Effects of Daily Herbage Allowance on Sward Structure, Herbage Intake and Milk Production by Dairy Cows Grazing a Pure Perennial Ryegrass Sward

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ABSTRACT : To explore the factors restricting animal performance in relation to sward structure under a strip-grazing system, measurements of sward factors, herbage intake and milk production at 3 levels of herbage allowance were made on perennial ryegrass (*Lolium perenne* L.) sward for 3 experimental periods. About 29%, 36% and 52% of the biomass offered was removed by grazing in high (42 kg OM·day^{-1}·head^{-1}), medium (30 kg OM·day^{-1}·head^{-1}) and low (18 kg OM·day^{-1}·head^{-1}) herbage allowance plots. Live leaf material was much more affected by grazing under different herbage allowance levels than dead material or leaf sheath. Grazing with a low herbage allowance decreased the proportion of live lamina by 93% and live lamina density by 96% before grazing. The density of dead material plus sheath was decreased by 17% after grazing at a low allowance, while it slightly increased or remained constant in the plots applied with high and medium allowances, respectively. The highly significant ($p<0.01$) correlations between herbage allowance and proportion ($r=0.94$) and density ($r=0.91$) of live lamina in residual sward after grazing were observed. Daily herbage intakes in the plots with high and medium levels of herbage allowance were not significantly different at 15.3 kg OM·head^{-1} in average, whereas with low level it decreased to 13.9 kg OM·head^{-1}. Daily milk production was significantly ($p<0.05$) declined from 22.3 kg·head^{-1} (at high herbage allowance) to 19.7 kg·head^{-1} (at low herbage allowance). The data obtained clearly indicated that herbage intake and milk production were highly affected by the characteristics of residual sward, which were closely related to the level of herbage allowance.
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Key Words : Daily Cows, Strip-Grazing, Herbage Allowance, Sward Structure, Herbage Intake, Milk Production

INTRODUCTION

There is general agreement in a pasture-based system of farming that animal performance is directly related to herbage intake, herbage availability and its quality (Le Du et al., 1981; Peyraud et al., 1996; Dalley et al., 1999). The availability of herbage to grazing animals depends not only upon sward characteristics (e.g pasture on offer), but also the number of the animals or stocking rate (pasture availability).

Numerous studies have investigated the production response of animals to stocking rate (Jones and Sandland, 1979; Le Du et al., 1979; 1981) and daily herbage allowance (Wales et al., 1998; Dalley et al., 1999), and have found a negative relationship. The decline in animal performance with these factors was more closely related to herbage intake than pasture available on offer (Hodgson, 1976). Le Du et al. (1979) reported that herbage intake appeared to be restricted if cows were forced to eat more than 50% of the herbage on offer. This would result in the residual sward height varying in direct proportion to the herbage mass. Individual animal observations (Allden and Whittaker, 1970; Penning, 1986) showed a linear decrease of intake per prehensive bite as sward height decreased.

Barthram and Grant (1984) found a gradual increase in the proportion of leaf sheath on the grazed horizon as sward height grazed down, and suggested that this was just as likely to be the cause of herbage intake restriction resulting from difficulty of prehension. While there is circumstantial evidence that the presence of leaf sheath in the grazed horizon of temperate swards may lead to reduction in herbage intake, there is equally no unequivocal evidence that it is not predominantly sward height which determines the rate of herbage intake of grazing animals.

Therefore there remains some confusion concerning the precise sward characteristics which determine the availability of herbage to grazing animals, particularly under rotational grazing. The objectives of this study were to fully understand the changes in morphological structure of swards under different herbage allowances and explore the factors restricting herbage intake and milk production in relation to sward structure.

MATERIALS AND METHODS

Treatments

The experiment was carried out under a daily strip-grazing system for three periods between 5 May and 25 May 1998. Each period of the experiment was 8 days, including 3 days of adaptation and 5 days of measurement.

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Within each period, 3 levels (OM·day^{-1}·head^{-1}) of herbage allowance (low, 18; medium, 30; high, 42 kg) were applied and the experimental plots were designated as R_L, R_M and R_H. The herbage allowance was determined by adjusting the sward area offered per head according to the estimated biomass. The mean pasture on offer at periods 1, 2 and 3 were 4,039, 4,830 and 5,515 kg OM·ha^{-1}, respectively.

Animals and grazing management

Fifteen Holstein cows in their second or later lactations were randomly allocated to the 3 levels of herbage allowance under a strip-grazing system, balanced for milk production and number of lactations. At the start of experiment, mean live weight and milk production of experimental animals were 570 kg and 25 kg fat-corrected milk (FCM)·day^{-1}·head^{-1}, respectively. The cows entered the experimental plots after the morning milking at about 08:30 a.m.

Sward condition and chemical composition

The sward used was two year-old perennial ryegrass (*Lolium perenne* cv. Belfort). The pastures were lightly grazed, then topped on 3 April, and 72 kg N·ha^{-1} was applied. The forage material obtained from motor scythe cuts leaving stubble of 4.5 cm was used for the analysis of chemical composition. The chemical composition of forage material offered to animals is presented in table 1. Samples for N analysis were freeze-dried then mineralized by modified Kjeldahl procedure following previous reduction of nitrate with salicylic acid (Eastin, 1978) and determined titrametrically. The content of fiber and lignin was analyzed by the method of Van Soest and Marcus (1964).

Estimation of herbage mass and sward structure

All pre-grazing measurements were carried out the day previous to entry and the post-grazing measurements on the day of exit. Both motor scythe and quadrat were used to estimate the herbage mass on offer in all treatments. A motor scythe was used to cut 2 randomly paced bands 5 m long and 0.5 m wide per date and treatment, leaving stubble of about 4.5 cm. A 30 cm by 30 cm quadrat was then placed in the cut band and the stubble inside was cut with scissors to ground level. This stubble herbage mass was added to the motor scythe estimate to give total herbage mass. Herbage samples were weighed fresh, then oven-dried at 80°C for 48 h to estimate dry matter. Herbage materials were carefully taken free of soil. After placing the dried-samples in a muffle furnace at 550°C for 8 h, the content of organic matter (OM) was determined. Herbage mass was expressed as OM basis.

The extended height of the longest leaf tip and leaf sheath from ground level was measured on the 20 randomly selected sampling points before and after grazing. In addition to the extended tiller measurement, sward height was determined daily both pre- and post-grazing for each treatment using rising plate sward stick (Frame, 1981), with 20 measurements per plot taken at random. The sward stick comprised of 30×30 cm plate which exerted a downward pressure of 4.77 kg·m^{-2}. The sample from an area of approximately 70 cm^2 adjacent to each area cut for herbage mass estimation was harvested to give a composite sample for each sampling date. A sample of 100 tillers was laid on paper with the cut bases placed together. The bunch of tillers was then extended and rolled up in the paper and whole length divided into sections of 5 cm, starting at the cut bases. All sections were separated into green lamina, green sheath and dead material. The separated section were dried at 80°C for 24 h and weighed. These weights were used to calculate the proportion of the total herbage mass and of each morphological unit per 5 cm stratum and the proportion of green lamina and sheath plus dead material in the whole sward.

Table 1. Herbage mass and chemical composition of *Lolium perenne* sward offered for three periods

Composition	Period 1 (5 May -9 May)	Period 2 (13 May -17 May)	Period 3 (21 May -25 May)
Biomass (kg OM/ha)	4,039^a	4,830^b	5,515^c
Organic matter (%)	89.8	90.1	90.3
Dry matter (%)	16.7^a	16.8^a	18.3^b
Crude protein (%)	22.5^c	19.0^b	16.3^a
Acid detergent fiber (%)	20.0^a	21.4^a	23.5^b
Neutral detergent fiber (%)	48.0^a	51.0^b	51.8^b
Acid detergent lignin (%)	1.9	2.0	2.2

The values are given the mean for three experimental plots obtained from ten sampling points each period.
^{a,b,c} Values with different superscripts in the same row are significantly ($p<0.05$) different.

Herbage intake and milk production

Chromic oxide (16 g) was compounded in about 1 kg of concentrate (50% of corn, 20% of barley, 24% of soybean meal and 4% of molasses). The concentrates were fed twice per day after milking. The dung of individual cows, identified by plastic pellets with different color (Le Du and Penning, 1982), was collected daily in order to estimate the concentrations of chromic oxide, N and acid detergent fiber (ADF) in it. These were used to determine the faecal production and herbage digestibility, from which daily herbage intake was calculated. The herbage intake was calculated from faecal output and the digestibility of herbage consumed. Faecal output was estimated using the chromic oxide dilution method as described by Le Du and Penning (1982). Random samples of herbage were cut to ground level and bulked for freeze-drying and subsequent *in* *vitro* fermentation for the determination of organic matter digestibility (Mayne et al., 1987). Milk production was recorded routinely twice a day.

Statistical analysis

Data were analyzed as a 3 by 3 Latin square design, and subjected to analysis of variance using GLM procedure. Where the *F*-test was significant ($p<0.05$) the differences were determined using Tukey's Studentized Range test (Steel and Torrie, 1980). The relationships between the measured variables were assessed using a Logistic Regression Model. All analyses were performed using Statistical Analysis System (SAS, 1988).

RESULTS

Herbage mass

The changes in herbage mass and sward characteristics before and after grazing at 3 levels of daily herbage allowance are summarized in table 2. The herbage mass of pre-grazing sward varied between 4,039 and 5,515 kg OM·ha^{-1} showing an increase ($p<0.05$) from period 1 to 3 (table 1), but it was not changed by different herbage allowance (table 2). Post-grazing, residual herbage mass over three experimental periods were 2,294, 2,959 and 3,536 kg OM·ha^{-1} for R_L, R_M and R_H, respectively. The difference in pre- and post-herbage mass reflecting pasture utilized was related to daily herbage allowance at 52.0, 36.0 and 28.9% for R_L, R_M and R_H, respectively.

The pre-grazing sward height and extended tiller height significantly increased ($p<0.05$) from 141 and 344 mm in period 1 to 177 and 478 mm in period 3 (data not shown). There was no significant difference in sward characteristics between the herbage allowance treatments (table 2). The extended height of sheath before grazing was in average 142 mm, corresponding to about 34.6% of extended tiller height. In all 3 treatments, sward height and extended height were significantly ($p<0.05$) decreased after grazing. In the plot R_L, 67.3% of the sward height was grazed down while less than 50% of decrease in the plots R_H and R_M. The extended tiller height was decreased with a similar amount in the R_H and R_M, while it was much lower ($p<0.05$) in the plot R_L. Of the sward offered, herbage materials presented above 4.5 cm to ground level were composed with 45% of live lamina and 25% of dead leaf plus sheath. In the plot R_L nearly all live lamina disappeared after grazing, while in the plots R_H and R_M this tissue still remained at 20% and 11%. The proportion of dead leaf plus sheath in the plots R_H and R_M significantly ($p<0.05$) increased after grazing compared with the plot R_L.

Changes in vertical distribution of green lamina and sheath plus dead material as affected by herbage allowance are presented in table 3. The density of live lamina was on average 540 kg OM·ha^{-1}·cm^{-1} before grazing, and it was decreased to 165, 87 and 21 kg OM·ha^{-1}·cm^{-1} by grazing in the plots R_H, R_M and R_L. The density of dead leaves plus sheath in pre-grazing sward was on average 674 kg OM·ha^{-1}·cm^{-1}, and it was not changed in the plots R_H and R_M, but 119 kg OM·ha^{-1}·cm^{-1} of these herbage materials were grazed in the plot R_L. Before grazing live lamina was distributed to 50 cm above ground level and a large portion (about 70%) of this tissue was presented at 10 to 25 cm. All of live lamina distributed above 30 cm in the plots R_H and R_M, and above 20 cm in the plot R_L were removed by grazing. In the sward offered about 80% of sheath and dead leaves were presented below 10 cm total density and were not affected by grazing in all three treatments.

Herbage intake and milk production

In vitro digestibility of ingested herbage, daily herbage

Table 2. Characteristics of *Lolium perenne* swards before and after grazing at three levels of herbage allowance under strip-grazing trial

Herbage allowance	Herbage mass (kg OM ha^{-1})	Rising plate (mm)	Extended tiller height (mm)	Sheath height (mm)	Live lamina (%)	Dead[1] leaf+sheath (%)
Pre-grazing sward						
Low (R_L)	4,780^c	165^d	408^d	136^c	45^d	25^a
Medium (R_M)	4,624^c	170^d	429^d	150^c	45^d	26^a
High (R_H)	4,980^c	168^d	418^d	139^c	46^d	24^a
Post-grazing sward						
Low (R_L)	2,294^a	54^a	93^a	80^a	3^a	28^a
Medium (R_M)	2,959^b	90^b	153^b	111^b	11^b	35^b
High (R_H)	3,536^b	107^c	181^c	122^{bc}	20^c	34^b
LSD	649	15	26	15	6	5

The value is given the mean of three periods obtained from 40 measures each period.

[1] Dead leaves and sheath materials presenting above 4.5 cm to ground level.

[a,b,c] Mean values with different superscripts within the same column are significantly ($p<0.05$) different.

Table 3. Changes in vertical distribution of herbage materials before and after grazing under three levels of herbage allowance

Extended tiller height	Pre-grazing sward		Post-grazing sward: Herbage allowance					
			High (R_H)		Medium (R_M)		Low (R_L)	
	L.L[1]	D.L+S[2]	L.L	D.L+S	L.L	D.L+S	L.L	D.L+S
(cm)	(kg OM·ha^{-1}·cm^{-1})							
46-50	3							
41-45	14							
36-40	27							
31-35	47							
26-30	73		3		1			
21-25	100	8	8		6			
16-20	113	30	40	24	11	17	1	2
11-15	108	83	70	73	33	43	11	12
6-10	55	192	44	210	36	205	10	143
0-5	0	361	0	418	0	411	0	398
Total	540	674	165	725	87	676	22	555

The values of pre-grazing sward represent the mean of three herbage allowance treatments.
[1] L.L: Live laminas. [2] D.L+S: Dead leaves plus sheaths.

Table 4. The effects of herbage allowance and experimental periods on digestibility of ingested herbage, daily herbage intake and milk production under strip-grazing system

Effect of herbage allowance	Herbage allowance			
	High (R_H)	Medium (R_M)	Low (R_L)	LSD
Digestibility (%)	76.9^a	76.2^a	74.9^a	1.4
Herbage intake (kg OM.day^{-1}.head^{-1})	15.4^b	15.2^b	13.9^a	1.0
4% FCM (kg.day^{-1}.head^{-1})	22.3^c	21.1^b	19.7^a	0.9
Effect of period	**Period**			
	1	2	3	LSD
Digestibility (%)	78.0^c	75.9^b	73.4^a	1.9
Herbage intake (kg OM.day^{-1}.head^{-1})	15.9^b	15.4^b	13.2^a	1.6
4% FCM (kg.day^{-1}.head^{-1})	22.4^c	21.0^b	19.6^a	1.2

[a,b,c] Means in the same row with different superscript are significantly ($p<0.05$) different.

intake and milk production as affected by three levels of daily herbage allowance through three periods are presented in table 4. The digestibility of forage materials was slightly decreased ($p<0.05$) from period 1 (78.0%) to period 3 (73.4%). There was no significant difference in digestibility affected by daily herbage allowance. The herbage intake for the first two periods was similar (15.6 kg OM·day^{-1}·head^{-1} on average), while significantly ($p<0.05$) decreased to 13.2 kg OM·day^{-1}·head^{-1} at period 3. The daily herbage intakes in the plots R_H and R_M when provided with more than 30 kgOM/cow/day did not differ (15.4 and 15.2 kg OM·head^{-1}), but intake in the plot R_L significantly decreased to 13.9 kg OM·head^{-1}. Daily milk production was significantly decreased from period 1 (22.4 kg·day^{-1}·head^{-1} in average of three treatments) to period 3 (19.6 kg·day^{-1}·head^{-1}). Milk production of cows in the treatment R_H, R_M and R_L was 22.3, 21.1 and 19.7 kg.day^{-1}·head^{-1}, respectively, showing a significant decline ($p<0.05$) as the level of herbage allowance lowered.

DISCUSSION

A wide range of herbage allowance (18 to 42 kg·day^{-1}·head^{-1}) was used in order to ensure that at least one level would not limit the daily herbage intake of cows. This was achieved, as is shown in table 4, so that the characteristics of sward residues associated with restricted and non-restricted herbage intake under strip grazing could be studied. The effect of herbage allowance on residual herbage mass after grazing was clearly evident (table 2). The amount decreased by grazing under high (42 kg·day^{-1}·head^{-1}, R_H) and medium (30 kg·day^{-1}·head^{-1}, R_M) was similar 1,444 and 1,665 kg OM/ha respectively, while under low (18 kg·day^{-1}·head^{-1}, R_L) herbage allowance it was much increased to 2,486 kg OM·ha^{-1}. This indicates that sward structure is closely affected by the time of experiment, and that the

Table 5. Correlations between the characteristics concerning herbage availability and the parameters related to animal performance

	HA	HM	ETH	SH	PLL	DLL	DDS	HI	MP
HA	-	r=0.62*	r=0.79**	r=0.34 ns	r=0.94**	r=0.91**	r=0.22 ns	r=0.84**	r=0.81**
HM		-	r=0.82**	r=0.58*	r=0.62*	r=0.54 ns	r=0.88**	r=0.59*	r=0.26 ns
ETH			-	r=0.63*	r=0.69*	r=0.72**	r=0.57 ns	r=0.71**	r=0.58*
SH				-	r=0.64*	r=0.68*	r=0.61*	r=0.33 ns	r=0.41 ns
PLL					-	r=0.85*	r=0.21 ns	r=0.86**	r=0.72**
DLL						-	r=0.07 ns	r=0.81**	r=0.67*
DDS							-	r=0.23 ns	r=0.08 ns
HI								-	r=0.83**
MP									-

The correlation coefficient and the significant level of differences (p) are reported : ns, non significant, * $p \leq 0.05$; ** $p \leq 0.01$ with n=12.
HA : Herbage allowance (kg OM·day^{-1}·head^{-1}), HM : Herbage mass after grazing (kg OM·ha^{-1}), ETH : Extended tiller height after grazing (cm), SH : Sward height after grazing (cm), PLL : Proportion of live lamina after grazing (%), DLL : Density of live lamina after grazing (kg OM·ha^{-1}·cm^{-1}), DDS : Density of dead leaves + sheath after grazing (kg OM·ha^{-1}·cm^{-1}), HI : Herbage intake measured by Cr_2O_3 (kg OM·day^{-1}·head^{-1}), MP : Milk production corrected with 4% of milk fat (kg·day^{-1}·head^{-1}).

repetition of grazing trials considering the vegetative stage of sward is important to fully understand the changes in characteristics of sward.

The significant changes in the sward structure were observed after grazing under different levels of herbage allowance (table 2). The proportion of live lamina in sward after grazing emphatically declined as the level of herbage allowance lowered, however that of sheath plus dead leaves was much less sensitive to herbage allowance treatment. The relations between herbage allowance (HA) and the parameters representing the presence of live lamina in sward after grazing (PLL, proportion of live lamina after grazing and DLL, density of live lamina after grazing) were highly significant ($p<0.01$), with coefficients of correlation r=0.94 and r=0.91. Much lower relation was obtained with residual sward height (r=0.34) or with extended tiller height after grazing (r=0.79). Thus it could be assumed that the availability of live lamina in sward has a close influence on herbage intake under different herbage allowances.

Herbage intake was similar for the first two periods (15.6 kg·day^{-1}·head^{-1} in average), but declined in the third period (13.2 kg·day^{-1}·head^{-1}). This was associated with a decline in herbage digestibility (78.0 to 73.4%), which will cause a reduction in herbage intake (Hodgson et al., 1977). The daily herbage intakes in the plots R_H and R_M supplied with above 30 kg.day^{-1}·head^{-1} were not significantly ($p>0.05$) different (15.4 and 15.2 kg OM·head^{-1}, respectively), showing no further increase and non-restriction of herbage intake despite a large difference in herbage allowance, but decreased significantly to 13.9 kg OM·head^{-1} for R_L (table 4). This confirms the results of Peyraud et al. (1996) who suggested that daily herbage intake was affected by daily herbage allowance but the herbage mass / structure of sward offered had an independent effect in regulating intake. The data obtained from sward measurements showed that herbage intake was restricted when swards were grazed to below the level of 84 mm rising plate or 153 mm extended tiller height (ETH) measurement (table 2 and table 4). However, the overall relation between herbage intake (HI) and residual sward height measured with rising plate (SH) was barely significant (r=0.39). Much better relationships were obtained between herbage intake and proportion of live lamina in residual sward (r=0.86), and density of live lamina after grazing (r=0.81) (table 5). These higher correlation coefficients with the parameter representing live lamina residues suggest that herbage intake was progressively restricted by either the absence of leaf lamina or the presence of leaf sheath in the grazed horizon as herbage allowance was decreased, rather than by reduced absolute sward height. Barthram and Grant (1984), on more dense temperate swards, indicated that the presence of leaf sheath in the grazed horizon might have contributed to or caused the decline of herbage intake with declining sward height. Chacon and Stobbs (1976) and Hendricksen and Minson (1980) observed in C4 tropical grasses sward that it was the presence (i.e. acceptability) and density (i.e. accessibility) of leaf in the grazed horizon which determined the level of daily herbage intake. Other grazing studies in perennial ryegrass swards have shown a reduction of grazing time, or even cessation, when leaf material is exhausted at the end of a short period at low herbage allowance (Combellas and Hodgson, 1979). Therefore, while residual sward height may be useful for practical guidance to herbage restriction (Baker et al., 1981), it is not a good guide to the actual sward factors which affect herbage availability, because availability does not depend upon absolute sward height alone.

This significant decrease in herbage intake in the plot R_L was likely to have relation to absolute decrease of herbage mass. In this plot 52.0% of herbage mass offered and nearly all of live lamina were cut off after grazing (tables 2 and 3). This corresponds to the finding of Le du et al. (1979) that restriction of herbage intake under strip grazing occurs when about half of the amount offered has been consumed. In agreement with the suggestions made by Baker et al. (1981) and Dalley et al. (1999), it is assumed that sward height and biomass directly affect herbage intake when enough herbage is allowed, but morphological structure of sward and herbage quality in the grazed horizon are the more important factors at low level of herbage allowance.

Significant effects of experimental period and herbage allowance on daily milk production per cow were observed. Milk production significantly decreased from period 1 (22.4 $kg{\cdot}day^{-1}{\cdot}head^{-1}$) to period 3 (19.6 $kg{\cdot}day^{-1}{\cdot}head^{-1}$). Comparing the response of digestibility and herbage intake to different herbage allowances, it has showed that milk production was much more sensitive to treatment. A significant decline in milk production was observed as herbage allowance lowered although there was no significant difference in digestibility and herbage intake between the plots R_H and R_M. The data obtained clearly indicated that herbage intake and milk production were highly affected by the characteristics of residual sward, which were closely related to the level of herbage allowance. In addition, it was considered most probable that milk production was a sensitive indicator of the initial fall in daily herbage intake.

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