The effect of grazing severity during winter on herbage regrowth and quality

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Abstract
Grazing management is concerned with managing the interactions between plants and animals. Two management factors that require consideration are the optimal grazing time and the effect of grazing severity on subsequent regrowth. The objective of the current study was to quantify the effect of grazing severity in winter on leaf appearance rate, herbage accumulation and quality, and plant energy reserves. Ten pasture areas were grazed to two different residual masses (1260 ± 101 and 1868 ± 139 kg dry matter (DM)/ha, Severe and Lax, respectively) over five consecutive days by dry dairy cows. Neither growth rate (average 15 kg DM/ha/day), nor leaf appearance rate (average 16 days/new leaf) differed between treatments. As a result, herbage accumulated over the 49-day regrowth period was similar between grazing treatments (736 and 715 kg DM/ha for Severe and Lax, respectively), although herbage mass when three new leaves had emerged on regrowing tillers (third leaf stage) was greater on the laxly grazed treatment. Perennial ryegrass plants defoliated more severely displayed a trend for lower levels of water-soluble carbohydrates (WSC) than plants defoliated more laxly, but this difference had disappeared by the third leaf stage of regrowth. Pasture quality was improved in the severely defoliated treatment, with higher digestibility, WSC and metabolisable energy (ME) concentrations, and (ADF) lower acid and neutral detergent fibre (NDF) concentrations.
Keywords: grazing severity, herbage production, water-soluble carbohydrates

Introduction
Too frequently, the focus of grazing management is on meeting animal requirements, rather than understanding the way in which the plants respond to the grazing management regimes imposed (Fulkerson & Donaghy 2001).

In most temperate regions of the world, combined effects of differences in temperature, moisture availability and radiation lead to variations in seasonal herbage production (McKenzie *et al.* 2000). These are generally characterised by feed surpluses during the spring, and depending on the farm system, potential feed deficits during winter and summer. Managing this variation in forage production can be difficult and involves changes in grazing frequency and severity throughout the year.

Previous studies (Wilson & Robson 1970; Simons *et al.* 1972; Fulkerson *et al.* 1994) recommend an optimal defoliation height of approximately 5 cm to optimise ryegrass growth and persistence. Defoliation below this height may reduce WSC stores, particularly during winter when radiation intensity, and therefore subsequent replenishment of carbohydrate stores, is low. It has also been suggested (Smith 1974; Booysen & Nelson 1975) that a less severe grazing (leaving residual leaf), will result in faster recovery of ryegrass swards, an important factor during winter when feed is scarce.

There are conflicting reports on the effect of defoliation severity on herbage production. Several studies demonstrated a reduction in subsequent DM yields and growth rates of pastures with more frequent (<2-3 weeks apart) and severe (<1500 kg DM/ha; <4 cm residual height) defoliation (Baker 1957; Jones 1933), whilst in others, herbage accumulation was greater when grazing residuals were lower (Binnie & Harrington 1972; Reid 1959, 1962; Reyes *et al.* 2000). In addition, severe grazing improved tillering (Brougham 1960; Michell & Fulkerson 1987; Xia *et al.* 1990) and subsequent herbage quality (Michell & Fulkerson 1987; Reyes *et al.* 2000).

The confounding effect of grazing frequency and severity in many reported studies makes it difficult to determine the true effect of grazing severity. In several studies pastures were defoliated at precise heights or after a certain length of time, which may have led to pastures being inadvertently grazed prior to emergence of the second new leaf (Binnie & Harrington 1972; Brougham 1960; Reid 1959, 1962), a physiological stage believed to reduce carbohydrate storage and plant vigour (Fulkerson & Donaghy 2001).

The aim of the current study was to quantify the effect of grazing severity in winter on leaf appearance rate, herbage accumulation and quality, and plant energy reserves, without the confounding effect of grazing frequency.

Materials and methods
The experiment was conducted on a humic silt loam soil at Scott Farm, Dexcel, Hamilton, New Zealand (37° 46'S 175° 18'E) between July and September 2004. The permanent grassland site consisted of a sward with 80-90% perennial ryegrass on a DM basis and had not been grazed in the last 70 days. The sward also

Table 1 Mean weekly weather data for the duration of the pasture regrowth period.

	Week One[1]	Week Two	Week Three	Week Four	Week Five	Week Six	Week Seven
Maximum air temperature (°C)	13.4	14.6	14.0	14.7	14.3	13.2	13.9
Minimum air temperature (°C)	0.9	3.0	3.8	6.6	3.8	1.1	0.9
Radiation (MJ/m^2)	9.4	8.1	8.0	8.5	10.3	13.2	12.9
Soil temperature at 10cm (°C)	9.2	9.9	9.9	10.6	10.5	10.0	9.6
Total rainfall (mm)	3.6	24.6	43.6	36.6	6.8	9.2	14.6

[1] Week One beginning 19th July 2004.

contained white clover (*Trifolium repens*), Poa (*Poa annua*) and prairie grass (*Bromus willdenowii* Kunth.)

Five blocks of two plots (ten plots in total) were defoliated by dry dairy cows over five consecutive days to achieve residuals of either 1200 kg DM/ha (Severe) or 1800 kg DM/ha (Lax). Three subplots (each 0.5 m^2) were randomly located in each of the ten plots for intensive herbage measurements.

Weather data were recorded at 0900 daily over the trial period, at a weather station less than 5 km from the trial site. Soil temperature (°C) data at 10 cm depth were also collected at the experimental farm. Weather data are presented in Table 1.

Herbage measurements

Compressed herbage height was measured on each subplot, immediately post-grazing, and on day 3, 6, 10, 13, 20, 28, 38, 45 and 49 post-grazing, using a Rising Plate Meter installed with an electronic counter (Farmworks, Palmerston North). These values were converted to DM yield using a regression equation derived from calibration cuts, as follows:

Herbage mass (kg/DM/ha) = 298.2 x compressed herbage height (cm) + 785.1; $R^2 = 0.75$; n = 457.

Three weeks following defoliation, perennial ryegrass leaf regrowth stage was determined using the method outlined by Fulkerson & Donaghy (2001), and thrice weekly thereafter.

When, on average, one, two or three new leaves had appeared on treatment subplots, 30 mature perennial ryegrass tillers (including roots) were randomly harvested at each stage, from each subplot. Tillers were collected approximately 3 hours after sunrise to minimise the effects of known diurnal variation in WSC content (Fulkerson *et al.* 1994) and placed on ice. The time from ice to freezer was no longer than 10 minutes. The numbers of daughter tillers per mature tiller were counted, tillers washed to remove soil contamination, and roots removed from the base of the tiller. Leaves were separated from the stem (stubble) at the auricle, and average stubble length measured. From each subplot, the length and width (at the widest part) of all leaves on three ryegrass tillers were measured to determine average leaf area. Leaves and stubble for each subplot and leaf stage were stored at –20°C, freeze-dried, ground to pass through a 1 mm sieve and analysed for WSC. Water-soluble carbohydrate concentration (g/kg DM) was determined as described in Technicon Industrial Method number 302-73A from the method outlined by Smith (1969).

When, on average, the third new perennial ryegrass leaf had appeared on treatment subplots, ryegrass tiller numbers in three randomly positioned 0.01 m^2 quadrats were counted in each subplot, providing an estimate of ryegrass tiller density. A representative herbage sample was cut to 3 cm height from the centre of each subplot (n=10), blended and subsampled. One subsample was dissected to determine botanical composition, and another dried at 60°C to a constant weight, ground to pass through a 1 mm sieve and analysed for quality parameters using near infrared spectroscopy (Corson *et al.* 1999).

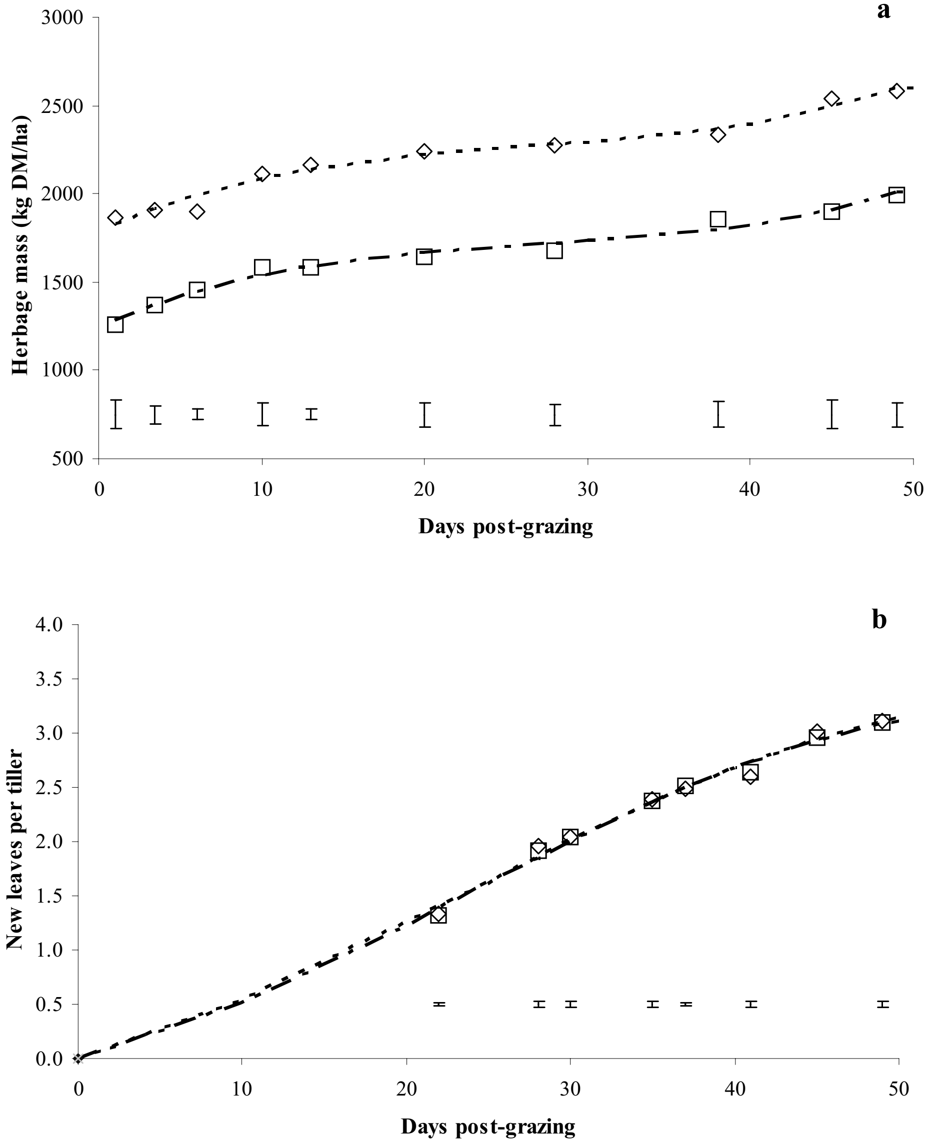
Statistical analysis

Data collected from the third block of plots were omitted from all analyses due to treading damage in the Severe treatment. All data were analysed by ANOVA using the statistical procedures of Genstat 7 (2004), with grazing severity as the fixed effect and block and plot as the random effect. The F-test was used to determine the significance of the explanatory variables. Cubic splines were fitted within subplot using PROC TRANSREG (SAS 2001) to both regrowth and leaf appearance rate data. Data were interpolated and extrapolated from the fitted splines.

Results

As planned, the post-grazing residuals on the severely grazed plots were significantly lower than the laxly grazed comparisons ($P<0.01$; 1.6 vs 3.6 cm compressed height, equating to 1260 and 1868 kg DM/ha, respectively). The R^2 of the splines averaged 0.88 and 0.99 for herbage mass and rate of appearance of new leaves, respectively. Growth rates during the 49 days of regrowth period averaged 15 kg DM/ha/day and average rate of appearance of new leaves was 16 days/ new leaf (Figure 1). Neither were affected by grazing severity. As a consequence, herbage accumulation was not different between grazing treatments, and averaged 726 kg DM/ha (715 and 736 kg DM/ha for Lax and

Figure 1 (a) Herbage mass and (b) leaf appearance rate of severely (square) or laxly (diamond) grazed pastures during the first 50 days postgrazing; fitted splines for severely (dash-dot line) and laxly (dashed line) grazed swards are presented. Vertical bars indicate twice the SED.



Severe, respectively). The laxly grazed treatment subplots had a higher DM yield than those severely grazed (2583 vs. 1996 kg DM/ha after emergence of the third new leaf; $P<0.01$).

The area of newly emerged leaves was not affected by grazing severity at the first or second leaf stage of regrowth. However, on appearance of the third new leaf, laxly grazed ryegrass produced larger leaves than those severely grazed (873 vs. 794 mm^2; $P<0.05$).

There was no effect of grazing severity on tiller density or the number of daughter tillers produced/mature tiller during the regrowth period, with an average of 7 daughter tillers produced/10 mature tillers.

There was a trend for lower WSC levels in the leaf and stubble of severely defoliated perennial ryegrass plants than laxly grazed counterparts, at the first and second leaf regrowth stage, but this difference was not significant following emergence of the third new leaf (Table 2).

Herbage quality was improved in the severely grazed treatment (Table 3) with ME concentrations increased by 0.3 MJ/kg DM, digestibility increased by 2.6 g/100 g

Table 2 Water-soluble carbohydrate levels (g/100g DM) in perennial ryegrass leaf and stubble at the first, second and third leaf stage of regrowth following defoliation to either 1.6 (Severe) or 3.6 (Lax) cm compressed height.

		Lax	Severe	SED	P value
WSC (g/100g) DM)					
First leaf stage	Leaf	13.4	10.9	0.71	<0.05
	Stubble	23.0	20.0	2.12	0.25
Second leaf stage	Leaf	17.3	14.0	1.08	0.06
	Stubble	30.3	25.7	1.36	<0.05
Third leaf stage	Leaf	30.8	28.8	1.03	0.15
	Stubble	39.9	39.0	2.50	0.63

Table 3 Botanical and chemical composition (g/100g DM) and ME (MJ/kg DM) content of pasture regrowth[1] after appearance of the third new leaf following defoliation to either 1.6 (Severe) or 3.6 (Lax) cm compressed height.

	Lax	Severe	SED	P value
Botanical composition				
Ryegrass leaf	71.9	82.5	2.64	<0.05
Ryegrass pseudostem	5.2	5.9	0.89	0.50
White clover	5.0	3.1	1.98	0.40
Other grasses	7.7	3.6	1.41	0.06
Weeds	2.6	1.8	0.84	0.42
Dead material	7.7	3.2	0.85	<0.05
Chemical composition				
CP	23.7	23.0	0.70	0.39
Lipid	4.8	5.0	0.12	0.15
Ash	9.0	8.6	0.20	0.10
ADF	16.7	14.8	0.50	<0.05
NDF	33.4	31.5	0.64	0.06
WSC	18.6	21.3	0.58	<0.05
OMD	81.8	84.4	0.57	<0.05
ME	11.9	12.2	0.08	<0.05

[1]Pasture was cut at a 3 cm stubble height.

DM and WSC concentrations increased by 2.7 g/100 g DM. Acid and neutral detergent fibre concentrations were also reduced in the severely grazed treatment by 1.9 g/100 g each.

After appearance of the third new leaf, severely grazed subplots contained more perennial ryegrass leaf and less dead material than laxly grazed subplots (Table 3). There was also a trend towards reduced proportions of other grasses, such as prairie grass and Poa, in the severely grazed treatments, compared with those laxly grazed.

Discussion

Growth rate, leaf appearance rate and leaf area were not affected by grazing severity. The effect on growth rate contrasts with previous studies (Smith 1974; Booysen & Nelson 1975) suggesting increased levels of residual leaf remaining following lax defoliation (>1500 kg DM/ha; >4 cm residual height) may increase regrowth, but supports the fact that these residual leaves are generally older and less photosynthetically active than younger emerging leaves (Gay & Thomas 1995) and therefore contribute very little to subsequent regrowth.

Despite the similar overall herbage accumulation, the laxly grazed treatment subplots had a higher final DM yield/ha due to higher residuals at the start of the experimental period. At the end of the 49-day regrowth period there was an extra 587 kg DM/ha in laxly defoliated swards compared to those severely defoliated (2583 vs. 1996 kg DM/ha, respectively). This remains important because pregrazing pasture mass can influence herbage intake and hence animal production.

Previous research recorded both increased and decreased leaf appearance rates when comparing severe and laxly defoliated treatments. In a glasshouse study, Davies (1974) reported an increasing leaf appearance rate as plants were more severely defoliated, although the difference was small and confined to the first week of herbage regrowth. In contrast, Grant *et al.* (1981) reported that severe defoliation (2 cm) decreased leaf appearance rate compared with lax (6 cm). In this case the effect lasted 4 weeks. This inconsistency in results suggests that other factors must influence the effect of grazing severity on leaf appearance. These could include soil fertility, fertiliser application, climate or previous grazing management that would influence the levels of energy reserves in the plant.

The major finding of this study was that WSC levels in both the leaf and stubble components of perennial ryegrass were high, suggesting that even when severely defoliated, sufficient reserves were present to allow regrowth (Alberda 1966). Accumulation of WSC in ryegrass is greatest in conditions that promote photosynthesis, such as full light, or reduce respiration, such as cooler temperatures (Alberda 1957). Kingsbury (1965) reported that WSC concentrations in perennial ryegrass in New Zealand were maximised in early winter after a bright, sunny afternoon. As well as the balance between photosynthesis and respiration, absolute levels of WSC also depend on plant growth rate (White 1973). The high levels of WSC recorded in this experiment are likely due to a combination of low minimum temperature (Table 1) and consequent low growth rates and plant respiration.

Alberda (1966) indicated that perennial ryegrass regrowth appeared retarded when stubble WSC concentrations were below 15%. Due to the high energy reserves of plants in the current study, severe grazing did not substantially lower WSC to levels where reserves may have limited the plant's ability to regrow. The effect of grazing severity on ryegrass plants with lower WSC reserves is an area for further research.

This study supports previous research (Michell & Fulkerson 1987; Reyes *et al.* 2000), showing improved pasture quality with greater grazing severity (<1500 kg DM/ha; <4 cm residual height). The improvement in herbage quality in the severely grazed subplots in the current study was due to favourable alterations in botanical composition, in particular increased ryegrass leaf and decreased proportions of other grasses and dead material in the sward. Reduced herbage quality in laxly grazed subplots is likely due to the carryover of older leaf material from the pregrazing pasture.

Conclusion

From this study we conclude that when plant energy reserves are high, pastures may be grazed more severely during winter, as long as soil and environmental conditions are such that treading damage won't occur, with no detrimental effects on herbage regrowth or energy reserve levels. Severe defoliation in winter resulted in significant beneficial effects on herbage quality and botanical composition.

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