Dry matter production of irrigated chicory, lucerne and red clover in Canterbury

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Abstract

A field experiment was established at Lincoln University, Canterbury to determine whether chicory, lucerne or red clover was the most suitable for inclusion in grazing systems as specialist forage. This initial evaluation compares the annual and seasonal dry matter (DM) production of the species. Plots were grazed with sheep and soil water was maintained at optimal levels with irrigation. After each grazing there was a lag phase while new shoot growth accelerated to a consistent rate termed the linear growth phase. Lucerne production was 28 t DM/ha in the 1997/98 season, which was at least 7 t DM/ha greater than red clover and chicory. Shorter growth duration in 1998/99 reduced lucerne production to 22 t DM/ha but this was still at least 7 t DM/ha more than both red clover and chicory. The greater lucerne production was due to higher linear growth rates and a longer duration of linear growth in early spring and autumn. There was no general relationship between air temperature and linear growth rates of each species, probably due to the storage and remobilization of root assimilate at different times of the year. From the total and pattern of DM production it was concluded that lucerne was the most suitable species for use as a specialist forage crop.

Additional key words: *assimilate partitioning,* Cichorium intybus, *forage species, grazing, linear growth rate,* Medicago sativa, *seasonal dry matter distribution,* Trifolium pratense

Introduction

The productivity of New Zealand grazing systems is dependent on the conversion of pasture into animal products and a common goal among farmers is to increase this production. One way of doing this is with the strategic use of high quality forages such as red clover, chicory and lucerne. These species yield high amounts of high quality herbage giving improved stock performance.

Chicory can be used as a specialist finishing crop, by itself or in a mixture with clover, or incorporated into grass pasture mixtures (Moloney and Milne, 1993). Chicory has high quality herbage (Barry, 1998) and lambs weaned onto chicory have greater live weight gain (335 g/day) than lambs weaned onto cocksfoot (200 g/day) following an adjustment period (Komolong *et al.*, 1992). Chicory is also capable of producing high yields, with 15 - 18 t DM/ha/y reported at Palmerston North (Matthews *et al.*, 1990), and has a greater daily growth rate than ryegrass, prairie grass and tall fescue (Paton, 1992).

Lucerne is commonly used in New Zealand as a specialist crop for finishing stock. For example Robertson *et al.* (1995) reported lamb growth rates of 243 g/day on lucerne compared with 165 g/day on ryegrass/white clover. Lucerne is also capable of higher herbage production than ryegrass/white clover pastures. Production of over 20 t DM/ha/y is common for irrigated lucerne (Vartha and O'Connor, 1968; Hoglund *et al.*, 1974; Theobald and Ball, 1983) compared with about 13 t DM/ha for pasture in Canterbury (Thomson, 1977)

Red clover can also grown in a mixture with grass and is grown as a specialist finishing crop in Southland where lucerne can not be grown (Hay and Ryan, 1989). Yields of 12 t DM/ha/y can be expected with late flower tetraploid cultivars (Anderson, 1973; Hay and Ryan, 1989;).

A limitation of red clover, chicory and lucerne is their lack of winter activity. This restricts the proportion of any one farm that can be sown in these species. However, determining which species should form the basis of a livestock finishing system is difficult because DM production comparisons between these species are rare. As a first step in this process the research outlined in this paper compares the seasonal pattern and total annual DM production of these species in non-limiting conditions in Canterbury. The most suitable species would have the greatest annual production and the shortest period of winter dormancy.

Live weight gain was not measured in this study. However, a summary of live weight gain trials show small and varied differences between pure red clover, chicory and lucerne which all supported greater production than grass/clover pasture (Young *et al.*, 1994; Barry, 1998). Thus, it is assumed that chicory, lucerne and red clover support the same growth rate in this analysis and differences in DM yield will translate to differences in stock production and carrying capacity.

Materials and Methods

Site preparation and description

The experiment was established on 1 November 1996 at the Field Service Centre experimental area, Lincoln University, Canterbury (43°38'S, 172°28'E, 11 m a.s.l). The soil was a Wakanui silt loam soil of variable depth (New Zealand Soil Bureau, 1968) with a water holding capacity of about 700 mm (to 2.3 m depth). The experiment was a randomised complete block design with three replicates of lucerne cv. Kaituna, chicory cv. Grasslands Puna and red clover cv. Grasslands Pawera.

Initial soil tests (19 September 1996) indicated pH and S levels were below optimum. Therefore, 4 t/ha of lime, 250 kg/ha of super phosphate (0,9,0,12) and 150 kg/ha sulphate of potash (0,0,40,7) were applied on 4 October 1996. The site was rota-crumbled on 10 October 1996 and irrigated to field capacity on 22 October 1996. Plots of 21 × 6.3 m were sown in 150 mm rows using an Øyjord cone seeder on 1 November at a rate of 10 kg/ha for red clover, 7 kg/ha for lucerne and 3.5 kg/ha for chicory.

Weeds were controlled with herbicide (flumetsulum). Plant populations at the end of the establishment season were 200 - 250 plants/m^2 for lucerne and red clover, and 140 plants/m^2 for chicory.

Site management

Irrigation was applied using a travelling mini-boom irrigator. Water was applied at a rate of 10 - 15 mm/h immediately after grazing, with the aim of complete recharge of soil water. The amount of water applied was determined from TDR (Trase Systems – Soil Moisture Equipment, Santa Barbara, California) soil water measurements for the top 0.2 m of soil and neutron probe (Troxler depth moisture gauge, Troxler Electronic Laboratories, North Carolina) measurements at 0.1 m intervals to a depth of 2.3 m.

Grazing management

Plots were grazed in common with sheep of different classes for 5 - 10 days duration depending on the number of stock available. The timing of each grazing was a compromise between the optimal management for each species. The first grazing (following winter) occurred at a time that minimised the risk of lucerne lodging but allowed chicory and red clover to achieve linear growth rates. The spelling period between successive grazing periods aimed to allow lucerne to reach late vegetative or early-bud stage but not allow flower stem thickening in chicory. Residual was trimmed just above crown height using a sickle bar mower to avoid the inclusion of old stem in future DM measurements. Red clover and chicory had ceased flowering by February so the rotation was lengthened to allow greater DM accumulation for all species.

There were 6 grazing rotations in the 1997/98 season and 7 rotations in the 1998/99 season (Table 1). For both years, August 1 was used as the start of Rotation 1, which finished when sheep were introduced. Subsequent rotations were defined as the time from measurement of the residual, when sheep were removed, until final cuts when sheep were re-introduced.

Measurement

Dry matter production was sampled at 7 - 10 day intervals throughout each rotation. The final DM sample for each rotation was taken in the 12 hours before the introduction of sheep. Residual DM cuts were taken the day following the removal of sheep. Samples were based on 0.2 m^2 quadrats cut at ground level with a set of hand shears. Atypical areas that had been sampled earlier in the rotation or in previous rotations were avoided.

Table 1. Summary of grazing rotations and meteorological data for the period 1/8/97 - 24/6/99 for an experiment sown at Lincoln University, Canterbury.

Rotation	Start date	Harvest date	Duration (days)	Mean air temperature (°C)	Total solar radiation (MJ/m^2)
1997/98					
1	1 August	6 October	66	8.2	749
2	10 October	19 November	41	13.0	935
3	23 November	23 December	31	15.5	743
4	27 December	3 February	39	17.4	970
5	7 February	12 March	34	18.7	647
6	16 March	29 May	74	12.6	781
	Total		285		4825
1998/99					
1	1 August	29 September	59	7.8	673
2	9 October	11 November	34	12.0	604
3	16 November	15 December	30	13.0	665
4	22 December	11 January	21	17.1	527
5	19 January	17 February	30	16.9	683
6	24 February	9 April	45	15.9	665
7	22 April	24 June	64	9.7	391
	Totals		283		4208

Note: Duration of grazing is the period from the start date to harvest. Temperature means and radiation totals exclude grazing period.

Meteorological data were recorded at the Broadfields weather station 2 km from the experimental site.

Statistical analysis

In most instances, final harvest was taken while crops were still in the linear growth phase. Therefore, it was not possible to accurately fit sigmoidal growth curves to describe DM accumulation over time. An alternative method of analysis was devised whereby the period until 5% of the final DM yield (termed lag phase) was assessed. The period from the end of the lag phase until final harvest was termed the linear phase. The slope of the linear phase was calculated to give the daily growth rate (LGR in kg DM/ha) and the time from lag phase to final harvest represented the duration of linear growth (duration).

All data were analysed using ANOVA and means were separated using Fisher's protected least significant difference (FLSD) test at a 5% level of significance. Annual DM production was analysed as a repeated measure (split-plot) with species as the main plot and year as the repeated measure (sub-plot). Yield, duration and LGR were analysed as a repeated measure with species as the main plot and the 13 rotations over 1997/98 and 1998/99 as repeated measures. This allowed comparison of data from each rotation within and among species treatments. A single factor analysis was also carried out on each rotation to allow more sensitive comparison of species means within each rotation.

Results

There was an interaction ($p < 0.05$) between species and year for annual DM production which was greater ($p < 0.05$) in 1997/98 than in 1998/99 but the difference was less for chicory than for red clover and lucerne (Table 2). Lucerne produced more DM ($p < 0.05$) than red clover and chicory in both seasons with a maximum of 28.4 t/ha in 1997/98.

Analysis of final DM yield as a repeated measure showed an interaction ($p < 0.01$) between species and rotation (Table 2). Generally there were significant species effects in spring and autumn but not in summer. Specifically, in Rotation 1, 1997/98 (Fig. 1) the yield of chicory (2.4 t DM/ha) was lower ($p < 0.001$) than red clover (5.2 t DM/ha) and lucerne (5.3 kg DM/ha). In

Table 2. Dry matter yield (t/ha) at final harvest for two years over 13 grazing rotations for three forage species grown at Lincoln University, Canterbury.

	Rotation							
	Spring		Summer		Autumn			
	1	2	3	4	5	6	7	Total
1997/98								
Red clover	5.2 b	5.0	4.0	4.6	1.2 b	1.6	-	21.6 b
Chicory	2.4 c	5.8	3.4	4.9	1.7 b	1.6	-	19.8 b
Lucerne	6.1 a	6.2	4.5	5.6	4.0 a	2.1	-	28.4 a
SE_A	0.32	0.28	0.22	0.44	0.36	0.23	-	
1998/99								
Red clover	2.7 b	3.9	2.7	2.1	1.2 b	1.8 c	0.9 b	15.3 b
Chicory	2.2 b	3.8	2.1	2.9	1.7 b	2.7 b	1.0 b	16.4 b
Lucerne	5.3 a	3.6	2.4	2.6	3.1 a	3.3 a	1.5 a	21.8 a
SE_A	0.24	0.32	0.36	0.28	0.17	0.17	0.11	
Interaction	***							**
SE	0.23_B	0.61_C					0.38_D	1.31_E

Note: SE subscripts: A, for comparison of species values within each rotation. B, for comparison of 13 rotation values within each species. C, for comparison of rotation values within and among species. D, for comparison of species totals between years. E, for comparison of species values within or between years. Letters represent mean separation of species within each rotation using FLSD ($\alpha = 0.05$).

addition, in Rotation 5 the lucerne yield (4.0 t DM/ha) was greater ($p < 0.01$) than for chicory (1.7 t DM/ha) and red clover (1.2 t DM/ha).

Similarly, in 1998/99 lucerne yield (5.3 t DM/ha) was greater ($p < 0.001$) than red clover (2.7 t DM/ha) and chicory (2.2 t DM/ha) in Rotation 1 but there were no differences among species in any other rotations. Single factor analysis of individual rotations showed some additional differences in Rotations 5, 6 and 7 in 1998/99 where lucerne yields were greater ($p < 0.05$) than chicory and red clover (Table 2).

The LGR for lucerne (105 kg DM/ha/d) was twice ($p < 0.01$) that of chicory in Rotation 1 of 1997/98 and 1998/99 (Fig. 2). For red clover, LGR was similar to lucerne in Rotation 1 of 1997/98 but reduced to a rate similar to that ot chicory (50 kg DM/ha/d) in 1998/99. Similarly, the LGR for lucerne (130 kg DM/ha) was double ($p < 0.01$) that of red clover and chicory in Rotation 5 of both seasons. The LGR of lucerne (230 kg DM/ha/d) was higher ($p < 0.01$) than for chicory and red clover in Rotation 2 of 1997/98 and was also higher in Rotations 6 and 7 of 1998/99.

In addition to the faster growth rate, the duration of linear growth was longest for lucerne in the first rotation (early spring) and the last two (autumn) rotations of both seasons (Table 3).

Discussion and Conclusions

Dry matter production

Lucerne produced the highest yield of 28 t DM/ha in 1997/98 (Table 2). This was consistent with previous yields (28 t DM/ha/y) recorded for an irrigated two year old stand at Lincoln (Hoglund *et al.*, 1974). Lucerne production was 5 t DM/ha lower in 1998/99 but the yield of 22 t DM/ha was still higher than the average irrigated yield of 14 t DM/ha/y reported by (Douglas, 1986). Our result was also consistent with other reports of irrigated lucerne yields of over 20 t DM/ha/y (Vartha and O'Connor, 1968; Thomson, 1977; Theobald and Ball, 1983).

Similarly, the chicory yields of about 17 t DM/ha were consistent with previous reports for grazed plots (Matthews *et al.*, 1990) but lower than that reported for an ungrazed seed crop which had significant reproductive growth (Hare *et al.*, 1987).

The red clover yields of 15 and 20 t DM/ha/y were higher than the 10 - 12 t DM/ha/y reported by Hay and Ryan (1989) following 10 years research in Southland. The yield difference between locations was likely to have resulted from the extended growing season due to warmer spring and autumn temperatures in Canterbury.

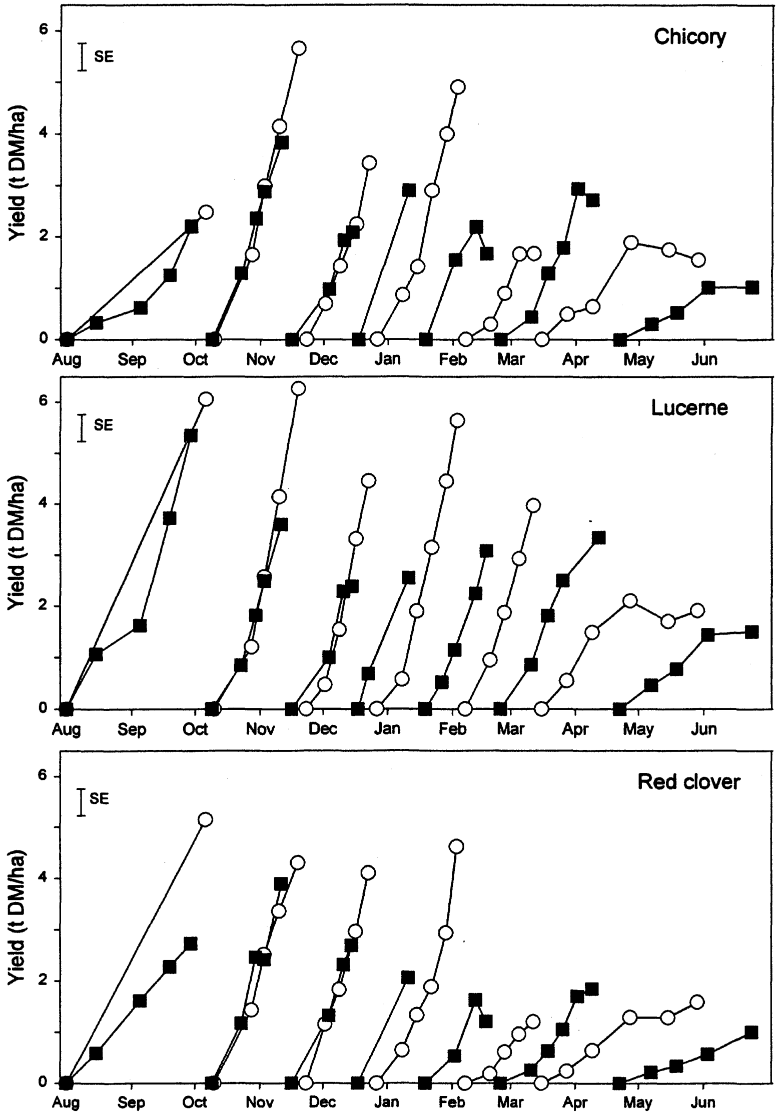

Figure 1. Dry matter (DM) accumulation for chicory, lucerne and red clover over 6 rotations in 1997/98 (O) and 7 rotations in 1998/99 (■).

The higher annual yield of lucerne, compared with red clover and chicory, came from greater production in early spring (Rotation 1) and autumn (Rotations 5 and 6). This was due to a combination of a higher LGR (Fig. 2) and a longer LGR duration (Table 3). This is because lucerne had already formed basal buds at grazing which allowed rapid canopy expansion from the remobilization of root assimilate (Ta *et al.*, 1990) giving the shorter lag phase and extended linear phase shown in Table 2. Chicory and red clover did not initiate re-growth until most of their herbage had been removed by grazing.

The difference in DM yields between years was probably caused by two factors. Firstly, the total solar radiation was 15% lower in 1998/99 than in 1997/98 reducing yield potential by 15% in 1998/99 (Avice *et al.*, 1997a). Secondly, the duration of linear growth was 5 days shorter in the first 5 rotations of 1998/99. The LGR was high in these rotations for all three species (Table 3)

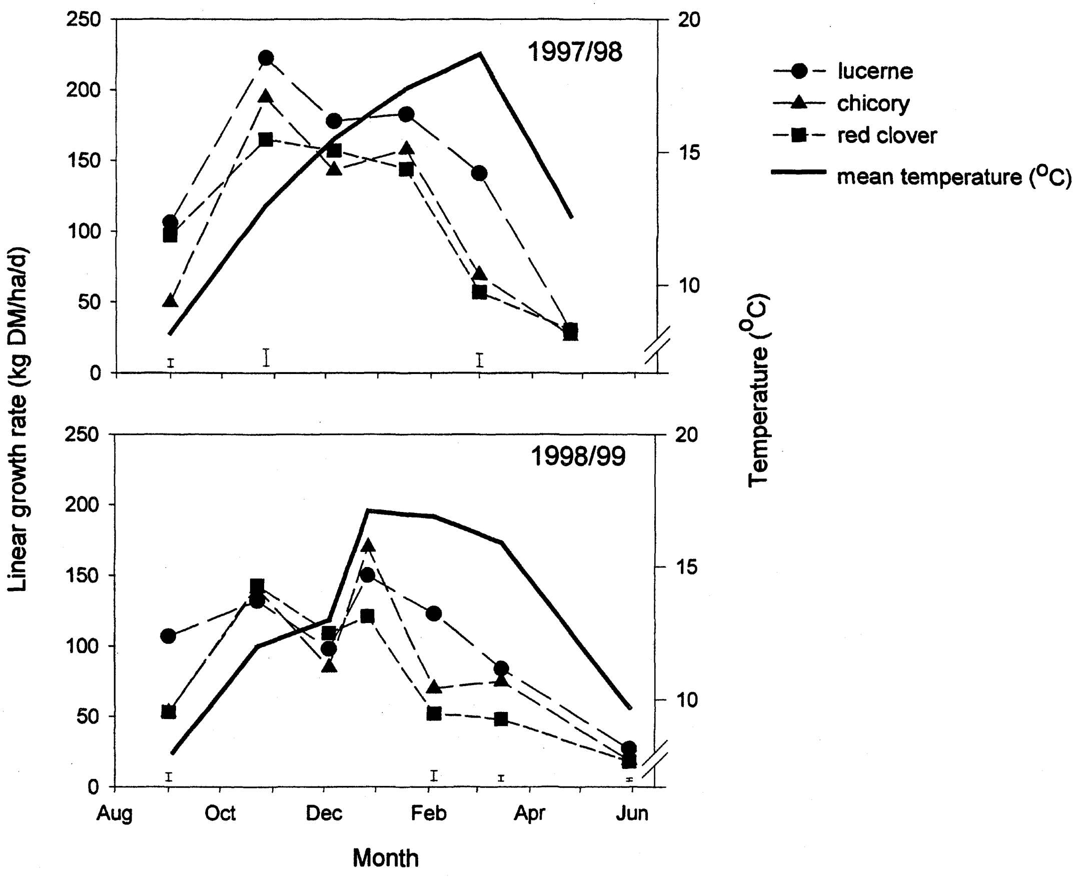

Figure 2. Linear growth rates for lucerne, chicory, and red clover, and the mean temperature for the 1997/98 and 1998/99 seasons. Bars represent the SE below rotations that differed significantly among species.

and the reduction of its duration in 1998/99 lowered yields despite an additional (7^{th}) rotation in 1998/99 (Fig. 1).

Seasonal production pattern

Linear growth rate was the main determinant of DM production for all three species. However, the relationship for LGR differed from that for mean air temperature throughout the 1997/98 season (Fig. 2). Spring LGRs (Rotation 1 and 2) were high at low temperatures compared with LGRs and temperature in autumn. This was probably due to remobilization of root stored assimilate supplementing photosynthetic production in the spring. Storage of assimilate is well documented for chicory (Li *et al.*, 1997), lucerne (Heichel *et al.*, 1988) and red clover (Collins, 1996) and a reduction in root assimilate in spring indicates remobilization for regrowth ((Li *et al.*, 1996).

Linear growth rates failed to increase with temperature from Rotation 2 - 3 suggesting that remobilisation had ceased and growth was dependent on environmental potential during the summer. Autumn LGR was low even though temperatures were higher than in the spring, indicating assimilate was being partitioned into root stores. This occurrence has also been reported by Khaiti and Lemaire (1992), where radiation use efficiency (RUE) was constant for total biomass production (2.4g DM/MJ) but RUE for above ground production decreased from 1.8 g DM/MJ in summer to 1.13 in autumn.

The same pattern occurred for all three species in the 1998/99 season indicating autumn stored assimilate was being remobilize in the spring. Summer LGR appeared to be environment dependent again as it decreased considerably from Rotation 2 - 3 when remobilization stopped and temperature only increased slightly. Linear growth rate rapidly increased with temperature in Rotation 4. Assimilate storage again became apparent in Rotation 5 when LGR decreased.

These results contrast with Hoglund *et al.* (1974) who showed growth of lucerne at Lincoln was closely related to mean air temperature, indicating assimilate storage and remobilization did not occur. A possible explanation for the difference is that the current experiment did not receive nitrogen (N) fertiliser, whereas the Hoglund *et al.* (1974) stand received 364 kg N/ha/y. Nitrogen in the most important root stored assimilate for regrowth (Avice *et al.*, 1997b).

Management implications

The DM results from this study indicated that lucerne was the most suitable species to use in farm systems due

Table 3. Duration of linear growth (days) for three forage species grown in two years over 13 rotations at Lincoln University, Canterbury.

	Rotation						
	Spring		Summer			Autumn	
	1	2	3	4	5	6	7
1997/98							
Red clover	53 b	30	26	32	21 a	52 a	-
Chicory	49 a	30	24	31	24 b	60 a	-
Lucerne	57 c	28	25	31	28 c	64 b	-
SE_A	0.4	1.0	0.3	0.3	0.3	0.7	-
1998/99							
Red clover	46 b	27	25	17	24	37 a	54 a
Chicory	42 a	27	25	17	24	36 b	55 ab
Lucerne	50 c	27	25	17	25	40 b	57 b
SE_A	0.2	0.9	0.3	0.3	0.3	0.3	0.7
Interaction	***						
SE	0.6_B	0.7_C					

Note: SE subscripts: A, for comparison of species within each rotation. B, for comparison of 13 rotation values within each species. C, for comparison of rotation values within and between species. Letters represent mean separation of species within each rotation using FLSD ($\alpha < 0.05$).

to its longer growing season. However, all three species are winter dormant and cannot be grazed in Canterbury until at least late September. This creates a problem on farms carrying capital stock, as the area of these crops must be balanced with sufficient pasture (winter active) to provide winter feed. However, the benefits that these species provide in their 8-9 month growing season and their potential for feed conservation still offer advantages to breeding enterprises.

To definitively determine which species would best form the basis of livestock finishing systems requires further analysis of dryland production, species persistence, herbage quality and animal live weight gain.

The effect of management on these species also needs to be noted. Grazing all species in common required a compromise for what is considered optimal grazing management for each species. For instance, plots were grazed in spring to avoid lodging in lucerne (i.e., when lucerne was at ceiling yield). However, chicory and red clover were still in linear growth phase at this time and would have benefited from a later grazing. Summer grazing was a compromise between obtaining high yields and maintaining chicory and red clover herbage quality and utilisation. During this period the quality of chicory declined faster than lucerne and a shorter grazing duration would have improved herbage utilisation and stock production from chicory.

Conclusions

- Annual DM production of lucerne was about 7 t/ha more than red clover and chicory in both years.
- Greater lucerne production resulted from higher spring and autumn growth rates.
- Lucerne was the most suitable species for use as a specialist forage due to its extended seasonal DM production.

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References

Anderson, L.B. 1973. Relative performance of the late-flowering tetraploid red clover 'Grasslands 4706', five diploid red clovers, and white clover. *New Zealand Journal of Experimental Agriculture* ***1***, 233-237.

Avice, J.C., Lemaire, G., Ourry, A. and Boucaud, J. 1997a. Effects of the previous shoot removal frequency on subsequent shoot regrowth in two *Medicago sativa* L. cultivars. *Plant and Soil* ***188***, 189-198.

Avice J.C., Ourry A., Lemaire G., Volenec J.J. and Boucaud J. 1997b. Root protein and vegetative storage protein are key organic nutrients for alfalfa shoot regrowth. *Crop Science* ***37***, 1187-1193.

Barry, T.N. 1998. The feeding value of chicory (*Cichorium intybus*) for ruminant livestock. *Journal of Agricultural Science* ***131***, 251-257.

Collins, M. 1996. Management, Utilization, Quality and Antiquality. *In:* Red Clover Science {eds., N.L. Taylor and K.H. Quesenberry) Dordrecht, The Netherlands: Kluwer Academic Publishers. pp. 57-79.

Douglas, J.A. 1986. The production and utilization of lucerne in New Zealand. *Grass and Forage Science* ***41***, 81-128.

Hare M.D., Rolston M.P., Crush J.R. and Fraser T.J. 1987. Puna chicory - a perennial herb for New Zealand pastures. *Proceedings Agronomy Society of New Zealand* ***17***, 45-49.

Hay, R.J.M. and Ryan, D.L. 1989. A review of 10 years research with red clovers under grazing in Southland. *Proceedings of the New Zealand Grassland Association* ***50***, 181-187.

Heichel, G.H., Delaney, R.H. and Cralle, H.T. (1988). Carbon assimilation, partitioning and utilization. *In*: Alfalfa and Alfalfa Improvement (eds., A.A. Hanson, D.K. Barnes and R.R.Jr. Hill) Wisconsin, USA: Madison. pp. 195-228.

Hoglund, J.H., Dougherty, C.T. and Langer, R.H.M. 1974. Response of irrigated lucerne to defoliation and nitrogen fertilizer. *New Zealand Journal of Experimental Agriculture* ***2***, 7-11.

Khaiti, M. and Lemaire, G. 1992. Dynamics of shoot and root growth of lucerne after seeding and after cutting. *European Journal of Agronomy* ***1***, 241-247.

Komolong, M., Nicol, A.M., Poppi, D.P., Fraser, T.J. and Kirsopp, S. 1992. Nutrient supply for lamb growth from Grasslands Puna chicory (*Cichorium intybus*) and Wana cocksfoot (*Dactylis glomerata*). *Proceedings of the New Zealand Society of Animal Production* ***52***, 85-97.

Li, G.D., Kemp, P.D. and Hodgson, J. 1997. Biomass allocation, regrowth and root carbohydrate reserves of chicory (*Cichorium intybus*) in response to defoliation in glasshouse conditions. *Journal of Agricultural Science* ***129***, 447-458.

Li, R., Volenec, J.J., Joern, B.C. and Cunningham, S.M. 1996. Seasonal changes in nonstructural carbohydrates, protein, and macronutrients in roots of alfalfa, red clover, sweetclover, and birdsfoot trefoil. *Crop Science* ***36***, 617-623.

Matthews, P.N.P., Kemp, P.D. and Austin, G.M. 1990. The effect of grazing management on the growth and reproductive development of chicory. *Proceedings Agronomy Society of New Zealand* ***20***, 41-43.

Moloney, S.C., Milne, G.D. 1993. Establishment and management of Grasslands Puna chicory used as a specialist, high quality forage herb. *Proceedings of the New Zealand Grassland Association* ***55***, 113-118.

Paton, R.J. (1992). Performance of dryland pasture options in the downlands. *In* Securing the Future of Dryland Farming in the East Coast Downlands (eds., R.J. Patton and W.J. Fraser).

Robertson, H.A., Niezen, J.H., Waghorn, G.C., Charleston, W.A.G. and Jinlong, M. 1995. The effect of six herbages on liveweight gain, wool growth and faecal egg count of parasitised ewe lambs. *Proceedings of the New Zealand Society of Animal Production* ***55***, 199-201.

Ta, T.C., Macdowall, F.D.H. and Faris, M.A. 1990. Utilisation of carbon and nitrogen reserves of alfalfa roots in supporting N_2 fixation and shoot regrowth. *Plant and Soil* ***127***, 231-236.

Theobald, P.W. and Ball, P.R. 1983. Performance of a stand of 'Wairau' lucerne and lucerne-annual ryegrass in the Manawatu. *New Zealand Journal of Experimental Agriculture* ***11***, 21-26.

Thomson, N.A. 1977. Factors affecting animal production: intake and utilization by ewes grazing grass/clover and lucerne pastures. *Proceedings of the New Zealand Grassland Association* ***9***, 86-97.

Vartha, E.W. and O'Connor, K.F. 1968. Prospects for high production from Canterbury plains pastures. *Proceedings of the New Zealand Society of Animal Production* ***28***, 65-73.

Young, O.A., Cruickshank, G.J., MacLean, K.S. and Muir, P.D. 1994. Quality of meat from lambs grazed on seven pasture species in Hawkes Bay. *New Zealand Journal of Agricultural Research* ***37***, 177-186.