pasture grazed by sheep. This similarity in the amount of N fixed by the two systems despite large difference in **herbage** production provides a contrast in fixation efficiency (kg N fixed/t legume DM yield). Grass-clover was much more efficient on this basis than the Herbal ley (Table 3), fixing about 50 kg N/t of legume. The legume yield from the Herbal ley was significantly greater (about 2 t DM/ha more in each year) but the N fixed was similar to Grass-clover, resulting in a lower efficiency of about 30 kg N fixed/t of legume. This difference could be because: i) more **herbage** N was recycled through animal **excreta** from the greater yield in Herbal ley, and/or ii) Herbal ley had less aggressive grasses and more deep-rooting

species (principally chicory) than the Grass-clover pasture, allowing greater uptake of soil N by the legumes in the Herbal ley.

Table 3 Legume yield, symbiotic N fixation and fixation efficiency.

	Legume yield (t/ha)	sNF (kg/ha-15 cm)	Fixation efficiency kg N fixed/t leg.
1989-1990			
Grass-clover	3.0	150	50.0
Herbal ley	5.1	156	30.6
1990-1991			
Grass-clover	2.5	123	49.7
Herbal ley	4.4	144	32.7

That more N was consumed and excreted in the Herbal ley pasture, especially during the warmer period of the year, is undeniable (Figure 2). However, that this was effectively recycled to plants in that sward is not so apparent. Associated studies showed that soil mineral N was not greater below Herbal ley than below **Grass-clover**, and we put down this lack of difference to greater losses of N by volatilisation from the Herbal ley during warm conditions. Further, only about 10% of total area within these swards was influenced by animal urine at any point in time (Ruz *et al.* 1992), so any possible advantage to the legumes in Herbal ley must have been **very restricted. Rather we consider the second explanation** more likely. The fixation process was limited by simple substitution of soil N. This mechanism has been well illustrated (Eady 1981; **Hoglund & Brock** 1987).

Symbiotic N fixation represented about 40% of total **herbage** N yield in the Grass-clover system, and 30% in the Herbal ley (average for the 2 years). These results indicate that the Herbal ley, while fixing a similar amount of N, was using more soil N than the Grass-clover pasture. The final outcome was a significant difference in forage production and N yield in favour of the Herbal ley.

Nitrogen inputs and herbage yield

The three pasture systems showed different patterns of utilisation of external N inputs in relation to **herbage** DM and N yields. **Grass+N400** produced the highest yield the first year, but required almost three times the input of N, in relation to the other two systems, to achieve this. **Herbage DM production** per kg of N input was higher in the Herbal ley than Grass-clover and, more obviously, than **Grass+N400** (Table 4). During the second year the result was again in favour of Herbal ley which produced the same, substantial **herbage** and N yields as **Grass+N400** but required only about one third of the external input of N.

Table 4 Nitrogen input and DM yield.

	Herbage yield (t/ha)	Herbage N yield (kg/ha)	N Input (kg/ha)	kg DM yield kg N input
1989-1990				
Grass-clover	10.9	327	150	72.7
Herbal ley	14.2	455	156	91.0
Grass+ N400	17.5	562	420	41.7
1990-1991				
Grass-clover	12.5	371	123	101.6
Herbal ley	16.6	526	144	115.0
Grass + N400	16.8	534	400	41.0

N input = **symbiotic** N fixation or **fertiliser** N

Another outstanding aspect of these results is the difference in apparent utilisation of soil N. The Herbal ley and Grass-clover pastures better utilised soil N than **Grass+N400** (Table 4). But more intriguing is the difference between Grass-clover and Herbal ley. With similar N inputs by **sNF**, they showed a **large** difference (more than 120 kg **N/ha/yr**) in apparent utilisation of soil N. So the Herbal ley, while fixing a substantial amount of atmospheric N, somehow enhanced the utilisation of soil N such that a larger amount of N was taken up to produce a more substantial **herbage** yield than did Grass-clover.

This large difference in utilisation of soil N opens up an interesting question. Did the additional N come from better exploitation of the current soil mineral N or was there some stimulation to mineralisation of organic N? It is possible that the deep-rooting systems of some of the species, especially chicory (Langer **1982**), in the Herbal ley promoted a more active mineralisation of organic N ("root-induced mineralisation", a phenomenon that has recently been described by Clarholm (1989) and Wheatley *et al.* (1990)) and, at the same time a rapid uptake of N, in this way avoiding accumulation of mineral N in the soil profile. This scenario may be supported indirectly by results from regular measurements of mineral N and losses by leaching and denitrification throughout this study. They were consistently at the same low level under the Herbal ley as under Grass-clover.

Conclusions

All species sown in the Herbal ley were established well. But as the experiment progressed, many herb species disappeared under the prevailing **management, involving** periodic mob-stocking with sheep. Others were still **present in low proportions, but chicory was most important** among these herbs and has made a substantial contribution to total yield, followed by white clovers and red clovers.

The dynamics of botanical composition in Herbal ley reflected a general ecological principle that, in a diverse mixture of species under grazing, about 80% of the **herbage** yield is usually achieved by 3 or 4 species. **Herbage** yield was greater in the system receiving fertiliser N, especially during the establishment year. In the second year the Herbal ley improved its production to the same level as that from the more intensive, **Grass+N400** system. Grass-clover production was about 25% below that from the other two systems.

Fertiliser N played a key role in determining **herbage production in Grass+N400. The greater pasture** production was almost entirely dependent on fertiliser N, and **herbage** yield was very sensitive to N being withheld. In **Grass+N400** pasture, fertiliser N determined a lower apparent utilisation of soil N, and this system was also **characterised** by inefficient conversion of N inputs to DM yield.

Herbal ley produced more forage from legumes than **Grass-clover**, but **symbiotic N** fixation was similar in both systems. Herbal ley was remarkably efficient in terms of **herbage** production per unit of N input. Because of an effective combination of biological processes (a significant amount of **symbiotic N** fixation with an enhanced apparent utilisation of soil N), this system exhibits a **substantial N** turnover through plants and, hence, an enhanced pasture production.

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