The effect of grazing pressure on rotationally grazed pastures in spring/early summer on subsequent sward characteristics

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Two experiments (E1 and E2) were carried out to examine the effect of grazing pressure (GP) in the early part of the grazing season on subsequent sward composition. Three GP levels, equating to 6.35, 4.24 and 3.53 cows/ha in E1, and 6.06, 5.05 and 4.03 cows/ha in E2, were used. The GP treatments were applied between April and July in E1, and April and June in E2. As GP decreased different swards, termed high (HQ), medium (MQ) and low (LQ) quality, were created. The post-grazing sward heights at the end of the GP periods were 6.6, 10.5 and 14.6 (s.e. 0.78) cm in E1, and 5.9, 8.8 and 11.4 (s.e. 0.39) cm in E2, for HQ, MQ and low LQ, respectively. Organic matter digestibility coefficients for herbage from the HQ, MQ and LQ swards during the subsequent grazing cycles averaged 0.770, 0.729 and 0.702 (s.e. 0.0055) in E1, and 0.761, 0.731 and 0.711 (s.e. 0.0038) in E2, respectively. Average live leaf proportions of the HQ, MQ and LQ swards were 0.583, 0.427 and 0.329 (s.e. 0.0193) in E1, and 0.600, 0.474 and 0.362 (s.e. 0.0155) in E2, respectively. GP had a significant effect on the proportion of grass area categorised as short grass (SG). The proportions of SG area in HQ, MQ and LQ were 0.711, 0.579 and 0.445 (s.e. 0.0106), respectively, in E1, and 0.700, 0.556 and 0.441 (s.e. 0.0133), respectively, in E2. Pre-grazing herbage mass (dry matter above 45 mm) was 2,065, 2,736 and 3,700 (s.e. 144.1) kg/ha for HQ, MQ and LQ, respectively, in E1 and 2,688, 3,735 and 4,722 (s.e. 145.0) kg/ha for HQ, MQ and LQ, respectively, in E2. The results show the importance of early season grazing pressure in creating a leafy high-digestibility sward for the remainder of the grazing season.

Keywords: grazing pressure; herbage composition; post-grazing height; stocking rate

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Introduction

In mown grass swards, maximum annual herbage production is normally obtained when harvesting is delayed until flowering (Binnie, Chestnutt and Murdock, 1980). However, because the nutritive value of grass swards declines markedly at culm extension and flowering, the annual yield of digestible herbage can be reduced when harvesting is delayed (Korte, Spall and Chu, 1982). Pasture herbage is a mixture of several components including leaves, stems and seed heads, at various stages of maturity from young living tissue to senescent and decaying material. The chemical composition and digestibility of these components can differ and vary widely with changes in age (Terry and Tilly, 1964; Hacker and Minson, 1981).

A significant factor influencing pasture chemical and component composition is previous grazing management (Stockdale and King 1980; Korte, Watkin and Harris, 1984; L'Huillier, 1987; Holmes *et al.,* 1992). Stocking rate is a major factor affecting output per unit area of land (McMeekan and Walsh, 1963), which in the short term may affect cow performance through its influence on daily herbage allowance per cow. For grazed swards, stocking rate may also have long-term effects on sward composition. Baker and Leaver (1986) showed that applying high stocking rates to continuously grazed pastures in spring produced swards with higher tiller density, higher live/dead tiller ratio and improved herbage digestibility. Korte (1981) and Holmes and Hoogendoorn (1983) showed that swards which were laxly grazed in spring had a higher proportion of stem and dead material in summer than swards which were grazed more severely. Swards that had a higher proportion of stem and dead material had a lower digestibility (Korte *et al.,* 1984). Leafy vegetative swards were obtained by severe grazing in spring, which removed reproductive tillers (Korte *et al.,* 1984). Thus, it was concluded that late spring grazing management of ryegrass dominant pastures should aim to leave low residual herbage mass as this would result in a leafy vegetative sward in summer.

The objective of the two experiments reported here was to manipulate the structure of grass swards by imposing different grazing pressures during spring/early summer and examine the consequences on subsequent sward characteristics and dairy cow performance from late summer to autumn. This paper contains the sward composition results. The effects on cow performance are reported in a companion paper (Stakelum and Dillon, 2007)

Material and Methods

The two experiments (E1 and E2) were carried out at Moorepark Research Centre in 1986 (E1) and 1987 (E2). The same experimental site was used in both years and consisted of swards with 80 to 90% perennial ryegrass (*Lolium perenne* L.) plus some *Agrostis* and *Poa* species. The *Lolium perenne* varieties were late flowering. The soil type was a free draining acid-brown earth of sandy loam to loam texture.

Swards and treatments

In both years a preliminary grazing took place to harvest the herbage that had accumulated over the winter/spring months. This occurred from 9 to 23 April in E1, and from 2 to 18 April in E2. Afterwards, the grazing season was divided into two periods. In Period 1 (P1) the swards were conditioned by using dairy cows to impose three different grazing pressures (GP). This took place between 28 April and 20 July in E1, and between 18 April and 21 June in E2. In Period 2 (P2) 22 July to 10 October in E1, and from 26 June to

5 October in E2, the resulting swards were grazed at two stocking rates (SR) by dairy cows.

Period 1: Twenty one equal-sized (0.472 ha) paddocks were grouped into 7 blocks of 3 and randomly assigned, from within block, to one of three GP, termed high, medium and low. Sixty three spring-calving Friesian dairy cows, balanced for calving date, parity and milk yield, were randomly assigned to three grazing groups in E1. In E2, 60 similar cows were similarly assigned. The residency time in each paddock was 1, 2 and 3 days for the low, medium and high GP, respectively. The grazing groups alternated between the different pastures according to a balanced design. The objective was to equalise any effects of GP on the performance of the cows, thus allowing the cows to be used in P2. An additional herd of 12 cows was used in E1 and two additional herds of 10 and 20 cows were used in E2. In E1, the additional herd grazed the low GP sward, while in E2 the two additional herds of 10 and 20 cows grazed the low and medium GP swards, respectively. The additional herds grazed for one day in the paddocks of the respective treatments following on behind the main herds. The objective was to achieve a higher grazing pressure in low GP in E1, and in low and medium GP in E2, than would have resulted from using only the three main herds. In E1 and E2, the GP treatments were applied for 4 and 3 grazing rotations of 21 days each, respectively. The GP in terms of stocking rates (cows/ha) and the number of cow grazing days for both E1 and E2 are shown in Table 1.

Period 2: The sward types (ST) produced as a result of the low, medium and high GP in P1 are termed low (LQ), medium (MQ) and high (HQ) quality. At the beginning of P2 each paddock was sub-divided in the ratio of 0.57:0.43 resulting in 0.20 and 0.27 ha in each sub-division. This allowed two SR, with equal numbers of cows, to be applied to each ST. The two SR were high (HR) or low (LR). In both E1 and E2 cows were blocked into groups of 6 on the basis of parity, calving date and milk yield, and were randomly assigned from within block to the 6 treatment groups. No first parity animals were used. Oesophageal fistulated (OF) cows were used to sample the swards and were grazed with the experimental cows. Stocking rate treatments were applied for 4 and 5 grazing rotations of 21 days each in E1 and E2, respectively. Cows entered a new paddock after evening milking and the residency time in each paddock was 3 days. The grazing rotation schedule and stocking rates during P2 are in Table 2. The reduction in SR over the experiment was achieved by withdrawing cows as follows. In E1, cows in blocks 3 and 6 were withdrawn for rotation 3 and the OF cows

Table 1. Number of cow grazing days per grazing rotation and resulting stocking rate (cows/ha) in Period 1 of Experiments 1 and 2

Experiment	Variable	Grazing pressure[1]		
		LP	MP	HP
1	Stocking rate	3.33	4.24	6.35
	No. of grazing days	231	294	441
2	Stocking rate	4.03	5.05	6.06
	No. of grazing days	280	350	420

[1] LP = Low pressure; MP = Medium pressure; HP = High pressure.

Table 2. The calendar (day/month) intervals and stocking rates (cows/ha) for each grazing rotation in Period 2 for high (HR) and low (LR) stocking rate treatments in Experiments 1 and 2

Experiment	Rotation	Calendar interval (dd/mm)	Stocking rate	
			HR	LR
1	1	22/07 – 11/08	5.44	4.09
	2	12/08 – 1/09	5.44	4.09
	3	2/9 – 22/9	4.03	3.03
	4	23/9 – 13/10	3.53	2.65
2	1	26/6 – 13/7	4.94	3.74
	2	14/7 – 3/8	4.94	3.74
	3	4/8 – 24/8	4.94	3.74
	4	25/8 – 14/9	4.23	3.18
	5	15/9 – 5/10	3.53	2.65

were removed for rotation 4. In E2, cows in block 5 was withdrawn for rotation 4 and the OF cows were withdrawn for rotation 5.

Fertiliser application

The experimental area received fertiliser N (51 kg/ha) in late January and again after the preliminary grazing in E1 and E2. In E1, fertiliser N was applied at the rate of 34 kg/ha after each of the 4 rotations of P1. In E2, fertiliser N was applied at 39, 34 and 34 kg/ha after grazing rotations 1 to 3, respectively, of P1. Fertiliser N was applied at the rate of 34, 39 and 34 kg/ha after grazing rotations 1 to 3, respectively, of P2 in E1, and at 39, 34, 34, and 34 kg/ha after grazing rotations 1 to 4, respectively, of P2 in E2. P and K were applied in early December, based on soil analysis and previous management (18 kg P and 35 kg K per ha).

Sward measurements

Sward measurements in P2 were recorded during rotations 1, 2 and 3 in E1, and during rotations 1, 2, 3 and 4 in E2.

Tall and short grass areas: The proportions of area in each sward designated as short (well grazed) grass (SG) and tall (partially rejected) grass (TG) were determined during the final grazing rotation in P1 on all blocks, and after each grazing in P2 on all blocks. A total of 100 point observations (5 transects with 20 observations per transect) were taken per plot. Each point was designated either SG or TG. Points were designated SG if within the immediate vicinity of the point, grazing occurred without the influence of a faecal deposit. If the alternative situation occurred, i.e., a faecal deposit affected grazing, the point was termed TG. This facilitated the evaluation of the area of each grazing paddock in terms of the proportion of SG to TG. Since the proportion of TG is the complement of the proportion of SG, only the proportion of SG is reported.

The number of TG patches was counted and their area was measured in P2 in grazing blocks 2 and 6. Two areas were selected at random within each paddock after grazing. A 10 m × 10 m square was constructed in each selected area and the number of TG patches within these areas was counted. The TG patch area and the number of patches per ha were calculated from these measurements and the proportion of the TG by area.

Post-grazing sward height: Post-grazing sward height (PGH) was measured using the HFRO sward stick (Hutchings, 1991). During P1, 40 measurements (20 per diagonal) were recorded on all paddocks immediately after grazing. In P2, 20 measurements were taken per plot from the SG, while 10 measurements were taken from the TG.

Herbage mass: Herbage mass (above 45 mm horizon) pre-grazing was measured in P2 for blocks, 1, 2, 3 and 6 in E1, and for blocks 1, 2, 4, 6 and 7 in E2. Due to inclement weather, the herbage mass measurements could not be taken on block 1 of rotation 1 in both experiments. Strips of grass (0.5 m wide and 5 to 8 m long) were cut with a reciprocating motor scythe. The measurements were taken separately in SG and TG and within the paddocks the cut strips were either SG or TG to avoid the influence of one on the other. A total of 4, 3 and 2 individual strips were harvested in the SG in the HQ, MQ and LQ swards, respectively, while 2, 2 and 3 strips were harvested in the TG from the HQ, MQ and LQ swards, respectively. The grass from each strip was weighed and a sub-sample (*ca.* 500 g) was taken. A large composite sample (*ca.* 2 to 4 kg) of SG and TG was taken from within each paddock. Two 100 g sub-samples were dried over-night at 90 °C for dry matter (DM) determination. Two further sub-samples were later obtained from the composite sample. The first sample (*ca.* 100 g) was placed in an aluminium tray, stored in a freezer at –20 °C, later freeze-dried, ground through a 1 mm screen and used for chemical analysis. The second sub-sample (*ca*. 50 g) was subjected to morphological separation (Thomas, 1980) before drying over-night at 90 °C. The components separated comprised live leaf (LL), dead leaf (DL), live stem (LS), dead stem (DS), weed and clover plant parts, and were expressed as g/g DM.

The proportion of SG in the total sward as well as the herbage mass, composition, organic matter digestibility (OMD) and PGH of the total sward were calculated from these values for SG and TG and the proportions of SG and TG in the total area.

Chemical analysis

The freeze-dried pre-grazing herbage samples were analysed for OMD by the procedure of Morgan and Stakelum (1987) as modified by Morgan, Stakelum and O'Dwyer (1989).

Statistical analysis

The model used for the analysis of PGH for the preliminary grazing and for the proportion of the grazing area as SG in the final grazing rotation of P1 had terms for GP and block only. The PGH for rotations 2 to 5 and 2 to 4 for E1 and E2, respectively, was analysed as a split-plot with a randomised block design in the main-plot.

The model was: Y_{ijkl} = mean + GP_i + Bj + $(GP \times B)_{ij}$ + R_k + $(GP\times R)_{ik}$ + e_{ijk}
where GP_i = grazing pressure effect (i = 1 to 3)
B_j = grazing block effect (j = 1 to 7)
R_k = grazing rotation effect (k = 1 to 4 for E1 and 1 to 3 for E2)
e_{ijk} = residual error term with 54 and 36 degrees of freedom for E1 and E2, respectively.

The effect of GP was tested using GP × B_{ij} as the error term.

The sward variables in P2 were analysed as a split-plot with a randomised block design and a factorial arrangement of treatments (3 × 2) in the main-plot.

The model was: Y_{ijkl} = mean + ST_i + SR_j + B_k + $(ST \times SR)_{ij}$ + $(ST \times SR \times B)_{ijk}$ + R_l + $(ST \times R)_{il}$ + $(SR \times R)_{jl}$ + $(ST \times SR \times R)_{ijl}$ + e_{ijkl}
where ST_i = sward type effect (i = 1 to 3)
SR_j = stocking rate effect (j = 1 to 2)
B_k = grazing block effect (k = 1 to 4 for E1 and 1 to 5 for E2)
R_l = grazing rotation effect (l = 1 to 3 for E1 and 1 to 4 for E2)

e_{ijkl} = residual error term with 36 and 72 degrees of freedom for E1 and E2, respectively.

ST and SR and the interaction between them were tested using $(ST \times SR \times B)_{ijk}$ as the error term.

For data measured on all grazing blocks, k was equal to 7, and e_{ijkl} had 72 and 108 degrees, for E1 and E2, respectively. For the number of TG patches and their area, e_{ijkl} had 10 and 15 degrees of freedom for E1 and E2, respectively. All analyses were carried out using the statistical procedures of SAS (SAS, 1991).

Results

Period 1

Post-grazing sward height: The effects of GP on the mean PGH for each grazing rotation of E1 and E2 are shown in Table 3. There was no effect of GP, as expected, on PGH for the preliminary grazing of E1. The low GP had a significantly lower PGH for the preliminary grazing of E2 compared to the other two. The difference, however, was not large (1.2 to 1.3 cm). There was a significant interaction between rotation and GP in both experiments. This was manifested in the trend for increasing PGH from rotation 2 to 4 for medium and low GP in E1 and from rotation 2 to 3 for low GP in E2.

Tall and short grass areas: Increased GP significantly ($P < 0.001$) increased the proportion of SG in the total area in both experiments for the last rotation of P1. The proportions in E1 were 0.78, 0.61 and 0.42 (s.e. 0.018) for high, medium and low GP, respectively. The corresponding values in E2 were 0.81, 0.66 and 0.50 (s.e. 0.015), respectively.

Period 2

Short and tall grass characteristics

Organic matter digestibility and morphological composition: The OMD and morphological composition of both the SG and TG for E1 and E2 are shown in Table 4. There was no significant interaction between the main effects and rotation so the data are presented as the means of the rotations. For both SG and TG, OMD and LL declined significantly ($P < 0.001$) as sward quality declined from high to low. The LS component increased significantly as sward quality deteriorated for SG in E1 and for both SG and TG in E2 while the DS component increased

Table 3. Effect of grazing pressure (GP) on post-grazing sward height (cm) for each grazing rotation (ROT) of Period 1 of Experiments 1 and 2

Experiment	Rotation	Grazing pressure[1]			s.e.	Significance		
		HP	MP	LP		GP	ROT	ROT × GP
1	P[2]	5.4	5.4	5.5	0.14			
	1	4.5[a]	7.2[b]	8.0[b]				
	2	5.7[a]	10.2[b]	13.2[c]	0.53	***	***	***
	3	5.8[a]	12.1[b]	17.0[c]				
	4	6.6[a]	10.5[b]	14.6[c]				
2	P[2]	6.3[a]	6.2[a]	5.0[b]	0.23	**		
	1	6.4[a]	7.5[a]	7.7[a]				
	2	5.5[a]	8.1[b]	10.0[c]	0.54	***	**	**
	3	5.9[a]	8.8[b]	11.4[c]				

[1] HP, MP, LP = High pressure, Medium pressure, Low pressure, respectively.
[2] Preliminary grazing rotation.
[abc] Values, within rows, with a common superscript do not differ significantly.

Table 4. The organic matter digestibility (OMD) and the proportions (g/g dry matter) of live leaf (LL), dead leaf (DL), live stem (LS) and dead stem (DS) in the short and tall grass of three sward types (ST) grazed at two stocking rates (SR) for Experiments 1 and 2

Variable	Sward type × Stocking rate†						s.e.	Significance‡
	HQ		MQ		LQ			
	HR	LR	HR	LR	HR	LR		ST
			Experiment 1: Short grass					
OMD	0.798^{a}	0.795^{a}	0.766^{ab}	0.765^{ab}	0.748^{b}	0.763^{ab}	0.0081	***
LL	0.740^{a}	0.750^{a}	0.635^{ab}	0.631^{ab}	0.577^{b}	0.645^{ab}	0.0292	***
DL	0.032^{a}	0.045^{ab}	0.083^{b}	0.066^{ab}	0.078^{b}	0.068^{ab}	0.0103	**
LS	0.163^{a}	0.160^{a}	0.173^{a}	0.195^{ab}	0.253^{b}	0.203^{ab}	0.0185	**
DS	0.042	0.022	0.073	0.070	0.067	0.060	0.0123	*
			Experiment 1: Tall grass					
OMD	0.761^{a}	0.751^{ab}	0.706^{cd}	0.724^{bc}	0.702^{cd}	0.681^{d}	0.0099	***
LL	0.512^{a}	0.465^{a}	0.334^{b}	0.369^{b}	0.262^{b}	0.271^{b}	0.0288	***
DL	0.082	0.128	0.122	0.103	0.119	0.122	0.0103	
LS	0.360^{a}	0.364^{a}	0.424^{ab}	0.431^{ab}	0.468^{b}	0.474^{b}	0.0236	***
DS	0.040^{a}	0.032^{a}	0.102^{bc}	0.081^{ab}	0.139^{c}	0.124^{bc}	0.0135	***
			Experiment 2: Short grass					
OMD	0.770^{a}	0.774^{a}	0.766^{ab}	0.755^{bc}	0.756^{bc}	0.745^{c}	0.0034	***
LL	0.687^{a}	0.715^{a}	0.660^{ab}	0.658^{ab}	0.604^{b}	0.595^{b}	0.0171	***
DL	0.061	0.042	0.066	0.063	0.069	0.070	0.0082	
LS	0.189^{ab}	0.176^{a}	0.198^{ab}	0.203^{ab}	0.237^{bc}	0.258^{c}	0.0136	***
DS	0.047	0.037	0.062	0.050	0.079	0.066	0.0124	*
			Experiment 2: Tall grass					
OMD	0.756^{a}	0.748^{a}	0.721^{b}	0.716^{bc}	0.693^{c}	0.708^{bc}	0.0068	***
LL	0.545^{a}	0.484^{ab}	0.424^{bc}	0.369^{cd}	0.308^{d}	0.289^{d}	0.0255	***
DL	0.074^{a}	0.100^{ab}	0.107^{ab}	0.107^{ab}	0.106^{ab}	0.120^{b}	0.0093	*
LS	0.337^{a}	0.365^{a}	0.395^{ab}	0.450^{bc}	0.487^{c}	0.489^{c}	0.0208	***
DS	0.035^{a}	0.047^{a}	0.068^{ab}	0.073^{ab}	0.101^{b}	0.099^{b}	0.0098	***

[abcd] Values, within rows, with a common superscript do not differ significantly.
† HQ = high quality sward, MQ = medium quality sward, LQ = low quality sward; HR = high stocking rate, LR = low stocking rate.
‡ SR had a significant ($P < 0.05$) effect on LL for tall grass in Experiment 2; the interaction between SR and ST was significant ($P < 0.05$) for DL of tall grass of Experiment 1 and for OMD of short grass in Experiment 2. No other effects involving SR were significant.

significantly as sward quality deteriorated for both SG and TG in both E1 and E2. There was less consistency with respect to changes in DL. Changes in DL as sward quality deteriorated were not significant for TG in E1 or for SG in E2 but DL increased as sward quality deteriorated for SG ($P < 0.01$) in E1 and for TG ($P < 0.05$) in E2.

There was little effect of SR on OMD or on herbage components except that LL decreased with decreased SR for TG in E2. There was no interaction between sward quality and SR except for DL in E1 for TG ($P < 0.05$) and OMD in E2 for SG ($P < 0.05$). The magnitude of these differences, however, was not of practical importance. Organic matter digestibility was linearly related to LL in the sward as follows:

SG in E1: 0.645 (s.e. 0.0152) + 0.191 (s.e. 0.0225) × LL.(r.s.d. 0.019; R^2 0.53),

TG in E1: 0.623 (s.e. 0.0098) + 0.264 (s.e. 0.0248) × LL.(r.s.d. 0.024; R^2 0.64),

SG in E2: 0.690 (s.e. 0.0141) + 0.107 (s.e. 0.0214) × LL.(r.s.d. 0.022; R^2 0.18), TG in E2: 0.643 (s.e. 0.0081) + 0.198 (s.e. 0.0192) × LL.(r.s.d. 0.026; R^2 0.49).

The intercepts tended to differ between experiments ($P < 0.10$) and did differ between SG and TG ($P < 0.01$). The slopes differed both between experiments ($P < 0.01$) and between SG and TG ($P < 0.01$). There was no interaction between experiments and SG and TG for either intercept or slope. Adding combinations of DL, LS or DS or a quadratic term for LL to the model did not improve the relationships significantly.

Herbage mass: In general, herbage mass of both SG ($P < 0.001$) and TG ($P < 0.05$) increased as sward quality deteriorated from high to low and the herbage mass of TG increased ($P < 0.05$) as SR decreased from high to low in E1 (Table 5). Similarly, herbage mass of both SG and TG increased ($P < 0.001$) as sward quality deteriorated in E2. There was a significant interaction ($P < 0.05$) between sward quality and SR for herbage mass in SG for E2 (Table 6). The herbage mass in SG increased as SR decreased from high to low for both MQ and LQ swards but this did not happen for the HQ sward. The effect of SR on herbage mass in TG was clearer – it increased ($P < 0.05$) as SR decreased from high to low for all levels of sward quality.

Post-grazing sward height: In general, PGH increased significantly ($P < 0.001$) as sward quality deteriorated and SR decreased for both SG and TG in E1 and effects were similar in E2 (Tables 5 and 6). There was an interaction between sward quality and SR for PGH of SG in E2.

Short grass proportion of area and of total sward: The proportion of SG area and the proportion of herbage as SG decreased significantly ($P < 0.001$) as sward quality deteriorated and SR decreased in both experiments (Tables 5 and 6).

Number of TG patches and area per patch: The means for number and area of TG patches are outlined in Tables 5 and 6 for E1 and E2, respectively. The number of TG patches per ha decreased significantly as sward quality deteriorated in E1 ($P < 0.01$) and E2 ($P < 0.001$). There was no effect of SR on the number of TG patches in E1 but the number of TG patches decreased significantly ($P < 0.05$) as SR decreased in E2. The area per patch

Table 5. The pre-grazing herbage mass (HM, kg/ha) (dry matter above 45 mm), post-grazing sward height (PSH, cm) for short (SG) and tall (TG) grass, the proportion of the paddock area under SG (PSGA), the proportion of the total herbage composed of SG (PTHSG), the number of TG patches per ha and the average area per patch (m^2) for three sward types (ST) grazed at two stocking rates (SR) over three grazing rotations of Experiment 1

Variable	Sward type × Stocking rate†						s.e.	Significance		
	HQ		MQ		LQ			ST	SR	ST × SR
	HR	LR	HR	LR	HR	LR				
HM in SG	1,040^a	1,112^a	1,080^a	1,452^b	1,650^b	1,546^b	95.3	***		
PSH for SG	4.1^a	5.3^b	5.1^b	6.2^c	5.6^b	6.4^c	0.15	***	***	
HM in TG	3,830^a	4,532^{ab}	4,558^{ab}	4,697^{ab}	4,763^{ab}	5,516^b	290.6	*	*	
PSH for TG	11.6^a	14.7^c	12.6^b	15.0^c	13.1^b	15.5^c	0.27	***	***	
PSGA	0.765^a	0.658^b	0.625^b	0.532^c	0.484^d	0.406^e	0.0150	***	***	*
PTHSG	0.469^a	0.280^b	0.266^b	0.245^b	0.219^b	0.145^c	0.0208	***	***	**
No. patches/ha	3,917^{ab}	4,100^a	3,071^{abc}	2,854^{abc}	2,346^{bc}	1,833^c	303.0	**		
Area/patch (m^2)	0.587^a	0.953^{ab}	1.328^{ab}	1.720^{bc}	2.538^c	3.666^d	0.2401	***	*	

[abcde] Values, within rows, with a common superscript do not differ significantly.
† HQ = high quality sward, MQ = medium quality sward, LQ = low quality sward; HR = high stocking rate; LR = low stocking rate.

Table 6. The pre-grazing herbage mass (HM, kg/ha) (dry matter above 45 mm), post-grazing sward height (PSH, cm) for short (SG) and tall (TG) grass, the proportion of the paddock area under SG (PSGA), the proportion of the total herbage composed of SG (PTHSG), the number of TG patches per ha and the average area per patch (m²) for three sward types (ST) grazed at two stocking rates (SR) over four grazing rotations of Experiment 2

Variable	Sward type × Stocking rate†						s.e.	Significance		
	HQ		MQ		LQ			ST	SR	ST × SR
	HR	LR	HR	LR	HR	LR				
HM in SG	1,735[a]	1,683[a]	1,758[a]	2,136[b]	2,051[ab]	2,552[c]	100.0	***	**	*
PSH for SG	5.4[a]	6.2[b]	5.7[a]	7.2[c]	6.6[d]	7.7[e]	0.12	***	***	*
HM in TG	4,702[a]	5,202[ab]	5,464[ab]	6,417[bc]	6,365[bc]	6,923[c]	298.6	***	*	
PSH for TG	13.6[a]	16.1[c]	15.4[bc]	17.7[d]	14.8[b]	17.7[d]	0.25	***	**	
PSGA	0.735[a]	0.665[b]	0.618[b]	0.494[c]	0.459[cd]	0.423[d]	0.0188	***	***	
PTHSG	0.528[a]	0.415[b]	0.346[c]	0.257[d]	0.245[d]	0.197[d]	0.0228	***	***	
No. patches/ha	4,363[a]	3,822[a]	3,653[a]	2,909[b]	2,438[b]	2,116[b]	193.6	***	*	
Area/patch (m²)	0.578[a]	0.848[a]	1.108[a]	1.731[b]	2.142[b]	3.175[c]	0.1443	***	**	

[abcde] Values, within rows, with a common superscript do not differ significantly.
† HQ = high quality sward; MQ = medium quality sward; LQ = low quality sward; HR = high stocking rate; LR = low stocking rate.

also increased significantly ($P < 0.001$) as sward quality deteriorated in both experiments. The area per patch increased significantly as SR decreased in E1 ($P < 0.05$) and E2 ($P < 0.01$).

Period 2
Total sward

Herbage mass: The mean values for pre-grazing herbage mass (combining SG and TG) for each treatment combination are shown in Tables 7 and 8 for E1 and E2, respectively. Herbage mass increased ($P < 0.001$) as sward quality deteriorated from high to low in both experiments. Herbage mass also increased as SR decreased from high to low in both E1 ($P < 0.01$) and E2 ($P < 0.001$). The most noticeable effect of rotation on herbage mass in E1 was a decrease from rotation 1 to rotations 2 and 3 (3,345, 2,395 and 2,760 kg DM, respectively; $P < 0.01$). Herbage mass decreased ($P < 0.01$) from rotations 1 and 2 to rotations 3 and 4 in E2 (4,046 and 4,252 to 3,608 and 2954 kg DM, respectively).

Organic matter digestibility and morphological composition: The calculated OMD and morphological composition of the total sward are also shown in Tables 7 and 8 for E1 and E2, respectively. Organic matter digestibility decreased ($P < 0.001$) as sward quality deteriorated from high to low in both experiments. The LL component decreased ($P < 0.001$) and the LS and DS components increased ($P < 0.001$) as sward quality deteriorated in both experiments. The DL component was lower for the HQ sward at high SR ($P < 0.05$) compared to the other treatments in E1. Also, the DL component was lower for the HQ sward ($P < 0.05$) compared to the MQ and LQ swards in E2.

There was no effect of SR on OMD or on any sward components in E1. There was a small decrease in LL ($P < 0.05$) and a small increase in LS ($P < 0.05$) as SR decreased from high to low in E2.

The OMD was similar for all rotations in E1. However, OMD for rotation 1 (0.756) was significantly higher ($P < 0.01$) than that for rotations 2, 3 and 4 (0.718, 0.728 and 0.736, respectively) in E2. The LL component was broadly similar for all rotations in both experiments. The DL ($P < 0.001$) and DS ($P < 0.01$) components

Table 7. The pre-grazing herbage mass (HM, kg/ha) (dry matter above 45 mm), organic matter digestibility (OMD) (g/g), the proportion (g/g dry matter) of live leaf (LL), dead leaf (DL), live stem (LS) and dead stem (DS) and post-grazing sward height (PGH, cm) in three sward types (ST) grazed at two stocking rates (SR) over three grazing rotations of Experiment 1

Variable	Sward type × Stocking rate†						s.e.	Significance		
	HQ		MQ		LQ			ST	SR	ST × SR
	HR	LR	HR	LR	HR	LR				
HM	1,705^{a}	2,425^{ab}	2,440^{ab}	3,032^{bc}	3,371^{c}	4,030^{d}	203.8	***	**	
OMD	0.778^{a}	0.763^{a}	0.723^{b}	0.735^{b}	0.711^{bc}	0.693^{c}	0.0077	***		
LL	0.622^{a}	0.544^{a}	0.419^{b}	0.435^{b}	0.331^{b}	0.326^{b}	0.0272	***		
DL	0.059^{a}	0.107^{b}	0.114^{b}	0.094^{b}	0.110^{b}	0.114^{b}	0.0092	*		**
LS	0.264^{a}	0.308^{a}	0.354^{ab}	0.373^{ab}	0.419^{b}	0.432^{b}	0.0194	***		
DS	0.040^{a}	0.027^{a}	0.091^{b}	0.078^{b}	0.123^{b}	0.116^{b}	0.0116	***		
PGH	5.9^{a}	8.6^{b}	7.9^{b}	10.3^{c}	9.5^{d}	11.8^{e}	0.27	***	***	

abcde Values, within rows, with a common superscript do not differ significantly.
† HQ = high quality sward, MQ = medium quality sward, LQ = low quality sward. HR = high stocking rate, LR = low stocking rate.

Table 8. The pre-grazing herbage mass (HM, kg/ha) (dry matter above 45 mm), organic matter digestibility (OMD) (g/g), the proportion (g/g dry matter) of live leaf (LL), dead leaf (DL), live stem (LS) and dead stem (DS) and post-grazing sward height (PGH, cm) in the three sward types (ST) grazed at two stocking rates (SR) over the four grazing rotations of Experiment 2

Variable	Sward type × Stocking rate†						s.e.	Significance		
	HQ		MQ		LQ			ST	SR	ST × SR
	HR	LR	HR	LR	HR	LR				
HM	2,506^{a}	2,871^{a}	3,223^{a}	4,247^{b}	4,272^{b}	5,171^{c}	205.1	***	***	
OMD	0.764^{a}	0.758^{a}	0.735^{b}	0.726^{bc}	0.707^{d}	0.715^{cd}	0.0053	***		
LL	0.623^{a}	0.577^{a}	0.506^{b}	0.441^{c}	0.376^{d}	0.348^{d}	0.0220	***	*	
DL	0.066^{a}	0.077^{ab}	0.093^{bc}	0.096^{bc}	0.097^{bc}	0.111^{c}	0.0071	***		
LS	0.260^{a}	0.290^{b}	0.327^{bc}	0.386^{cd}	0.428^{d}	0.445^{d}	0.0171	***	*	
DS	0.040^{a}	0.044^{ab}	0.065^{abc}	0.068^{bc}	0.097^{c}	0.092^{c}	0.0082	***		
PGH	7.6^{a}	9.4^{b}	9.4^{b}	12.4^{c}	11.0^{d}	13.4^{e}	0.30	***	***	

abcde Values within rows with a common superscript do not differ significantly.
† HQ = high quality sward, MQ = medium quality sward, LQ = low quality sward; HR = high stocking rate, LR = low stocking rate.

increased (0.077, 0.100 and 0.122 for DL; 0.060, 0.067 and 0.112 for DS in rotations 1 to 3, respectively) and the LS component decreased ($P < 0.001$) with increasing rotation number in E1 (0.414, 0.351 and 0.312 LS in rotations 1 to 3, respectively). Similarly in E2, the DL and DS components increased ($P < 0.001$) (0.052, 0.080, 0.110 and 0.118 for DL; 0.021, 0.045, 0.090 and 0.115 for DS in rotations 1 to 4, respectively), and the LS component decreased ($P < 0.001$), with increasing rotation number (0.428, 0.424, 0.330 and 0.243 in rotations 1 to 4, respectively).

Post-grazing sward height: The PGH increased ($P < 0.001$) as sward quality decreased from high to low and as SR decreased from high to low, in both experiments (Tables 7 and 8). The PGH also decreased ($P < 0.001$) with increasing rotation number in both E1 (10.6, 8.4 and 8.0 in rotations 1 to 3, respectively) and E2 (13.3, 11.3, 9.0 and 8.6 in rotations 1 to 4, respectively).

Discussion

The main objective of this study was to evaluate the effects of GP in the early part of the grazing season on subsequent sward morphological composition. This required the measurement of a number of sward characteristics repeatedly over time. Additionally, because the swards produced by the different early season GP were likely to change over time with the SR imposed on them subsequently, it was important to examine the interaction of the early season GP with subsequent SR.

Herbage mass has been shown to increase in the base of swards in late season (Michell, 1982), due to an accumulation of stem and dead material (Mayne *et al*., 1987). However, since dairy cattle, irrespective of GP, select their diet from horizons above 45 mm (Mayne, Clements and Woodcock, 1990; Meijs and Hoekstra, 1984), this was the horizon of interest in the present study.

Three contrasting swards were produced by the three GP treatments applied in P1. Compared to the LQ, the HQ sward was characterised by higher OMD and LL. The HQ sward also contained a higher proportion of short grass area, a higher proportion of total herbage mass as short grass, lower herbage mass, lower LS, DL and DS, and a higher number of smaller sized rejected areas. The MQ sward was intermediate between these. Simon and Lemaire (1987) and Baker and Leaver (1986) have reported that increasing GP early in the season reduces PGH but increases tiller number and the subsequent nutritional value of the herbage. Similarly, Fisher, Roberts and Dowdeswell (1995) reported that swards that were severely grazed had a higher proportion of short grass areas than swards that were laxly grazed. These effects have been observed with both continuously grazed (Le Du, Baker and Newberry, 1981) and rotationally grazed pastures (Mayne *et al*., 1987). The similarity of the results between E1 and E2, suggests that early season GP can be reduced from late June onwards. The late flowering ryegrass varieties present in these swards had heading dates in late June and would have been close to the end of their physiologically reproductive stage of growth at the start of P2.

Swards grazed by cattle are characterised by the rejection of herbage growing in the vicinity of faecal deposits. The initial reason for rejection is smell (March and Campling, 1970) followed by secondary effects such as the maturation of the herbage and the fall in its nutritive value (Leaver, 1985). This is in marked contrast to sheep-grazed swards, which do not contain tall grass areas. Cattle-grazed pastures develop a mosaic of grazed and less-well grazed areas, which are distinctly different. The composition of the tall grass and its herbage mass in each treatment had a bigger influence on total herbage mass and composition than the short grass, particularly in the MQ and LQ swards. This was principally due to the proportionate contribution of the tall grass to the total herbage mass (0.626, 0.744 and 0.818 in E1 and 0.529, 0.699 and 0.779 in E2, for HQ, MQ and LQ swards, respectively).

The area of a dung deposit has been estimated to vary from 0.02 to 0.07 m^2 (MacDiarmad and Watkin, 1972; Bastiman and Van Dijk, 1975). March and Campling (1970) estimated that the number of deposits varied from 7 to 13 per animal per day. At a stocking rate of 4 cows/ha and a grazing season of 180 days (assuming overlaps are ignored), Wilkins and Garwood (1985) estimated that proportionately 0.025 to 0.07 of the area of a paddock would be covered in dung in any particular year. The area around the dung deposit that is rejected has been estimated to be five (Bastiman and Van Dijk, 1975) to twelve (Greenhalgh and Reid, 1969) times that of the dung deposit itself. Therefore, the proportion of the sward influenced by dung could range from 0.125 to 0.84 (Wilkins and Garwood, 1985). Taylor and Large (1955) reported a value of 0.45 from direct observations. The size and utilisation of the tall grass area has been shown to be an important indicator of grazing severity (Kristensen, 1988; Greenhalgh and Reid, 1969; Gibb and Ridout, 1986). Early season GP had a major effect on the area affected by dung in the present study. However, increased SR from mid-season onwards reduced the level of contamination. This decrease was larger for the HQ and MQ swards than for the LQ sward.

Wilkins and Garwood (1985) speculated that gross under-utilisation of herbage in tall grass areas might be expected to result in increased grazing severity in the remainder of the sward. This was not found in the present study as evidenced by the PGH for both the short and tall grass. Also, the short grass showed a similar but smaller decrease in quality with decreased GP compared to the tall grass. Stocking rate from mid-summer onwards had only a small effect on quality. This indicates that quality parameters of the sward (mainly OMD and LL) are determined by GP in the late spring to early summer period. This is consistent with the findings of L'Huillier (1987). In the present study there was a gradual increase in dead material and a gradual decrease in live stem over the course of both experiments for both short and tall grass components. The absence of any important effect of SR, or a SR by rotation interaction for sward quality traits supports the conclusion that GP in the early season is the predominant grazing management effect on sward quality.

The different GP imposed during P1 resulted in large differences in subsequent herbage mass in P2. These differences can be explained on the basis of unutilised herbage carried over from P1 to P2, and the higher gross production of herbage that occurred with higher grazing residuals on the LQ sward (Parsons, Leafe and Penning, 1983). A higher rate of death and decay of herbage accompanies this (Parsons and Johnson, 1985). Herbage growth and tiller dynamics were not measured. However, ceiling herbage mass is likely to have been reached in the LQ swards and the tall grass in the MQ swards. Higher summer growth rate has been reported for swards that were severely grazed in the spring (Michell and Fulkerson, 1985). High grazing intensity in spring has been shown to reduce reproductive development and increase the number of developed vegetative tillers (Korte *et al.,* 1984). Compared to the LR, HR in P2 reduced herbage mass in both experiments. This was probably due to higher utilisation in HR compared to LR. The disappearance of material out of the sward through decay or movement into the lower horizon is likely to have been similar within sward quality categories.

The OMD of the herbage was mainly determined by the proportion of live leaf. The regression equations relating OMD to LL are of little value for the prediction of OMD. The difference between the short and tall grass can be explained by the different ages of the plant components in short and tall grass. The inclusion of the other components, such as DL, DS and LS, did not improve the relationship because of collinearity. Hoogendoorn *et al*. (1992) and Korte *et al.* (1984) showed that OMD of both leaf and stem is reduced with increasing age of tissue. The OMD of LL is higher than LS and senescent material has an even lower OMD (L'Huillier, 1988; Terry and Tilley, 1964; Hacker and Minson, 1981; Michell and Fulkerson, 1985). The regression coefficients for tall grass were higher than for short grass. This indicates that the OMD of stem and senescent material in tall grass is lower than in short grass because replacing one unit of LL in tall grass with the other components had a greater depressing effect on OMD than in short grass.

The results show the importance of high early season grazing pressure in creating a leafy high digestibility sward for grazing in the latter half of the grazing season. They also emphasise the greater influence of the tall grass component of a cattle grazed sward in determining the overall composition of the total sward.

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