Herbage production under grazing, of some subterranean clover lines compared with lucerne.

M. L. Smetham and D. W. Jack

Department of Plant Science, Lincoln University, Canterbury, New Zealand.

Abstract

The herbage production of 18 lines of subterranean clover (*Trifolium subterraneum* L.); a naturalised sward, and one line of lucerne (*Medicago sativa* L. cv. 'Otaio'), grown on a shallow stony soil in an area of New Zealand with low to moderate rainfall and a cool temperate climate was compared. Measurements of subterranean clover herbage production were taken every month, followed by sheep grazing to a residual herbage mass between 200 and 600 kg DM/ha. Lucerne production was measured every month in cages which were shifted whenever the crop reached 5% flowering, or at two monthly intervals. The paddock was periodically grazed by sheep. Pure swards of six of the subterranean clover lines produced between 4103 kg DM/ha and 5231 kg DM/ha. These included the mid-season flowering line 9756, and the late flowering lines 14454B and 14205B. Herbage production of the subterranean clovers was highly significantly correlated with seedling numbers/m^2 after full autumn germination had occurred (r^2 = 0.57). A sward of naturalised clovers produced only 764 kg DM/ha. The lucerne cultivar produced 3310 kg DM/ha, which is low by comparison with other published reports. Growth rates of subterranean clover exceeded those of lucerne during autumn, winter and spring. It was concluded that (a) the low lucerne yield was due to abnormally low rainfall, and (b) the growth rates of subterranean clover exceeded those of lucerne because of the ability of this species to grow in the cool moist winter and early spring when moisture was still present.

Additional key words: *seedling numbers, cool-season growth, cool temperate, low rainfall*

Introduction

In the early 1930s subterranean clover (*Trifolium subterraneum* L.) came to be recognised in New Zealand as a pasture legume with superior productivity and persistence in areas where soils dry below wilting point for periods of a month or more in summer (Saxby, 1956). In 1936, Levy published a comparison of the herbage production of a number of Australian cultivars, of which Nangeela was the best, although because seed of only Mt Barker and Tallarook was readily available, these were recommended " until seed of superior strains is available". Considerable areas of North Island hill country, and shallow stony soils in both islands were sown to these cultivars between 1930 and 1950 (Saxby, 1956). When sown into worked ground in combination with perennial ryegrass and managed intensively, such pastures in low rainfall areas were nearly three times as productive as those based on white clover (Calder, 1951). However, rotationally grazed lucerne (*Medicago sativa* L.) was subsequently shown by Iversen (1965) to produce more herbage than subterranean clover-based swards. There are no more recent comparisons, except by inference. Rickard and Radcliffe (1976) found the long term average production of dryland, subterranean clover-based pastures to be around 5000 kg DM/ha, with subterranean clover contributing an average of 23% to the total. On a similar soil type Vartha and Fraser (1978) measured an average 8500 kg DM/ha from lucerne cv. Wairau. The contribution of subterranean clover to North Island hill country pasture production can be up to 29% (Ledgard *et al.*, 1988), but does depend greatly on seedling density which in turn is determined by losses from false strikes (Sheath and Macfarlane, 1990a) and competition from associated grasses (Sheath and Macfarlane, 1990b).

Production of herbage in subterranean clover is closely correlated with seedling density (Silsbury and Fukai, 1977; Evans *et al.*, 1992). Smetham and Wu Ying (1991) have shown that hardseededness is reduced only slowly under the climatic regime experienced in New Zealand; consequently the majority of subterranean clover seed may remain hard and not germinate in the autumn. However, there are some accessions which are better adapted to conditions in New Zealand and therefore set more seed than current Australian cultivars (Smetham *et al.*, 1993). Although this seed has a high level of hardseededness, the greater amount of seed produced means that large and adequate numbers of seedlings establish in autumn (Smetham *et al.*, 1994). The experiment described here was designed to measure the herbage production from a range of accessions of subterranean clover and compare this with production from lucerne.

Materials and Methods

On 2 May 1993, 15 numbered accessions and three Australian cultivars of subterranean clover were drilled after inoculation into worked ground at a site 11 km southwest of Christchurch, New Zealand (latitude 43° 38'S) which experiences a cool temperate climate with a long term mean annual rainfall of 625mm. The seed was obtained originally from the *Trifolium* gene bank, Department of Agriculture, Western Australia, Perth. Smetham *et al.* (1994) have recorded the dates of first flower appearance for these lines and cultivars when growing in New Zealand.

The seed rate was adjusted to sow 1000 germinable seeds/m^2 into cultivated ground. The soil was a shallow, very stony phase of the Eyre-Paparua set (Cutler, 1968) with a pH of 5.7. Four hundred kg/ha of 20% sulphur enriched superphosphate was broadcast on the experimental area a week after drilling. The experiment used a randomised block design with 6 replicates; plots were 3m by 1.5m and separated from each other by an unsown 1.5m strip each way.

The experimental area remained ungrazed during the period May 1993-January 1994, after which it was grazed, and sprayed with 'Buster' at 7.5 l/ha (200 g/l of a.i. glufosinate ammonium) on 21 February 1994 to kill weeds and grasses. Natural regeneration of subterranean clover occurred from 30 March 1994. Plots not sown to subterranean clover regenerated strongly to be co-dominated by the naturalised species striated clover (*Trifolium striatum* L.) and clustered clover (*T. glomeratum* L.)together with some hairgrass (*Vulpia* spp) and flatweeds; henceforth referred to as 'native'.

Measurements of lucerne productivity were made on an immediately adjacent paddock, plots being within 28m of the subterranean clover plot area. The paddock was sown on 20 September 1993 with 6 kg/ha of inoculated lucerne cv. Otaio, and 125 kg/ha of "Longlife" superphosphate having an NPKS analysis of 0:10:0:8. Lime was applied at 2.5 t/ha just prior to cultivations for the previous crop of turnips in November 1992. The turnip crop was sown with 200 kg/ha of "Cropmaster 20" with an NPKS analysis of 20:10:0:12.. Cv. Otaio is the latest lucerne cultivar to be released in New Zealand, and has been selected for good persistence, pest and disease resistance, with production at least equal to cv. Wairau (R. G. Purves, pers. comm.).

Subterranean clover seedlings were counted at the cotyledon or unifoliate true leaf stage in one 0.1m^2 quadrat per plot on 6 April 1994, as soon as full autumn germination had occurred. Assessment of standing herbage commenced on 17 May 1994, and thereafter on 2 August, 7 September, 7 October, and 7 November. After each assessment the fenced experimental area of 0.26 ha was grazed with sheep over one or two days to a low residual herbage mass of 100-600 kg DM/ha. Table 1 gives details of post-assessment treatment. Individual plot yields were assessed using a single probe capacitance meter placed at 20-25 positions in each plot, but only where the sown species constituted at least 95% of herbage cover.

After each assessment ten plots with a wide range of herbage mass were each cut to leave 1 cm residual herbage using a 0.1m^2 quadrat, to allow calibration of the probe after washing and drying of the cut herbage. The percentage contribution to total plot yield of the sown species was estimated by eye at the time of each assessment.

On 29 April 1994 six 1.5m square cages were placed at random on the lucerne area within a strip 25m from the subterranean clover area. The area within each cage was mown to 2 cm height using a rotary mower. The first cut was taken on 5 August 1994. In each cage a 0.1m^2 quadrat was placed at random, and cut to ground level. The herbage was then washed, dried to constant weight and weighed. Prior to cutting, two other quadrat areas as similar as possible to the one being cut were marked with small pegs. This was to allow growth rate to be assessed using the "Australian difference" method

Table 1. Post-assessment grazing of the experimental area.

Date of assessment	17 May	2 Aug	7 Sept	7 Oct	7 Nov
Period of grazing	28,29 May	10 Aug	18,19 Sept	8,9 Oct	10,11 Nov
Stock	250 hoggets	150 ewes	36 ewes & lambs	63 ewes & lambs	100 ewes
Residual herbage mass (kg DM/ha)	300	400	200	600	100

(Lynch, 1960). At approximately monthly intervals another of the marked quadrats was cut, and the herbage washed, dried and weighed to constant weight. The whole proceedure was repeated each time the cages were shifted. Cages were moved when the crop reached the 5% flower stage, or after two months. Sheep grazed the area of paddock outside the cages approximately every two months, but no records were kept of grazing days.

Results and Discussion

Weather data from the nearest official weather station 'Broadfields', 9.6 km due East of the experimental site, are given in Table 2.

Herbage production and subterranean clover seedling populations

Six lines of subterranean clover listed in order of decreasing yield - 9756, 14205B, 14454B, 14555A, 14205A, and cv. Enfield - produced significantly more DM ($P<0.05$) than most other lines, including cv. Tallarook, although four other lines were not significantly different from the six above. There was considerable overlap of total herbage production from the lines of subterranean clover examined (Table 3), with the highest yield being 5231 kg DM/ha; the lowest 942 kg DM/ha, and the mean 2793 kg DM/ha. The naturalised legume sward consisting of co-dominant striated clovers and clustered clovers ("Native") produced only 764 kg DM/ha.

All six of the lines named above as being superior in the production of herbage were also ranked in the top six both for the production of seed, and for the highest numbers of seedlings in autumn in an evaluation in the previous year at the same site (Smetham *et al.*, 1994), and results are consistent with performance in the same location but at a different site, over the period 1986-1990 (Smetham *et al.*, 1993).

Because of differences between lines in the amount of seed set, and the hardseededness of that seed (Smetham *et al.*, 1994), the numbers of seedlings per unit area in autumn varied widely at the start of the present measurements of herbage production (Table 3). Such initial population differences have been shown to have a marked influence on the herbage productivity of subterranean clover (Silsbury and Fukai, 1977) in winter, but not in spring (Evans *et al.*, 1992). In this experiment the regression of total annual herbage production on seedling number in autumn was highly significant ($Y = 1409 + 18.4\ X$, $P < 0.001$), with seedling numbers accounting for 57 % of the variation in yield. In an evaluation of nine named subterranean clover cultivars at eight dry hill country sites Williams *et al.* (1990) and Sheath and Macfarlane (1990a) found a straight line relationship between herbage production and seedling numbers in the first year of natural regeneration, but this

Table 2. Climate data including long term means for April 1994-April 1995 from Broadfields Meteorological station, Lincoln, Canterbury, New Zealand, 43° 38' S, 178° 15'E.

Month	Mean daily air temperature (°C)		Penman evaporation (mm/month)		Rainfall (mm/month)		Dry soil days
	Actual	Mean	Actual	Mean	Actual	Mean	Actual
April '94	12	12	68	66	17	56	7
May	9	9	38	49	46	71	8
June	5	6	23	36	55	61	0
July	6	6	28	41	115	68	0
August	9	7	58	57	5	62	0
September	8	9	73	74	56	47	3
October	10	12	100	103	20	49	14
November	14	14	160	121	22	53	26
December	16	15	161	136	24	57	28
January '95	17	16	131	146	32	60	24
February	17	16	84	118	25	54	18
March	16	16	84	98	32	57	21
April	13	15	37	66	30	56	12
Total (13 months)	-	-	1045	1111	479	751	161

Table 3. Total annual herbage yield, contribution to total plot yield, and initial numbers of seedlings of nineteen lines of annual pasture legumes.

Line or cv.	Numbers of seedlings/m^2 16 Apr. 1994	Contribution to plot yield (%)	Total annual prod. (kg DM/ha)
9756	1950 bcde	69 defghij	5231 abcd
12683	310 m	37 mlk	942 ml
12722	340 ijk	47 jklm	2168 ijk
14198	760 fghi	34 klm	1614 jklm
14205A	6130 cdef	77 cdefghi	4253 cdefg
14205B	3430 abc	83 abcdefg	5147 abcdef
14211A	580 hij	60 fghijk	3644 efghi
14211B	650 ghij	55 hi	2688 ghij
14211C	700 fgh	54 hijklm	3016 fghij
14326H	550 hij	63 efghij	2819 ghij
14454B	1790 cde	80 bcdefgh	5015 bcdef
14555A	990 defgh	71 defghi	4325 defg
15077	220 klm	28 mn	951 lm
15258B	250 klm	45 jklm	1944 ijkl
15258C	410 jkl	59 ghijk	2579 hijk
Dalkeith	130 lm	31 lmn	1167 klm
Enfield	890 efgh	55 hijkl	4103 defg
Tallarook	610 ghij	51 ijklm	2243 hijk
"Native"	not recorded	8 klm	764 m
Mean	810 ± 10	52 ± 3	2793 ± 164
Signif.	****	****	****

Duncan's multiple range test of significance is indicated by lower case letters. Means without a letter in common differ significantly P <0.05.

weakened with increasing ingress of grass in subsequent seasons.

In the experiment reported here there were also highly significant correlations between production, and the population of seedlings for each yield assessment (Table 4), and between the percentage contribution to plot yield and seedling population ($r = 0.564$, $P < 0.001$).

Cultivar/accession and herbage yield

Cultivar and accession differences in herbage yield are largely, although not completely determined by the date of first flower appearance. The latter determines the amount of seed produced (Donald, 1960) which, although modified by the proportion of seed which remains hard, in turn affects the number of seedlings which appear in autumn. In the evaluation being reported the most successful lines were in the mid-season (cv. Enfield - 3 October; 14205A and 9756 - 5 October; and 14555A - 8 October) and late-flowering groups (14454B - 14 October; and 14205B - 24 October). Cv. Tallarook and one other line were also late flowering but failed to set enough seed (Smetham *et al.*, 1994) for high herbage yield. In the higher rainfall environment of the seven wetter sites in a New Zealand wide evaluation (Williams *et al.*, 1990) the late flowering cv. Tallarook produced the greatest numbers of seedlings and produced the most herbage seed over a four year period. However at the driest of the eight sites, Carvossa (Hoglund 1990), early, or early mid season flowering lines set most seed and produced most herbage. Measurements made in the 1993 season (Smetham *et al.*, 1994) suggest that in dryland areas with a very variable rainfall, the ability of some mid and late flowering subterranean clovers to recommence flowering after drought may be more important than time of first flower appearance in determining seed production.

Table 4. Correlations between autumn seedling numbers and herbage production.

Correlation with numbers of seedlings 6 April 1994	Correl. coeff
Total annual herbage production	0.695 ***
% legume contribution to total plot yield	0.564 ***
Herbage production 17 May	0.750 ***
Herbage production 2 August	0.564 ***
Herbage production 7 September	0.635 ***
Herbage production 7 October	0.691 ***
Herbage production 7 November	0.642 ***

n = 120. *** = P < 0.001.

Productivity of pure swards

The levels of herbage production recorded for the pure swards used in this experiment are generally lower than those reported by other workers. White and Meijer (1979) obtained 7000kg DM/ha from cv. Woogenellup established by planting seedlings at 49/m^2 into a herbicide treated sward in low rainfall hill country, and in a similar environment Scott (1972) recorded yields of 3000-9000 kg DM/ha from hand sown plots with high seedling densities. However, in neither case was production measured from naturally regenerated swards. In the evaluations above, grazing by stock was limited to periodic defoliation leaving high residual herbage mass. In the current work, grazings were frequent, and severe enough (see Table 1) to delay the attainment of fast rates of regrowth and hence probably reduced total yield.

Lucerne production

Lucerne produced a total of 3310 kg DM/ha in the period 29 April 1994 to 12 April 1995 (Table 5). This is considerably lower than the four year yield average of 8500 kg DM/ha measured by Vartha and Fraser (1978), or Iversen's (1965) two year average of 8900 kg DM/ha on the same soils. The Penman evapotranspiration was 30% higher during November and December 1994 while rainfall in the thirteen months from April 1994 was well below the long term average for ten of these, averaging only 40% of the long term average for those months Table 2. Calculations from the recorded weather data show that soils were below wilting point for 161 days of the 13 month period (N.J. Cherry, pers. comm.). It is considered that the low rainfall receipt over the whole period, plus the higher than normal evapotranspiration during November and December, is sufficient to explain the low yield of lucerne recorded. Farmers in the area experienced no spring flush in September or October 1994, and no surplus herbage was available for conservation from lucerne in the 1994-1995 season (K.J. Townley, pers. comm.).

There was no evidence that the lucerne used in this study was affected by the root-feeding Sitona weevil.

Subterranean clover and lucerne comparison

The three top producing subterranean clovers each yielded more than 5000 kg DM/ha; the next three more than 4000 kgDM/ha, compared to lucerne production of 3310 kg DM/ha. Although there can be no statistical evaluation because the two species were not in the same trial, the growth rates for the lucerne for each period, compared with the mean growth rate of the top six subterranean clover lines (Table 5) can be (Table 6). The subterranean clovers grew faster in all periods. During the first period April to mid May the clovers grew at 19.6 kg DM/ha/d compared to lucerne at 4.9 kg DM/ha/d for the whole period late April to early August. Subterranean clover growth during mid- May to August was 11.6 kg DM/ha/d. From mid August to early September clover growth was 20 .4 kg DM/ha/d-just higher than lucerne, but from mid September to the finish of growth in early November, subterranean clovers grew at 48-56 kg DM/ha/d which was five times faster than lucerne. This is unusual because lucerne can achieve growth rates of 29, 55, and 98 kg DM/ha in September, October and November respectively, on similar soils when moisture is non-limiting (Hoglund 1971).

Above normal rainfall fell during July, and rainfall was just above average in September. These were periods when the subterranean clover, having a lower temperature optimum for growth of 18°C (Mitchell 1956), was able to grow more rapidly than lucerne with an optimum around 27°C (Smith 1970). In addition the lucerne cultivar Otaio, used in this study, does not have a high level of winter activity (R.G. Purves, pers. comm).

The ranking order of monthly and total seasonal production among the six most productive subterranean clover lines (Table 6) was consistently within four ranking positions, i.e., the herbage production of the lines relative to one another stayed much the same right through the season of growth.

In Figure 1 the mean growth rate of the six most productive subterranean clovers is plotted against that of the lucerne using figures, interpolated where necessary, to fit monthly periods. The result illustrates the superior ability of the subterranean clovers to grow in the cool

Table 5. Seasonal and total annual herbage accumulation of lucerne cv. Otaio from 29 April 1994 to 12 April 1995 on a Lismore stony silt loam at Ashley Dene, Canterbury, New Zealand (kg green herbage DM/ha).

	Period 1					Period 2			Period 3			Period 4
	5 Aug	13 Sept	12 Oct	10 Nov	Total	12 Dec	9 Jan	Total	9 Feb	9 Mar	Total	12 Apr
Herbage accumulation												
Mean	483	668	293	286	1731	312	396	708	484	-21	463	408
SD	86	194	165	828	535	101	63	110	76	136	62	42
Cumulative yield					1731			2439			2902	3310
Daily growth rate												
kg DM/ha/d	4.9	17.1	10.1	9.8	-	9.5	14.1	-	15.6	0.75	-	12.0
SD	0.8	4.5	5.2	26.1	-	2.8	2.0	-	2.5	4.9	-	1.3

x

Table 6. Seasonal yields (kg DM/ha) and daily growth rates for the six highest yielding subterranean clover lines from germination 6 April to senescence 7 November 1995.

	6 Apr - 17 May		29 May - 2 Aug		10 Aug - 7 Sept		19 Sept - 7 Oct		9 Oct - 7 Nov	
Cultivar/accession	Mean[a]	Rank[b]	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
9756	892 bcd	3	947 abcdef	1	624 bcdef	2	1020 abcd	2	1748 ab	1
14205B	1026 abcd	1	649 ef	5	713 abcdef	1	1025 abcd	1	1734 ab	3
14454B	931 abcd	2	837 bcdef	2	561 cdef	5	951 bcd	3	1735 ab	2
14555A	672 d	5	762 def	3	563 cdef	3	818 cd	5	1510 b	5
14205A	613 cd	5	584 f	6	561 cdef	4	916 bcd	4	1579 b	4
Enfield	691 cd	4	759 cdef	4	400 f	8	759 d	6	1494 b	6
Mean	804		756		570		915		1633	
SD	152		118		94		98		109	
No. of days	41		65		28		19		29	
Growth rate (kg DM/ha/d)	19.6		11.6		20.4		48.2		56.3	
Statistical analysis summary for seasonal growth of all 19 cultivars (see Table 3.)										
Mean	401		437		360		559		1034	
Signif.	****		****		****		****		****	

[a] Means without a letter in common differ significantly P <0.05, Duncan's multiple range test.
[b] Rank order of the yield figure within each assessment date amongst all 19 lines (see Table 3).

season. The good spring growth of this clover is particularly valuable for feeding stock over the period August, September and October, when lucerne is growing but not yet at a stage when growth can be utilized without prejudicing yield and persistence.

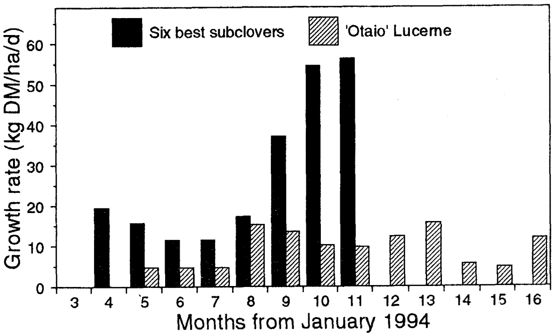

Figure 1. The mean growth rate of the subterranean clover lines 9756, 14205A, 14205B, 14454B, 14555A and Enfield, compared with that of 'Otaio' lucerne on a monthly basis.

The place for subterranean clover

The absolute contribution of subterranean clover to the yield of mixed pasture with a strong perennial grass component ranges from 1300 kg DM/ha on intensively managed pastures (Rickard and Radcliffe, 1976) to 150-700 kg DM/ha on steep high rainfall North Island hill country (Sheath and Boom, 1985). However the results reported here show that pure sward yields of 4-5000 kg DM/ha equivalent to total yields of mixed pasture, can be obtained. In view of the greater value of legume herbage for animal production (Ulyatt *et al.*, 1977), and the high cool-season growth rates of 12-20 kg DM/ha/d recorded here for subterranean clover, it would be more logical to use this species as a pure sward rather than in mixture with perennial grasses. Of the perennial grass cultivars which might be considered for use with subterranean clovers on dry sites, Yatsyn and Nui ryegrasses have recorded growth rates of 7-8 kg DM/ha/d over winter in Canterbury (Kerr, 1987); Wana cocksfoot 12-14 kg DM/ha/d on North Island hill country (Barker *et al.*, 1985); and Maru phalaris from 4-15 kg DM/ha at three hill country sites (Stevens *et al.*, 1989) all of which are below the figures recorded for the best six subterranean clover lines in Table 6. Pure swards are relatively easy to achieve as long as adequate competition is provided by high seedling numbers in autumn, and where summer conditions are dry enough to limit the ingress of perennials.

Conclusions

1. The growth rates of subterranean clover exceeded those of lucerne because of the ability of this species to grow in the cool moist winter and early spring when moisture was still present.
2. The use of subterranean clover in moderate to low rainfall areas of New Zealand experiencing lower than normal spring summer rainfall, can result in a yield advantage over lucerne.
3. Winter and spring growth rates of subterranean clover are likely to exceed those of perennial pasture grasses, which makes it more logical to grow subterranean clovers as a pure sward rather than with a perennial grass.

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