

PASTURE RESPONSES TO GRAZING MANAGEMENT IN HILL COUNTRY

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Abstract

Components of growth and defoliation of perennial ryegrass and browntop tillers and white clover stolon apices were measured for 12 months in hill pastures set stocked (SS) or rotationally grazed (RG) with sheep. Leaf appearance intervals of the grasses were unaffected by grazing management. Tiller densities were greater under SS (annual mean 29,700 total tillers/m² cf. 20,100/m² under RG), compensating for greater leaf extension rates and lamina lengths of individual tillers under RG. White clover leaf appearance intervals were similar under both managements except in summer when RG was superior to SS during 3 grazing rotations.

Defoliation of grass tillers was more frequent under SS when rotation lengths exceeded 3 weeks, but more severe (in terms of leaf length removed) under RG throughout the year. These mechanisms, combined with tiller density differences, contributed to the likelihood of equal leaf removal per unit area under both managements. Some advantage to RG in ryegrass leaf growth and total leaf removal was indicated but the differences were small and unlikely to affect animal production. White clover leaf removal was similar under both managements.

Grazed swards are dynamic and can change rapidly under different grazing managements; however, at acceptable levels of pasture utilisation, the dominant responses appear to maintain an equilibrium in leaf growth. Thus the use of other procedures, e.g. fertiliser application and increases in stocking rate, in conjunction with management changes is required to substantially alter pasture and animal production.

Keywords: hill country, grazing management, pasture productivity, perennial ryegrass, browntop, white clover, leaf growth, tiller density, defoliation frequency, defoliation severity.

INTRODUCTION

There have been numerous comparisons of grazing managements for sheep on North Island hill country (Suckling 1959, 1975; Collin 1966; Clark *et al.* 1982; Lambert *et al.* 1983). These have not shown clear superiority in herbage or animal production of either set stocking or rotational grazing despite probable advantages to the latter in pasture light interception (Black 1964; Brown & Blaser 1968), botanical composition (Harris 1978) and root system development (Smith & Dawson 1976). Recently, doubts have been expressed concerning the degree to which herbage production may be affected by grazing management (Hodgson & Wade 1978; Hodgson *et al.* 1981; Hodgson & Maxwell 1982; Clark *et al.* 1982).

The imposition of different defoliation frequencies and severities is central to the development of contrasting grazing managements. Hodgson & Wade (1978) found only limited sward responses to variations in defoliation severity between 25 and 150 mm, or defoliation intervals exceeding 2 weeks. The frequency and severity of defoliation of New Zealand hill pastures have not been measured so no basis exists for critically appraising different managements.

The purpose of this study was to measure components of growth (density, rate of growth and size) and components of defoliation (frequency and severity) of individual grass tillers and white clover stolon apices under set stocking and rotational grazing to assess species responses to different grazing managements.

This information can be used, with data on herbage production and animal performance obtained from the same systems (Clark et al. 1982; Lambert et al. 1983). to suggest management options which may improve pasture and animal production at critical times of the year.

MATERIALS AND METHODS

The study was conducted within a grazing management and fertiliser application experiment at Ballantrae, the hill country research area of Grasslands Division, DSIR, near Woodville. Pastures were set stocked (SS) or rotationally grazed (RG) with sheep at 12.8 ewes/ha. Rotation lengths varied from 14 days in late spring and summer to 63 days in winter and RG ewes were set stocked during lambing (20 August - 14 October 1980). SS ewes were mob stocked during mating (17 March - 21 May 1980). Full details of soils, pastures and experimental procedures were given by Lambert et al. (1983).

Fifty-four tillers of perennial ryegrass (*Lolium perenne* L.) and browntop (*Agrostis tenuis* Sibth.) and 54 stolon apices of white clover (*Trifolium repens* L.) were marked in each management, in different fertiliser level, slope and aspect combinations. Leaf appearance intervals and extension rates, leaf and tiller lengths, defoliation frequency and severity, and leaf death rates for grasses were measured weekly from 11 March 1980 to 24 March 1981. For white clover, leaf appearance rate, defoliation frequency and severity, and leaf death rate were measured. On 6 occasions (Table 2), turf samples were removed for measurement of tiller densities. Full details of experimental procedures were presented by Chapman et al. (1983).

Results were analysed in 16 periods, each corresponding to the length of one grazing rotation, and periods have been combined in the following seasons: autumn = March, April and May (3 periods with SS ewes mob stocked for 9 weeks); winter = June, July and August (2 periods); spring = September, October and November (5 periods with RG ewes set stocked for 8 weeks), and summer = December, January and February (6 periods).

COMPONENTS OF GROWTH

Leaf Appearance

The interval between appearance of successive leaves on grass tillers was unaffected by grazing management (Table 1). However, whiteclover leaf appearance intervals were less under RG during 3 periods in summer, resulting in greater leaf production per stolon. Reasons for this difference are unclear, though reduced defoliation frequency under RG may have alleviated some stress at the time of maximum white clover growth.

Leaf Extension

The rate of extension of grass leaves was considerably greater under RG than SS throughout the year (Table 1). Rates for ryegrass were about twice those for browntop. Leaf and tiller lengths showed the same seasonal pattern and management responses as leaf extension rates for both species.

Tiller Density and Total Leaf Growth

Tiller densities were greater under SS than RG, particularly for browntop (Table 2). Mean annual total tiller densities were 29,700/m² for SS and 20,100/m² for RG, with SS significantly greater at 5 of the 6 sampling dates. Thus there was

Table 1: LEAF APPEARANCE INTERVALS (days) FOR ALL SPECIES; AND LEAF EXTENSION RATES (mm/day) FOR BROWNTOP AND RYEGRASS, UNDER SET STOCKING (SS) OR ROTATIONAL GRAZING (RG).

Season	Browntop			Ryegrass			White clover		
	ss		RG	ss		RG	SS		RG
Leaf appearance intervals									
Autumn	12.0	ns'	11.6	12.4	ns	12.7	12.6	ns	11.6
Winter	18.8	ns	20.1	20.8	ns	20.6	27.7	ns	24.7
Spring	12.6	ns	13.1	14.1	ns	13.9	12.9	ns	13.4
Summer	11.9	ns	11.4	14.4	ns	14.1	14.9	***	11.5
Leaf extension rates									
Autumn	1.2	**	1.7	2.4	***	3.6			
Winter	0.7	**	1.0	1.3	**	1.7			
Spring	1.0	***	1.3	1.7	***	2.1			
Summer	0.9	***	1.6	1.7	***	2.8			

¹ Means not significantly different.
(*), *, **, *** means significantly different at P<0.1, P<0.05, P<0.01, P<0.001 respectively (applies to tables 2, 3 and 4).

Table 2: DENSITY OF BROWNTOP OR RYEGRASS TILLERS (No./m²) UNDER SET STOCKING (SS) OR ROTATIONAL GRAZING (RG)

Season	Browntop			Ryegrass		
	ss		RG	ss		RG
Autumn (24 April)	14,500	**	6,900	4,400	*	2,500
Winter (24 June)	11,200	(*)	9,000	2,400	(*)	3,900
Early Spring (1 September)	11,600	**	6,500	3,500	(*)	2,000
Late Spring (4 November)	11,300	(*)	9,200	6,000	ns	5,500
Summer (6 January)	13,800	*	8,700	4,600	ns	4,700
Early Autumn (11 March)	12,500	*	9,500	4,400	ns	4,400

an inverse relationship between tiller density and individual tiller growth rates which probably equalised total grass leaf growth per unit area under SS and RG, substantiating the results of Lambert *et al.* (1983) who measured similar herbage accumulation rates under SS and RG in the same systems over 6 years. As the density of white clover stolon apices was similar under SS and RG (annual mean = 4035/m² v. 4008/m² respectively, Chapman 1983), and leaf size was unaffected by management (Lambert *et al.*, in prep), total white clover leaf production under the two managements was also likely to have been similar. Slightly greater ryegrass growth per unit area in RG pastures was indicated when mean superiorities of 44% in leaf extension rate and 49% in lamina length under RG were compared to only 17% more tillers under SS. For browntop, the reverse was indicated (45% faster leaf extension and 34% longer laminae under KG v. 54% more tillers under SS). These results, and those for white clover leaf production, are consistent with botanical composition data presented by Clark *et al.* (1982) from the same systems.

COMPONENTS OF DEFOLIATION

Defoliation Frequency

Defoliation intervals, the reciprocal of defoliation frequency, show that comparisons of SS and RG are in fact comparisons of two rotational systems (Table 3). Tillers were defoliated more frequently under SS than RG when rotation lengths exceeded 3 weeks (principally in winter and late summer). Significant differences in defoliation frequency for white clover occurred in autumn only. In winter there was little defoliation of white clover and Clark *et al.* (1982) measured only 1-2% legume in sheep diets at this time of year. Ryegrass tillers were defoliated more frequently than browntop.

According to the results of defoliation experiments summarised by Hodgson & Wade (1978), the frequency of defoliation under SS was unlikely to have been sufficient to depress herbage production and the differences between SS and RG were probably too small to influence herbage production rates.

Table 3: INTERVAL BETWEEN DEFOLIATIONS (days) OF BROWNTOP OR RYEGRASS TILLERS OR WHITE CLOVER STOLON APICES UNDER SET STOCKING (SS) OR ROTATIONAL GRAZING (RG)

Season	Browntop			Ryegrass			White clover		
	ss		RG	ss		RG	ss		RG
Autumn	31.5	ns	34.0	21.0	**	28.9	26.1	*	35.7
Winter	36.3	**	59.9	21.5	***	49.4	74.8	ns	71.0
Spring	21.8	ns	22.8	14.3	(*)	16.3	25.4	ns	29.0
Summer	22.8	(*)	28.4	17.8	***	25.0	26.5	ns	29.0

Defoliation Severity

Defoliation severity, as indicated by both the number of leaves grazed and mean individual leaf length removed at each grazing, was greater under RG than

SS throughout the year (Table 4). Approximately twice as much leaf was removed from ryegrass tillers as from browntop tillers.

Table 4: DEFOLIATION SEVERITY FOR BROWNTOP AND RYEGRASS TILLERS OR WHITE CLOVER STOLON APICES UNDER SET STOCKING (SS) OR ROTATIONAL GRAZING (RG) AS INDICATED BY a) NUMBER OF LEAVES GRAZED AT EACH GRAZING, AND b) MEAN LENGTH OF LEAF REMOVED (mm) FROM INDIVIDUAL GRAZED LEAVES (GRASSES ONLY)

Season	Browntop			Ryegrass			White clover		
	ss		RG	ss		RG	ss		RG
a) Number of leaves grazed									
Autumn	1.9	(*)	2.2	1.8	***	2.2	1.5	***	2.4
Winter	1.5	*	2.0	1.5	***	2.3	1.0	ns	1.2
Spring	1.5	ns	1.7	1.6	***	2.1	1.3	*	1.5
Summer	1.6	**	2.4	1.6	**	2.1	1.4	*	1.8
b) Mean leaf length removed									
Autumn	10.3	***	17.2	20.1	***	40.7			
Winter	6.7	***	11.8	15.3	***	28.9			
Spring	7.3	**	10.5	12.5	***	19.3			
Summer	7.0	***	13.2	13.8	***	24.6			

Total Leaf Removed

The number of times a tiller was defoliated during any season (frequency), multiplied by the mean length of leaf removed from the tiller at each grazing (severity, the product of Table 4(a) and (b)), gives an estimate of total leaf removed per tiller during each season. The isoquants of Fig. 1 show that any value for total leaf removal can be achieved by quite different frequency x severity combinations, as occurred for browntop under SS and RG in winter. However, at most times of the year, leaf removal per tiller was greater under RG than SS (annual mean = 38% for ryegrass and 72% for browntop) as shown by the relative position of mean values for each management within a season in Fig. 1. When combined with tiller density data (Table 2), much smaller differences in leaf length grazed per unit area (which approximates intake) can be expected.

Slightly higher ryegrass leaf removal per unit area under RG than SS during at least part of the winter and summer is indicated by comparisons of total leaf removed per tiller (frequency x severity, Fig. 1) and tiller density data (Table 2). A similar comparison for browntop suggests slightly higher leaf removal under RG in summer. Maximum leaf removal per tiller occurred in summer for both grasses under both managements and exceeded minimum values for leaf removal by a factor of 4. There is little difference in total white clover leaf removal between managements when defoliation frequency and severity data are combined (Tables 3 and 4).

Relationships between Frequency and Severity

A positive linear relationship between defoliation frequency and severity under RG occurred at most times of the year (Fig. 1). The regressions shown were significant at $P < 0.001$; all other regressions were non-significant. Each regression line was derived from 18 points (2 fertiliser levels $\times$ 3 aspects $\times$ 3 slope classes) and essentially describes the distribution of defoliation across the varied topography within RG farmlets. Larger tillers from areas of less than 12° slope (Chapman *et al.*, 1983) are represented nearer the top of each regression, while small, slower-growing tillers from steep areas were distributed nearer the origin. In some cases, the latter tillers were undefoliated during a grazing rotation, hence the fit through the origin.

These results imply that areas of rotationally grazed hill pasture are defoliated in proportion to their rate of growth, and accessibility (which is largely determined by tiller size) rather than stock selection for preferred species influences the frequency and severity of defoliation of plant units. These observations are supported by multiple regression analyses of total plant defoliation using plant and pasture parameters such as tiller length, herbage mass and botanical composition as independent variables (Clark *et al.*, in prep).

The absence of any relationship between defoliation frequency and severity under SS is perhaps a reflection of these uniformly short pastures offering less scope for variation in defoliation severity. In these circumstances, sheep compensate to a degree with higher defoliation frequency (Table 3) so that regression lines for SS data would tend to parallel the x-axis of Fig. 1.

OVERALL EFFECT OF MANAGEMENT

Compensatory mechanisms within the sward and at the pasture-animal interface acted to largely equalise both the amount of herbage grown and the amount consumed under both managements. Examples were the inverse relationship between tiller density and tiller growth, and greater defoliation frequency under SS partially offsetting greater severity under RG. Leaf and tiller parameters are probably closely related to current photosynthetic activity but may provide a better explanation of differences in herbage growth between managements than simple leaf area index information. Other factors such as sward height, leaf alignment and the proportion and distribution of active photosynthetic tissue in the sward (Hodgson & Maxwell 1982) could influence overall photosynthetic efficiency in well utilised SS swards.

Some differences were detected in leaf growth and removal in favour of RG but given the ability of stock to compensate through body reserves and other mechanisms, and the small size of the differences, they are unlikely to have resulted in greater animal production. Ryegrass did respond better to RG than browntop and this management may improve herbage production in areas where ryegrass is the major sward component.

Herbage left ungrazed ultimately dies and decays. As may be predicted from similarities in growth and defoliation recorded under the two managements, leaf utilisation and leaf death rates were also similar between managements. Leaf death rates were of similar magnitude to, and followed the same seasonal pattern as, leaf appearance rates. Utilisation of leaf tissue, calculated by difference from leaf growth and leaf removal data, ranged between 54 and 80% for ryegrass, 37-55% for browntop and 40-66% for white clover during the year. Minimum utilisation occurred in autumn for the grasses and in winter for white clover,

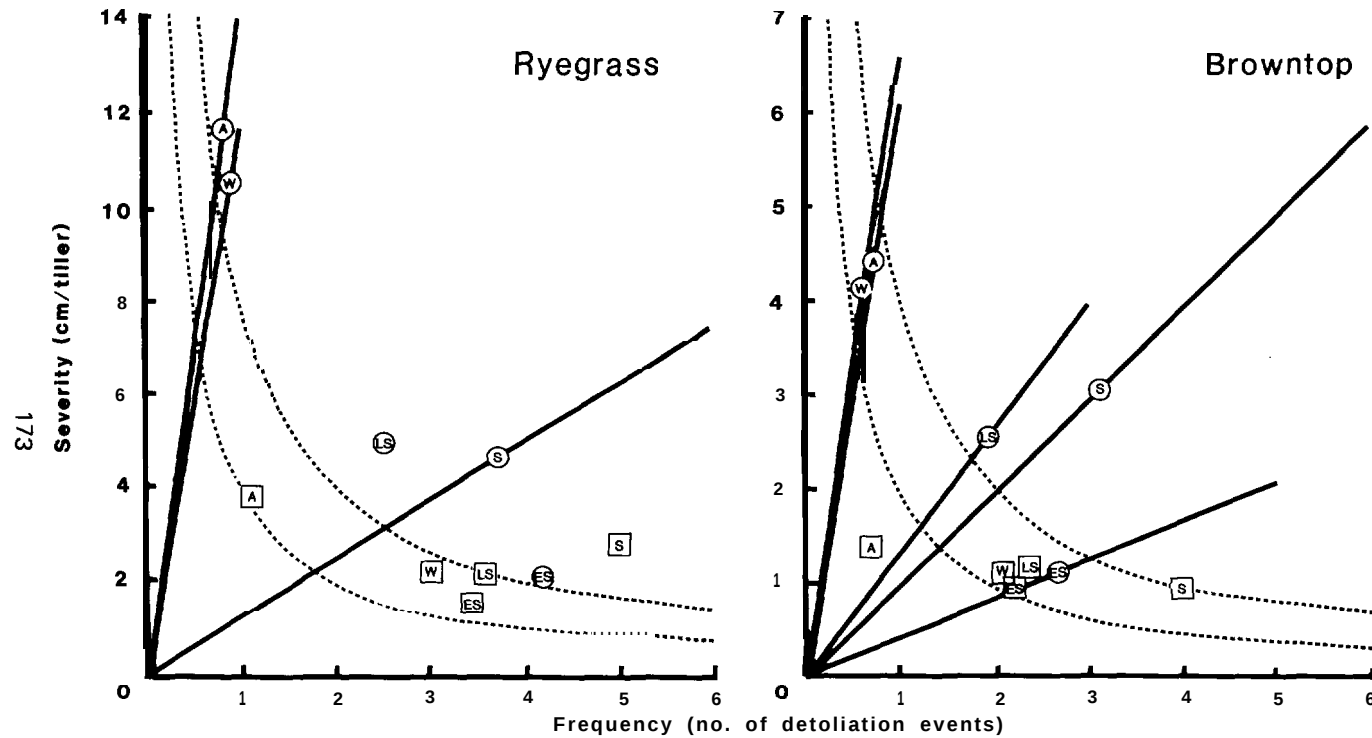


Fig. 1: Relationship between defoliation severity (leaf length grazed per tiller at each grazing) and frequency (no. of defoliation events during a season) for *ryegrass* and *browntop* during autumn (A), winter (W), early spring (ES, when all pastures were set stocked), late spring (LS) and summer (S). Mean values for each management in each season are indicated by circles (rotational grazing) or squares (set stocking); these means are estimates of the total length of leaf removed from tillers during each season. The dotted curves are isoquants which join equal values for total leaf removal during any time period e.g. the lower curve for ryegrass = 4 cm/tiller, which can be obtained by one defoliation event removing 4 cm leaf, or 4 defoliation events removing a mean of 1 cm leaf.

while maximum utilisation occurred in late spring-early summer when both ewes and lambs were grazing, for all species. Thus despite a relatively high stocking rate and good year-round pasture control under both managements, considerable quantities of herbage escaped defoliation and entered the litter cycle.

FARM APPLICATIONS

It has been shown (Hodgson *et al.* 1984) that compensatory mechanisms can maintain similar net growth and animal intake between 1000 and 2500 kg DM/ha herbage mass. Our results, obtained in pastures ranging between 750 and 2500 kg DM/ha mass during the year, and the results of Clark *et al.* (1982) and Lambert *et al.* (1983), support this observation and provide explanations for differences between managements that may occur above and below these levels. For instance, below 1000 kg DM/ha longer defoliation intervals under RG may give better net growth and higher intakes as more frequent grazing under SS can no longer compensate for low intake per defoliation. Above 2500 kg DM/ha, longer defoliation intervals under RG allow more reproductive growth in spring and summer causing a decline in pasture quality, ewe and lamb intakes and animal performance (Clark *et al.* 1982).

There are several management options which should help avoid these problems:

1. Combination of rotational grazing in late autumn and winter with set stocking for the rest of the year.
2. Set stocking all year with tactical use of N fertiliser when herbage mass falls below a certain level in late autumn. Tillers in set stocked swards are defoliated in a rotational sequence and hence can respond to N. Resulting increases in herbage accumulation should improve nutrition of ewes in late winter.
3. Rotational grazing with winter rotation lengths dependent on pasture growth rate, and with fast rotations (two weeks) from docking until prior to mating to control spring-summer pasture growth.

The most effective grazing management for hill country is likely to involve both set stocking and rotational grazing. Set stocking during spring and summer will maintain high tiller densities and therefore more stable pasture performance in the event of soil moisture stress or other factors causing tiller death, and help control spring pasture surpluses (Clark *et al.* 1982). Rotational grazing will allow better nutrition of livestock when the balance between tiller density, tiller growth rates and defoliation patterns may break down, e.g. during low pasture growth rates in winter and when herbage mass is less than 1000 kg DM/ha. However, procedures such as fertiliser application and concurrent increases in stocking rate, used in conjunction with management changes, are required to rapidly increase pasture and animal production.

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