An investigation into the effects of different starts to the grazing season on sward structure and sward dynamics and dairy cow performance during the grazing season

Authors: Michael O'Donovan[1], Emer Kennedy[1], Luc Delaby[2] and John Paul Murphy[1]

[1]Teagasc, Dairy Production Research Centre, Moorepark, Fermoy, Co Cork.

[2]INRA, UMR Production du Lait 35590 St. Gilles, Rennes, France

End of project report 5227

December 2005

Summary and Implications

- Cows outdoors from mid February to early April offered an 80:20 grazed grass concentrate diet produced similar milk yield with higher protein yield and content compared to cows offered a 40:60 grass silage concentrate diet.
- The improvement in animal performance is attributed to a higher energy, protein and total DM intake.
- In the carryover period when both groups were grazing fulltime, the cows with early turnout had higher milk protein concentrations and higher grass DM intakes (1kg DM/cow/day)
- An early grazed sward had a similar grass growth potential as a late grazed sward.
- Herbage from early grazed swards have higher grass digestibility (OMD and UFL) value than late grazed swards
- A lower daily herbage allowance can be tolerated with early grazed swards to achieve similar milk production performance as from late grazed swards. Up to 5-6 kg grass DM of late grazed swards will achieve the same level of milk production from early grazed swards.
- With late turnout allocating high daily herbage allowance with large pre -grazing herbage mass is wasteful and compounds the effects of poor grass utilisation and undergrazing.
- Early grazing is recommended when conditions allow even on heavy soil types.

- From mid April onwards the optimum-stocking rate on early grazed swards is between 4.0 - 4.5 cows/ha. At this stocking rate a balance is found between feeding the cow adequately at pasture and achieving the correct post - grazing residuals.
- Grass dry matter intake was significantly higher for the early grazed medium stocked cows in both studies, which clearly shows that the improvements in sward quality with early grazed swards can be converted to higher dairy cow performance.
- Cows grazing the early grazed sward at a medium stocking rate had higher milk production performance which persisted in subsequent grazing rotations. This was due to the higher quality herbage available with the lower herbage mass swards.
- When modelled to the whole farm system the reduced feed cost and higher performance achieved with early grazing, resulted in each extra day at grass increasing cow profitability by €2.70 cow/day

Introduction

Grazed grass can be included in the overall diet of the dairy cow by allowing cows access to grass early in spring. Many studies have shown the improvement in dairy cow performance with this practice. As well as improving animal performance, early spring grazing can have beneficial effects by increasing grass utilisation, sward quality and easing grazing management. But early spring grazing can reduce the herbage mass availability in the second and third grazing rotations and thus reduce the number of grazing days. At high grazing stocking rates or in difficult weather/soil conditions, early grazing may not be possible and turnout may have to be delayed. Late turnout to grass, can lead to under-grazing of pastures for a variety of reasons, *i.e.* excessively high pre-grazing herbage mass, low grazing stocking rates or poor grass utilisation conditions.

A number of studies investigated the effects of early grazing on herbage mass production and sward dynamics. Carton et al. (1989) showed that early spring grazing (late March) compared with late grazing (mid April) reduced total herbage mass production but increased leaf dry matter production in the period up to mid June. Contrary to this, McFeely and MacCarthy (1981) found no significant effect of turnout date on herbage mass production for the period up to mid June. However, the effects of preliminary grazing in spring on animal performance and subsequent sward quality is poorly investigated, the only previous work was completed by Holmes et al. (1992). A number of questions arise with the practice of early grazing. If sward quality is improved with early grazing, is it possible to allocate a lower herbage allowance with an early grazed sward to achieve a similar level of milk production performance as a late grazed sward with a higher herbage allowance? Do sward carryover effects with earlier grazed swards persist into later rotations? Can these effects be transferred into animal production advantages? Furthermore, in the context of the dairy system, is milk production per hectare affected by early as compared to late grazing?. To further understand the dynamics of grazing management the current studies were undertaken.

The objective of the work was to examine the effect of contrasting spring grazing date and stocking rate on grazing management, milk production and grass dry matter intake of dairy cows.

Experiments

Experiment I. The effect of early turnout with a low level of concentrate compared to a high level of concentrate feeding indoors using spring calving dairy cows in early lactation

2.1 Description of feeding regimes

High concentrate (HC)

Animals (n=32) on the HC treatment were group housed and offered a medium quality grass silage [Dry matter (DM), 0.21 (s.d. 0.17); dry matter digestibility (DMD) 696 g kg (s.d. 8.1), crude protein 141 g kg (s.d. 3.5)]. This was supplemented with 12.6 kg (fresh weight) of coarse mixed concentrate (crude protein concentration of 161 g kg DM), offered in a mixed ration, which was mixed and dispensed through a Keenan diet feeder.

The fresh mix (weighed and sampled before feeding) was offered daily. Prior to feeding the previous day's refusals were removed, weighed and sampled. The individual ingredients (concentrate and grass silage) were sampled twice weekly. The feed was offered at a constant +0.15 above requirement, to encourage high voluntary intakes. No concentrate was offered in the milking parlour. Concentrate composition, on a fresh weight basis was: barley (rolled) 0.33, maize distillers 0.10, unmolassed beet pulp 0.36, soyabean meal 0.15, Megalac 0.04, DCP 0.008, Cal mag 0.006, limestone 0.004, salt 0.003, trace elements 0.007.

High grass (HG)

All the animals grazed as a single group (n=32). A grazing area of 13.9 ha (34.2 ac) was available for grazing; resulting in a stocking rate of 2.4 cows ha. The rotation length was 49 days. The herbage offered was primary spring pasture as paddocks were closed from the previous October. Grass was allocated on a herbage allowance basis with fresh grass offered after each milking. Concentrates were offered in individual stalls in the milking parlour (Dairymaster, Causeway, Co. Kerry) in two equal feeds. The concentrate ingredients were, on a fresh weight basis (in gross percentages) barley 0.24, unmolassed beet pulp 0.35, corn gluten 0.26, soya bean 0.11, DCP 0.015, limestone flour 0.007, salt 0.005, cal mag 0.012, mineral and vitamins 0.04. Concentrates offered in the parlour were sampled twice weekly and were bulked into weekly samples.

2.3 Swards

The experiment took place at Moorepark Research Centre, Fermoy, Co. Cork (55^{o}10'N; 8^{o}16'W). The soil type is a free draining, acid brown earth with a sandy loam-to-loam texture. A grassland site consisting of a predominantly perennial ryegrass sward (*Lolium perenne)* was used; on average the swards were two years old. The late diploid cultivars sown were cv. Twystar, cv. Cornwall and cv. Gilford.

The first nitrogen application (Urea) was applied in mid-January at a rate of 60-kg N/ha. Nitrogen (CAN) was reapplied at the same rate as paddocks were grazed. No P and K applications were made as the soil index (soil sampled the previous autumn) showed adequate concentrations.

2.4 Sward measurements

Herbage mass (>40mm) was determined twice weekly for each allocated grazing area by cutting four strips (1.2 × 10 m) with a motor Agria. Ten grass height measurements were recorded before and after harvesting on each cut strip using an electronic plate meter. This determined the sampled height precisely and allowed the calculation of the sward density (kg DM/cm/ha). All mown herbage from each strip was collected. It was weighed, sampled and then bagged (0.3 kg). Approximately 0.1 kg of the herbage sample was dried for 24 h at 90 ^{o}C in a drying oven for DM determination. The remaining 0.2 kg of the herbage collected from the four sample strips was bulked; a sub-sample (approx. 0.1 kg) was taken and stored at –20 ^{o}C before being freeze dried and milled prior to chemical analysis.

Pre-grazing and post-grazing sward heights were measured daily with a rising plate meter, 70 measurements were taken across the two diagonals of the grazed strip. The measured pre-grazing sward height, multiplied by the mean sward density was used to calculate the daily herbage allowance of the herd.

Herbage mass production and utilisation were calculated using the method of Delaby and Peyraud (1998). It was further used to evaluate the herbage mass produced and removed. Grass removed (kg DM/cow/day) was calculated using the following equation; (pre-grazing height - post grazing height) × sward density × area grazed cow/day. Pasture cover (>4 cm) was monitored weekly.

2.5 Animal Measurements

Milk production and live weight

Individual milk yields (kg) were recorded daily. Milk fat, protein and lactose were determined from one successive morning and evening sample taken weekly. The concentrations of these constituents were determined using the Milkoscan 203 (Foss Electric, DK-3400 Hillerod, Denmark). Solids corrected milk yield (SCM) was calculated using the equation of Tyrell and Reid (1965). Milking took place at 0700 h and 1600 h daily during the study period. All cows were weighed weekly. Each body weight was recorded electronically using a portable weighing scales and winweigh software package. Liveweight change was calculated using liveweight values from the first and last weeks of the study. Body condition score was recorded once every 3 weeks.

Following this experimental period, all cows were re-randomised according to their previous treatment. The carryover effects of this study on milk yield and composition, bodyweight and body condition score were measured for 12 weeks (April to July) in a subsequent four treatment grazing study (Experiment II).

Intake measurements

Individual dry matter intake was estimated once during the trial period, during Week 6, using the n-alkane technique (Mayes et al., 1986) as modified by Dillon and Stakelum (1989).

2.6 Chemical analyses

The chemical analysis of the sampled feed is presented in Table 1. The pre grazing herbage samples, composited for each week, were freeze dried and analysed for dry matter, acid detergent fibre (ADF) (Clancy and Wilson, 1966), neutral detergent fibre (NDF) (Van Soest, 1963), organic matter digestibility (OMD) (Morgan, Stakelum and O'Dwyer, 1989), dry matter digestibility (DMD) (Tilley and Terry, 1963), water soluble carbohydrates (WSC) (Birch et al. 1974), Kjeldahl nitrogen and ash. Similarly, a composite silage sample from each week was analysed for dry matter, pH, Kjeldahl nitrogen, ADF, NDF, DMD, WSC and ash. The concentrates were sampled weekly, bulked over the 7 weeks and analysed for DM, Kjeldahl nitrogen, crude fibre, oil and ash.

2.7 Statistical Analysis

All statistical analysis was carried out using SAS (SAS Institute, 2002). Mean daily milk yield, milk constituent yield, milk composition, body weight and body condition score were analysed using a randomised block design with the following model:

$$Y_{ijk} = \mu + P_i + T_j + b_1X_{ijk} + b_2DIM_{ijk} + e_{ijk}$$

where: Y_{ijk} represents the response of the animal *k* in parity *i* to treatment *j;* μ=mean;P_i = Parity effect (i = 1 to 2); T_j = Treatment effect (j = 1 to 2); b_1X_{ijk} = the appropriate pre-experimental milk output or bodyweight variable and b_2DIM_{ijk} = days in milk and e_{ijk} = residual error term.

The interaction between parity and treatment was also tested but the difference was not significant.

3. Results

Weather

Total rainfall for the month of February was below the ten-year average (-55 mm) while in March total rainfall was 39 mm greater than average. March benefited from a mean temperature equivalent to that of the ten year average but the mean temperature for February was almost a degree lower than average. Total hours of sunshine exceeded the mean for both February and March.

3.1 Grass budgeting

Autumn grazing management is of vital importance when turnout is targeted for early spring. To facilitate the present study the mean closing date of pastures during the previous grazing season was October 15th (s.d. 7 days). When the cows were turned out to pasture on February 16th the pasture cover was 1100 kg/DM/ha (>4cm). In February, the mean paddock cover increased to 1124 kg/DM/ha (s.d. 36) while in March it decreased to 1082 kg/DMha (s.d. 116). Average pasture cover for the experimental period was 1080 kg/DM/ha (s.d. 97).

3.2 Feeding systems and sward measurements

High concentrate treatment

Table 2 shows the DM utilisation and total estimated dry matter intake of the HC herd over the 7-week period. The level of concentrate inclusion was increased incrementally over the first four weeks and then remained static for the last three weeks of the study. As the concentrate inclusion increased the quantity of grass silage decreased – 11.4 kg DM/cow/day of grass silage was offered in Week 1, this was reduced to 7.1 kg DM/cow/day for the final four weeks of the study.

On average 19.7 kg DM/cow/day (s.d. 0.02) of the feed mix was offered during the study. The mean concentrate inclusion of the feed diet was 0.56 (s.d. 0.10) or 11.1 kg DM/cow/day (s.d. 2.3); grass silage inclusion was 0.44 (s.d. 0.11) or 8.6 kg DM/cow/day (s.d. 1.9) for the study. The mean concentrate DM (g kg) was 0.87 (s.d. 0.001) and the mean silage DM was 0.21 (s.d. 0.002). The mean DM (g kg) of the offered mix was 0.35 (s.d. 0.04). Total DMI (dry matter intake) of the HC herd was estimated at 15.3 kg DM/cow/day (s.d. 2.8), this resulted in 0.83 of the offered feed being consumed.

High grass treatment

Cows were allocated fresh grass after each milking for the duration of the experiment. The average farm grass cover (>4cm) in January was 788 kg DM/ha (s.d. 39). Mean pre-grazing plate meter sward height was 9.8 cm (s.d. 0.97), mean post-grazing sward height was 4.5 cm (s.d. 0.49). Mean pre-grazing herbage mass >4 cm was 1,681 kg DM/ha (s.d. 397), mean sward density >4 cm was 286 kg DM/cm/ha (s.d. 38). The first rotation was completed in 49 days, during which the mean grazing area offered was $90m^2$/cow/day.

The least quantity of herbage offered was during Week 1 consequently concentrate supplementation was highest at this time. Between Weeks 2 and 6 DHA increased and the quantity of concentrate offered decreased. By Week 7 the quantity of herbage offered had increased by 7.3 kg DM/cow/day from Week 1 and the concentrate input had decreased by 3.0 kg/DM/cow/day. Mean DHA over the 7-week period was 15.1 kg/DM/cow/day (s.d. 3.7); mean concentrate input was 3 kg/DM/cow/day (s.d. 1.0). The average estimated dry matter intake, based on herbage removed by the HG herd, was 16.8 kg/cow/day which includes 3.0 kg DM cow concentrate (s.d. 1.0) and 13.8 kg/DM/cow grazed grass (s.d. 3.2).

3.3 Milk yield and composition

Table 3 shows the mean milk production performance of both the HC and HG treatments for the study duration. There was no significant milk production difference between the two treatments even though the HG herd had a numerically higher milk yield (+1.0 kg/cow/day). The cows on the HG treatment had a greater milk protein concentration ($P<0.001$, +0.290 g kg) and protein yield ($P<0.001$, +117.3 g kg) than the HC herd, however they had a significantly lower fat concentration ($P<0.001$, -0.300 g kg). No significant difference was observed for any of the other milk production characteristics.

On average the HC herd had a higher (+18.3 kg, $P<0.001$) live weight compared to the HG herd yet the HG cows had a greater live weight gain (+0.17 kg).

Table 7 shows the milk production parameters recorded during the 12-week carryover period. One cow from the HC treatment was omitted from this analysis due to ill health. The HG treatment recorded a higher milk protein content (P<0.02) during the 12-week period. There was no significant treatment effect on the other milk production parameters.

3.4 Intake measurements

The DM intake estimates, using the n-alkane technique, are presented in Table 4. There was no significant difference in total dry matter intake (TDMI) between the two herds. The TDMI of the HC animals was 15.3 kg DM cow day compared to a DM intake of 15.7 kg DM/cow/day for the HG animals. Due to the different feeding regimes imposed there was a significant difference (P<0.001) in forage DMI and the concentrate DMI of the two herds. The HG herds had a herbage intake of 12.9 kg DM/cow/day compared to the HC treatment, which had an estimated grass silage intake of 5.7 kg DM/cow/day. There was a significant difference (P<0.001) in both dry matter digestibility (DMD) (+0.002 g kg DM) and organic matter digestibility (OMD) (+0.017 g kg DM). The OMD of the HG diet was 0.829 g kg DM compared to the HC diet, which had an OMD of 0.812 g kg DM.

4. Discussion

Milk production and liveweight change

Although not significantly different the HG animals yielded +1 kg day more milk than the cows on the HC treatment. These results support previous studies (Sayers and Mayne, 2001; Dillon *et al.*, 2002) which all reported milk production advantages when early turnout to pasture was practised. Ferris *et al.* (2001a) found no significant increase in spring milk production when cows offered a low level of grazed grass were compared to cows offered high levels of concentrate indoors. In contrast to previous studies the animals in the present study were turned out to pasture full time and offered a DHA of 15.1 kg DM/cow/day with a low level of concentrate (3 kg DM/cow/day).

The large difference in milk protein yield and composition, in this study, illustrates the potential benefit of increasing the proportion of grass in the diet of the spring calving dairy cow in early lactation. The increases in milk protein yield and content (Table 6) for the HG group were large when compared to similar studies (Roche *et al.*, 1996; Dillon *et al.*, 1995, 2002

The findings of this study disagree with that of Ferris *et al.* (2001b), in that study an increased milk protein concentration was noted when concentrate was included in the diet at a rate of either 0.50 or 0.60, irrespective of silage quality. The continued elevation of milk protein content of the HG herd in the carryover period is similar to that reported by Gordon *et al.* (2000) and Dillon *et al.* (2002). Such significant carryover effects (P<0.01) subsequent to the initial study may be explained by the large initial treatment difference in milk protein content and the possible adaptation of the HG herd to grazing. Allowing cow's access to pasture had a positive effect on liveweight gain. This is in agreement with the higher total DM intake (+0.4kg DM cow/day) of these animals. The additional amount of nutrients supplied was sufficient to allow this higher gain.

Dry matter intake

The production performance of the lactating cow in any milk production system is primarily controlled by the quantity and quality of feed consumed. During the intake estimation period there was no difference in the quantity of DM offered to each treatment as both treatments were offered 18.8kg DM cow/day. Yet, given the difference in milk production (+1 kg) a higher dry matter intake was expected from the HG treatment, as grazed grass is considered a more highly digestible feed (Table 2) with greater intake characteristics (Dillon *et al.*, 2002). However no significant difference in total dry matter intake was observed (Table 8). From the outset of the present study a higher level of milk production, expressed by a higher intake, was expected from the HC treatment given that concentrate was included at such a high level in the diet. Additionally Ferris *et al.* (2001b) stated that regardless of the silage feed value total dry matter intake and milk yield usually tended to increase with an increased concentrate proportion in the diet however it should be noted that Dermaquilly (1973) reported that the voluntary intake of forage DM when conserved is lower than that of the herbage from which it was produced.

5. Conclusions

Early turnout of spring calving dairy cows with a high DHA in the early post-partum period resulted in an improvement in milk production characteristics and liveweight when compared to cows housed indoors offered a high level of concentrates. The increased production performance achieved by the HG animals is attributed to a higher total DM intake, energy and protein intake supported by excellent grass utilisation conditions. The outcome of this study supports previous studies recommending that in early spring dairy cows should have access to grazed grass. A high DHA is desirable and is facilitated by closing paddocks early the previous autumn ensuring that a high pasture cover is available for grazing in spring. If possible cows should be turned out full-time – depending on soil conditions and weather, this practise along with the use of a single supplement (e.g. concentrate) can eliminate the need to offer grass silage to the cow in early lactation in spring. This study clearly shows that even a high level of concentrate supplementation and a medium quality grass silage will not increase the performance levels achievable with a high DHA and a low concentrate level.

Table 1. Chemical analysis of herbage offered, grass silage and concentrate offered to both herds during the study

	Grass (s.d.)	Silage (s.d.)	TMR (s.d.)	Concentrate	
				HC (s.d.)	HG (s.d.)
Dry matter (g kg DM)	195 (34.7)	214 (16.5)	347 (40.7)	874 (2.7)	861 (4.0)
PH	-	4.02 (0.35)	-	-	-
Crude protein (g kg DM)	236 (12.9)	141 (3.5)	161 (14.4)	161 (9.0)	182 (5.2)
ADF (g kgDM)	202 (17.5)	345 (9.5)	307 (22.8)	-	-
NDF (g kgDM)	387 (10.1)	494 (9.0)	438 (23.1)	-	-
DM digestibility (g kgDM)	825 (19.6)	696 (8.1)	737 (25.9)	-	-
OM digestibility (g kgDM)	844 (16.6)	-	-	-	-
Crude fibre (g kgDM)	-	-	-	111 (14.2)	100 (7.4)
Oil (g kgDM)	-	-	-	46 (6.7)	21 (2.3)
Ash (g kgDM)	66 (3.0)	84 (5.2)	94 (3.7)	65 (2.2)	91 (3.3)

Table 1. Chemical analysis of herbage offered, grass silage and concentrate offered to both herds during the study

	Grass (s.d.)	Silage (s.d.)	TMR (s.d.)	Concentrate	
				HC (s.d.)	HG (s.d.)
WSC (g kgDM)	270 (46.8)	260 (21.2)	290 (13.8)	-	-

ADF= Acid Detergent Fibre, NDF=Neutral Detergent Fibre, OM=Organic Matter, WSC=Water Soluble Carbohydrates

Table 2. The mean dry matter (kg DM cow) allowance and utilisation of both the HC and HG treatments over the 7 week study

Dry matter allowance (kg/day)				
	Concentrate (s.d.)	**Silage (s.d.)**	**Grass (s.d.)**	**Total (s.d.)**
HC	11.1 (2.3)	8.6 (1.9)	-	19.7
HG	3.0 (1.0)	-	15.1 (3.7)	18.1
Dry matter utilised (kg/day)				
	Concentrate	**Silage**	**Grass**	**Total**
HC	9.2	7	-	15.3
HG	3.0	-	13.8	16.8

Table 3. The effect of forage type and supplementation level on the performance of spring calving dairy cows in early lactation

	HC	HG	SED	Sig.
Milk production				
Milk yield (kg day)	27.3	28.3	2.86	NS
Fat (g kg)	41.6	38.6	3.45	***
Protein (g kg)	30.7	33.6	1.38	***
Lactose (g kg)	48.7	49.0	1.10	NS
SCM yield (kg day)	25.9	26.6	2.92	NS
Fat yld (g kg)	1124.0	1093.7	147.1	NS
Protein yld (g kg)	832	949.3	92.47	***
Lactose yld (g kg)	1324	1383	144.3	NS
Live weight (kg)	517.2	498.9	19.12	***
Live weight gain (kg day)	+0.03	+0.20	0.43	NS
Body Condition Score	2.92	2.87	0.14	NS

NS=Non-significant, ***=P≤0.001. SCM = Solids Corrected Milk Yield

Table 4. Total dry matter intake (TDMI), silage and concentrate intake and digestibility coefficients

	HC	HG	SED	Sig.
TDMI (kg DM/cow)	15.3	15.7	2.09	NS
Silage (kg DM/cow)	5.7	-	1.69	***
Grass (kg DM/cow)	-	12.9	1.69	***
Concentrate (kg DM/cow)	9.58	2.76	1.007	***
DMD (g kg DM)	0.800	0.802	0.001	***
OMD (g kg DM)	0.81	0.83	0.004	***

NS=Non-significant, ***=P≤0.001. OMD = Organic Matter Digestibility. DMD = Dry matter digestibility

Experiment II. The effect of early and delayed spring grazing on the milk production performance, grass dry matter intake and grazing management of dairy cows

Treatments and experimental design

Four grazing treatments were studied - two grazing dates and two stocking rates were contrasted. Swards were grazed in February/March (early grazing; E) or remained ungrazed until April (late grazed; L). In early April two stocking rates were imposed across each sward, high (H) and medium (M). The resulting treatments were early high(EH); early medium(EM); late high (LH) and late medium(LM).

Animals

Sixty-four cows were originally selected from the Moorepark general spring calving herd. Thirty-two animals were primiparous while the remaining thirty-two animals were multiparous (twenty-four second lactation animals and eight cows greater than third lactation). The animals assigned to the present study were previously assigned to an early lactation feeding study (Experiment II). The production data from the last three weeks of the previous study was used in the randomisation of animals to experimental groups for this study. Four groups of cows (n=16) were balanced on lactation number 1.9 (s.d. 1.47), days in milk to April 1st, 58 days (s.d. 9), milk yield (kg) 28.7 (s.d. 5.47), milk fat content 39.6 g kg (s.d. 4.26), milk protein content 32.1 g kg (s.d. 2.23), lactose content 48.81 g kg(s.d. 1.54), solids corrected milk yield (kg) 26.9 (s.d. 4.82), bodyweight (kg) 511 (s.d. 52.4) and body condition score 2.82 (s.d.0.35). Previous treatment (within Experiment I) was also used as a balancing factor. Once the groups were assembled and balanced they were randomly assigned to one of four grazing treatments.

Swards and grazing management

A total grazing area of 14.6ha (36ac) was used. This area was divided into an early grazed portion and a late grazed (ungrazed) portion. The entire land base used for the present study was closed on October 15th (s.d. 7 days) the previous autumn. To create the early grazed sward approximately half of the total area was grazed once between February 16th and April 4th (49 days). The average post grazing rising plate meter height for the rotation was 4.5 cm (s.d. 0.49). Utilisation of the sward was approximately 92% (s.d. 0.08). Surface damage was minimised during this period as animals were removed from the pasture during inclement weather conditions. The late grazed sward remained ungrazed during this time.

Nitrogen was applied at a rate of 60 kg N ha to each sward for rotations 1 and 2, after grazing. The application rate was decreased to 40 kg N ha for rotations 3 and 4.

Before the study commenced 84 paddocks (4 treatments x 21 day rotation) were measured and fenced. All paddocks had an individual water supply. Each treatment was allocated 21 paddocks for the experimental period. The area allowance for each herd was EH - 0.14 ha day, EM - 0.17 ha day, LH - 0.15 ha day, LM - 0.17 ha day. Fresh herbage was allocated after morning milking; residency time in each paddock was 24 hours.

Sward & Animal Measurements

As described in Experiment I.

Intake estimation

Individual dry matter intake was estimated three times during the trial period, during rotations 1, 2 and 4, using the n-alkane technique (Mayes et al., 1986) as modified by Dillon and Stakelum (1989).

Chemical analyses

As in experiment I

Statistical Analysis

All statistical analysis was carried out using SAS (SAS Institute, 2002).

All the herbage data was analysed using the following model:

$$Y_{ijk} = \mu + T_i + R_j + W_k + T_j \text{ x } R_k + e_{ijkl}$$

Where; μ = mean, T_i = grazing treatment (i = 1 to 4); R_j = rotation (j = 1 to 4), W_k = Week (k = 1 to 3), T_j x R_k = the interaction between grazing treatment and rotation and e_{ijkl} = residual error term.

Daily milk yield, milk constituent yield, milk composition and body weight (n = 63) were analysed using covariate analysis with the following model:

$$Y_{hijk} = \mu + L_i + F_j + G_k + F_j \times G_k + b_1 X_{hijkl} + b_2 DIM_{hijkl} + e_{hijkl}$$

Where: Y_{hijk} represents the response of the animal h in parity i with previous treatment j to treatment k; μ = mean;L_i = lactation number (i = 1 to 2); F_j = previous feeding treatment (j = 1 to 2); G_k = grazing treatment (k = 1 to 4); $F_j \times G_k$ = interaction of previous feeding treatment × grazing treatment; $b_1 X_{hijkl}$= the respective pre-experimental milk output or bodyweight variable and $b_2 DIM_{hijkl}$ = days in milk and e_{hijkl} = residual error term.

Results

Weather

Total rainfall was less than the ten-year average for the months of April (64.5 mm), May (42.9 mm) and July (46.6 mm) by 11.6 mm, 29.9 mm and 6.8 mm, respectively. However average rainfall exceeded the ten-year average during June (+29.2 mm) while rainfall in August (171.1 mm) was twice the average. Mean temperatures for the months of April, May and August concurred with the average temperature of the previous ten years. In June temperatures (15^{o}C) surpassed the ten-year average by +1.7^{o}C but were over 1^{o}C lower than average during July (14.3^{o}C). Total sunshine hours were lower than the ten-year average for all months except May when the average was exceeded by almost 9 hours.

Grazing Management

The study was completed over 4 x 21 day rotations beginning on April 12th and finishing on July 3rd (84 days). No topping was carried out during the study period. The stocking rate of the LH treatment decreased by 0.6 cows/ha to 5.9 cows/ha in the final rotation, this was completed by removing two non-experimental cows from the treatment. The level of growth in conjunction with the high stocking rate resulted in a DHA that was deemed insufficient to maintain the animals (<15 kg DM/cow/day). The differences in stocking rate between the treatments throughout the four rotations resulted in a significant ($P<0.001$) difference in the area offered to each cow. Cows on the EH treatment were allocated 87 m^2/cow/day while cows on the EM treatment were allocated 105 m^2/cow/day for the duration of the study. Due to the reduction in stocking rate, cows on the LH treatment were offered 73 m^2/cow/day for the first three rotations and 81 m^2/cow/day for thefinal rotation. The animals on the LM treatment were allocated 87 m^2/cow/day for all four rotations.

Chemical Composition

The chemical analysis of the herbage offered to all treatments over the four rotations is presented in Table 5. The organic matter digestibility (OMD) of the early grazed sward (828 g kgDM) was higher than that of the late grazed sward (808 g kgDM). The crude protein (CP) content of the early grazed sward (238 g kg DM) was also higher than that of the late grazed sward (214 g kg DM). There was no significant difference in ash, ADF or NDF between any of the treatments.

Herbage Production

Grazing treatment had no effect on herbage production over the study period (Table 6). There was however a significant difference ($P<0.001$) in pre grazing herbage mass > 4 cm between the EH and LM swards (+ 876 kg DM ha), there was no significant difference between the EM and LH swards. Over the four grazing rotations the LG sward had a higher pre grazing herbage mass > 4 cm compared to the EG sward. Pre grazing sward height was significantly higher ($P<0.001$) for the LM sward (+2.0 cm) than the EH sward. The sward density of the late grazed sward was significantly higher ($P<0.001$) than that of the early grazed sward.

Herbage allowance and grass utilisation

Daily herbage allowance was significantly different (P<0.001) between treatments over the four rotations (Table 7). However, DHA was similar between the EM and LM treatment approximately 28.5 kg/DM/cow/day. The EH and LH treatments had a lower daily herbage allowance of approximately 20.7 kg/DM/cow/day. Post grazing surface sward height (PGSSH) was significantly different (P<0.001) between the treatments. The PGSSH for the highly stocked swards (EH and LH treatments) was significantly lower (-1.3 cm) than that of the other two treatments.

Herbage removed per cow was significantly different (P<0.001) between the high medium stocking rate treatments. Herbage removed per cow on the medium stocked swards was approximately 20.7 kg DM/cow/day however the quantity of herbage removed on the more highly stocked swards was significantly lower (P<0.001), and was approximately 17.1 kg DM/cow/day for the EH and LH treatments. Herbage utilisation was significantly higher (P<0.001) for the highly stocked treatments, cows grazing the EH sward utilised 86% of the offered herbage, this level was also significantly higher than that of the LH sward (82%). There was no significant difference in sward utilisation between the EM (75%) and LM (73%) swards.

The number of grazing days per hectare was significantly different (P<0.001) between treatments. The LH treatment had the greatest number of grazing days per ha (133.4 days) compared to the EM treatment which obtained 94.3 grazing days/ha, the least number of grazing days. Both the EH and LM treatments had an equal number of grazing days per ha (115.3 days).

Milk yield and milk composition

Table 8 shows the effect of grazing treatment on milk yield and composition, bodyweight and body condition score. A significant difference (P<0.001) in milk yield and milk composition was recorded between treatments. Cows grazing the EM treatment had significantly higher (P<0.001) milk, SCM, fat, protein and lactose yield as well as a higher protein concentration than the other three treatments. Animals grazing the LH sward had significantly lower (P<0.001) milk, SCM, protein and lactose yield in addition to lower protein concentration when compared to all other treatments. Animals on the EH and LM treatments recorded values that were intermediate between the EM and LH treatments for these parameters. There was no significant difference in liveweight and BCS between the treatments, although the more highly stocked treatments tended to have a lower bodyweight.

Intake estimation

The grass dry matter intake (GDMI) measured during rotations 1, 2 and 4 are presented in Table 9. Cows grazing the early sward at a medium stocking rate had a consistently higher GDMI than the other treatments over the three intake estimation periods. Conversely the animals grazing the LH sward had a significantly lower (P<0.001) GDMI than the other three treatments. The mean dry matter intakes of the treatments followed a similar pattern to the milk production performance. Cows grazing the EM sward had the highest mean GDMI (17.5 kg DM/cow/day), while the LH herd had the lowest (P<0.001) mean GDMI (15.2 kg/DM/cow/day). The GDMI's of the animals grazing the EH (16.3 kg/DM/cow/day) and

LM (16.5 kg/DM/cow/day) swards were between the values recorded by the cows grazing the other treatments.

Sward composition

Chemical analysis

The chemical composition of the early grazed sward differed markedly from that of the late grazed sward. A higher OMD and crude protein content in the early grazed sward may be associated with a lower average age of the plant tissues, as well as the removal of stem material before elongation occurs. The composition of the herbage sampled from the early grazed swards is characteristic of early spring swards and indicates a high proportion of digestible leaf material within the sward. The less digestible material in the LG sward, especially in the lower horizon of the sward may have inhibited the animals from grazing deeper into the sward profile.

Sward Production and Utilisation

The results of the present study suggest that early spring grazing does not reduce the sward's growth potential as there was no difference in grass growth rates between the different grazing dates were found. This was in agreement with the findings of Mayne and Laidlaw (1995) in Northern Ireland and O'Donovan (Experiment III) in France.

Late turnout can lead to large accumulations of herbage, which can be difficult to graze. High post grazing sward height reduces grass utilisation and leads to reduced sward productivity. Grass utilisation was significantly lower for the late grazed swards (-4%) in this study. Brereton and Carton (1986) have shown that the rate of dry matter production in the upper harvested horizon of a high stubble sward was lower than the rate in short stubble swards. When the difference in pre-grazing herbage mass was calculated between the early and late grazed swards in the first rotation of this study the mean difference was 1610 kg DM/ha. However there was no difference in total herbage production between the swards within the study. As there was a reduced herbage mass available to the early grazed treatments in rotation 1, the cows grazed to lower post grazing sward heights, which in turn reduced the pre-grazing herbage mass further for these treatments in rotation 2 (-471 kg DM/ha) compared to the late grazed treatments. However there was no difference between swards in the third and fourth rotations.

Animal Performance

Milk Production

The results of this study agree with previous studies (Experiment I) showing that increasing the stocking rate significantly affects milk production. The stocking rates used in the experiment were set at practical levels. If however, they had been set to match availability, then a much larger effect of poor sward quality would have been found.

Early grazing has previously been found to improve dairy cow performance in early lactation (Experiment I) usually coinciding with the first grazing rotation (February to early April). However, this study investigated the conditioning effect which early grazing has on milk production in subsequent rotations. The findings show that animals grazing the early grazed sward at a medium stocking rate had significantly higher ($P<0.001$) milk, SCM and protein concentration when compared to animals on the late grazed sward. In spite of higher pre grazing herbage mass, similar DHA and higher post grazing height a reduced milk yield was produced by cows grazing the LM treatment when compared to the EM treatment thus emphasising the importance of sward structure and OMD. This effect is further highlighted when compared to the EH treatment (lower DHA and low post grazing height). It has also been reported that cows grazing swards with a high herbage mass yielded less milk when compared to cows grazing a low herbage mass sward.

This study showed that for early turnout, cows grazing at the medium stocking rate (4.5 cows/ha) had superior performance. For late turnout there was no difference between stocking rates with similar effects found for fat, protein and SCM yields and also lactose content.

Dry Matter Intake

Efficient use of grassland and a high performance level are achievable when animals have an elevated intake of a high quality sward. The larger DHA’s offered to the cows grazing the medium stocked swards corresponded to dry matter intakes that were higher than those of the cows grazing the more highly stocked swards.

Holmes *et al.* (1992) postulated that the difference in milk composition was probably due to differences in the chemical composition of the sward or differences in dry matter intake between animals. The results of this study show that the higher performance levels achieved by animals grazing the early grazed swards are due to both superior sward quality as well as a higher DM intake.

With a higher herbage mass available, the animals grazing the late swards had access to swards with lower levels of leaf and higher levels of stem material. This is evident when EM and LM treatments are compared and is confirmed by the chemical analysis and nutritive value of grass offered. Both EM and LM treatments had a similar DHA, but different GDMI. It is clear that the sward structure presented to the cows affected their performance. This indicates that with later grazed swards it is difficult for the grazing animal to achieve high GDMI as the stem proportion of the sward is higher up the sward horizon and places a physical barrier for animals grazing through the horizon.

Conclusions

Increasing the proportion of grass in the diet of the dairy cow is one of the fundamental objectives of Irish milk production systems. Turnout date has a major effect on the level of milk production both per cow and per hectare. Early turnout results in increased sward quality, higher sward utilisation and also conditions the sward for subsequent grazing rotations. This in turn supports higher individual cow productivity as the present study has shown that animals grazing the early grazed sward maintained a higher milk yield as well as higher milk composition throughout the grazing season. The higher solids corrected milk yield achieved by the animals grazing these swards produced milk of a higher value and also led to the efficient conversion of a low cost feed. The high level of milk production performance achieved by the cows grazing the early grazed sward at a medium-stocking rate in this study reinforces the results achieved by other authors. Grazing swards early in spring is recommended in order to optimise milk production per cow while at the same time maintaining sward quality; it is also an effective strategy to use land more efficiently.

Table 5. Chemical analysis for all swards over four grazing rotations which investigated the effect of grazing date and subsequent stocking rate

	EH	**EM**	**LH**	**LM**	**SED**	**Sig**
Organic matter digestibility (g/kg DM)	836[a]	819[b]	812b[c]	804[c]	7.1	***
Ash (g/kg DM)	109	107	116	113	4.7	NS
Crude protein (g/kg DM)	246[a]	230[b]	221[bc]	207[c]	8.0	***
Acid detergent fibre (g/kg DM)	256	265	271	275	7.9	NS
Neutral detergent fibre (g/kg DM)	437	457	461	447	11.6	NS

NS, not significant; ***, $P<0.001$; EH = Early grazed sward, high stocking rate ; EM = Early grazed sward, medium stocking rate ; LH = Late grazed sward, high stocking rate ; LM = Late grazed sward, medium stocking rate

Table 6. The effect of grazing date and stocking rate on herbage production, herbage mass, pre-grazing sward height and sward density from April 12th to July 3rd

	EH	**EM**	**LH**	**LM**	**SED**	**Sig**
Total Herbage Production (kg/DM/ha)	2065	2229	1989	2158	100.2	NS
Pre-grazing herbage mass >4cm (kg/DM/ha)	2355[a]	2741[b]	2801[b]	3231[c]	145.7	***
Pre grazing sward height (cm)	13.4[a]	14.6[b]	14.1[ab]	15.4b[c]	0.45	***
Sward density >4cm (kg/DM/cm/ha)	253[a]	258[a]	278[b]	284[b]	6.4	***

Abbreviations as in Table 5.

Table 7. The effect of initial spring grazing date and stocking rate on herbage allowance and utilisation from April 12th to July 3rd

	EH	**EM**	**LH**	**LM**	**SED**	**Sig**
Herbage Allowance >4cm (kg/DM/cow/day)	20.4[a]	29.0[b]	21.0[a]	28.0[b]	1.33	***
Herbage Utilisation						
Post grazing sward height (cm)	5.4[a]	6.8[b]	6.0[c]	7.2[b]	0.18	***
Herbage removed (kg/DM/cow/day)	17.4[a]	21.2[b]	16.8[a]	20.2[b]	0.91	***
Herbage removed (kg/DM/ha)						
Utilisation (%)	86[a]	75[b]	82[c]	73[b]	0.01	***
Grass growth (kg/DM/ha/day)	90.7	98.8	84.7	93.0	4.70	NS
Grazing days (days/ha)	115.3[a]	94.3[b]	133.4[c]	115.3[a]	0.06	***

Abbreviations as in Table 5.

Table 8. The effect of initial grazing date and stocking rate on milk yield, milk composition, bodyweight and body condition score of spring calving dairy cows over four rotations from April 12th to July 3rd

	EH	EM	LH	LM	SED	Sig.
Milk yield (kg)	22.7[a]	24.5[b]	20.9[c]	22.4[a]	0.73	***
Fat (g/kg)	38.9	37.8	40.0	37.8	1.21	NS
Protein (g/kg)	32.9[a]	34.1[b]	32.1[c]	32.7[a]	0.32	***
Lactose (g/kg)	47.3[a]	47.4[a]	46.7[ab]	47.0[ab]	0.32	NS
SCM yield	20.9[a]	22.5[b]	19.4[c]	20.4[ac]	0.61	***
Fat yield (g/kg)	871.8[a]	917.8[b]	829.5[a]	845.9[a]	27.47	**
Protein yield (g/kg)	744.4[a]	831.4[b]	670.2[c]	733.2[a]	23.01	***
Lactose yield (g/kg)	1068.1[a]	1158.6[b]	976.0[c]	1051.9[a]	37.69	***
Liveweight (kg)	503	514	509	516	10.04	NS
Liveweight gain (kg/day)						
BCS	2.76	2.75	2.71	2.73	0.06	NS

Abbreviations as in Table 5.

Table 9. The effect of initial grazing date and stocking rate on grass dry matter intakes (kg/DM/cow/day) during rotations 1, 2 and 4 for four grazing treatments

	EH	EM	LH	LM	SED	Sig.
GDMI (Rot. 1)	16.6[a]	18.2[b]	16.3[a]	17.0[a]	0.65	**
GDMI (Rot. 2)	16.6[a]	18.1[b]	16.8[ac]	17.7[bc]	0.65	**
GDMI (Rot. 4)	15.2[a]	16.3[b]	12.4[c]	14.9[a]	0.62	***
Mean GDMI	16.3[a]	17.5[b]	15.2[c]	16.5[a]	0.52	***

Abbreviations as in Table 5.
GDMI - Grass dry matter intake

Experiment III. Effect of time of initial grazing date and daily herbage allowance on pasture production and dairy cow performance

Materials and Methods

Treatments and experimental design

Four grazing treatments were studied. Two different sward types and two stocking rates were contrasted. Different swards were created by either grazing in March (early grazing; E) or by delaying the start of grazing until mid April (late grazing; L). Two stocking rates were imposed across each sward, High (H) and Medium (M).

The experiment took place over a 10 week period from April 17 to June 20 (in 2003) at the experimental farm of Mejusseaume (INRA, Le Rheu) located in the Rennes Basin in Brittany (France) using 48 cows and a total area of 12.1 ha.

Pasture and grazing management

Perennial ryegrass pastures which were on average 5 years old (range 12 - 2 years) were used. The grass cultivar sown in the paddocks was either; *cv*. Belfort, Hercules or Ohio. All cultivars were sown as monocultures. There was no clover in the pastures. Approximately half of the total land area was grazed off during March (early grazed treatment) The remaining half of the land area was left ungrazed. The animals grazed the early grazed paddocks to an average post grazing rising plate meter height of 3.9cm. The pasture height for ungrazed paddocks during this period was 7.9cm.

Grazing took place only when the animals were liable cause the least amount of surface damage. During the pre experimental grazing period the animals were housed by night. The sum of this grazing period equated to 36 cows grazing at a stocking rate of 6 cows/ha for half-day periods, this grazing regime lasted for 22 days (which is in total 66 grazing days/hectare).

After the preliminary spring grazing each paddock was sub divided on a proportional basis. The H stocking rate treatments were allocated 45% of the paddock area while the M stocking rate treatments were allocated 55% of the land area, on both grazed and ungrazed paddock areas. There were 5 paddocks assigned to each treatment, the range in paddock size was (0.43 - 0.71ha) for the H stocking rate treatments and (0.53 and 0.89ha) for the M stocking rate treatments, respectively.

The nitrogen fertilisation was the same for each treatment, 60kg nitrogen/ha was applied in the form of ammonium nitrate after each grazing. Initial nitrogen application commenced for each paddock block after grazing in early spring. Since their sowing, the pastures have bi-annually received a basic dressing of 120, 220 and 100 kg/ha of P, K and Mg, respectively.

The four groups of cows were strip grazed throughout the trial. The daily offered area for each treatment was calculated from the herbage mass in each paddock. Therefore there were no differences between treatments in residency time. The front fence was moved once each day after morning milking. A back fence was erected mid-way through the grazing area of each paddock. Water and a mineral block were always available to each grazing herd.

In rotation 1, the stocking rate imposed on the high and medium treatments was 6.3 and 5.0 cows/ha, respectively. In rotation 2, the effective stocking rates was reduced. The stocking rate was 4.6 and 4.0 cows/ha in rotation 2, for both high and medium stocking rate treatments. Table 10, describes in detail the grazing management rules applied during the study.

Table 10. Methodology used to define stocking rate according to the herbage mass present.

In this study, the high stocking rate was defined with the objective of maintaining a herbage allowance of 18 kg DM/day for the cows grazing the LH treatment. The difference in stocking rate between high and medium was calculated to obtain a similar herbage allowance (> ground level) for the LH and EM treatment.

Consequently, the daily grazing area was allocated based on the four following rules :

1. Daily grazing area for LH treatment was calculated to offer 18 kg DM/cow/day(>50mm).
2. The same grazing area/cow/day was allocated to the LH and EH treatments.
3. The daily grazing area for EM was calculated to offer the same DM/cow/day from ground level as the LH treatment.
4. The same grazing area was offered to the LM and EM grazing treatments.

Example of the calculation of the stocking rate according to the herbage mass and grazing rules applied

Grazing date Stocking rate	Early High	Early Medium	Late High	Late Medium
Herbage mass > 50 mm (kg DM/ha)	1500	1500	2500	2500
Herbage mass > ground level (kg DM/ha)	3500	3500	4500	4500
Herbage allowance > 50mm (kg DM/cow/day)	10.8	13.9	**18.0**	23.1
Area (m^2/cow/day)	72.0	92.6	72.0	92.6
Herbage allowance > ground level (kg DM/cow/day)	25.2	**32.4**	**32.4**	41.7
Stocking rate (1)	5.5	4.3	5.5	4.3

(1) for a 25 days rotation

Animals

The herd of 48 cows was made up of 25% primiparous and 75% multiparous animals. All animals were in mid lactation at the beginning of the experiment. Treatment groups (n = 12) were balanced on the basis of the following criteria: parity, stage of lactation (160 ± 35.2.days), milk yield (31.8 ± 4.1), milk fat content (35.6 ± 5.9), milk protein content (29.2 ± 1.6), body weight (622.4 ± 48.8) and body condition score (2.3 ± 0.45) recorded in the previous 2 weeks (23 March to April 7). Once the groups were assembled, they were randomised to one of the four grazing treatments.

Sward and animal measurements

Herbage mass (>50mm) was determined in each grazing paddock by cutting either four or six strips (0.5 × 10m) with an Agria motorscythe. Before and after harvesting, ten grass height measurements were recorded on each cut strip using an electronic plate meter with a plastic plate (30 x 30cm and 4.5kg/m^2) in order to determine the sampled height precisely and to calculate the sward density (kg DM/cm/ha). All mown herbage for each strip was collected and bagged. It was then weighed and sampled. Approximately 1.5 kg herbage samples were then dried in a drying oven for 48h at 80^{o}C for DM determination. The sward height was estimated (100 measurements per ha) on each sub-paddock. This sward height multiplied by the mean sward density from the Agria cuts was used to calculate the herbage mass at the paddock level.

To estimate herbage mass from ground level, the residual herbage mass after cutting by the Agria mower was measured. In each strip, residual herbage mass was cut with a scissors at ground level in a $0.1m^2$ area. After manual removal of soil and roots the samples were weighed and dried in an oven for 48 h at 80^oC to determine DM content.

Pre and post grazing sward heights were measured each day with a rising plate meter with 30 measurements per treatment taken at random across the grazed strip. The pre-grazing sward height measured multiplied by the mean sward density was used to calculate the daily herbage allowance to the herds.

The calculation method specified by Delaby and Peyraud (1998) can be applied to assess the herbage mass production and utilisation. It was used in this study to evaluate the herbage mass produced and the herbage mass removed. Grass production (kg DM/ha) was calculated with the following equation; (pre-grazing height - previous post grazing height) × sward density. Grass growth (kg/DM/day) was calculated by dividing the grass production figure by the number of days regrowth. Grass removed (kg DM/cow/day) was calculated using the following equation ; (pre-grazing height - post grazing height) × sward density × area grazed/cow/day. The grazing outcomes (stocking rate, grazing days/ha, milk/ha) were calculated by rotation according to the methodology of Hoden et al. (1991).

Milk yield was recorded daily at both morning and evening milkings (07:00 and 17:00h) using flowmeters (Westfalia). During six consecutive milkings per week, an individual milk sample was taken in order to determine the fat and protein concentration by infrared spectrophotometry (Milkoscan, Foss Electric, DK-3400 Hillerod, Denmark). Animals were weighed one morning per week, after morning milking.

Results

Grazing Management

The first rotation lasted 33 days beginning on April 17. The mean offered area was $61m^2$ for the medium stocking rate treatments compared to 48 m^2 for the high stocking rate treatments. One paddock was cut for silage the May 19, this paddock was grazed in the second rotation. Rotation 2 lasted 32 days, the grazing area increased in rotation 2 due to lower grass supply. The mean offered area was $10m^2$ (78 v. 68) larger for the medium stocked treatments.

Grass growth and herbage mass

There was no effect of grazing date on herbage production or grass growth in rotation 1, however the interaction between grazing date and stocking rate tended towards significance. This may have been due to two paddock's reduced grass growth and DM production in the LM treatment. In rotation 2, later grazed swards had lower DM production (-199 kg DM/ha, $P < 0.04$), they also had lower daily grass growth (-7 kg DM/ha/day, $P < 0.03$).

Grazing date ($P < 0.001$) had a significant effect on pre-grazing herbage mass (>50mm)and herbage mass (>ground level) in both rotation 1 and 2 (Table 11). Herbage mass (>50mm) in rotation 1 was -1217 kg DM/ha lower for early grazed swards compared to late grazed swards. Herbage mass (>ground level) was -451 kg DM/ha for early grazed swards compared to late grazed swards. In rotation 2, the difference in herbage mass (>50mm) declined, early grazed swards recorded -516 kg DM/ha lower herbage mass (>50mm) than late grazed swards. Herbage mass (>ground level) was -523 kg DM/ha for early grazed swards.

Pre-grazing sward height was significantly affected by grazing date (*P* < 0.001) and stocking rate (*P* < 0.05) in rotation 1. Early grazed swards had a lower pre-grazing height (-4.3cm) than late grazed swards. The pre-grazing height for high and medium stocking rate swards in rotation 1 was 15.1 and 14.0cm, respectively. Early grazed swards had higher sward density (+24.6 kg DM/cm/ha, *P* < 0.02) than later grazed swards, while medium stocked swards had (+19.7 kg DM/cm/ha, *P* < 0.05) higher sward density than highly stocked swards. In rotation 2, earlier grazed swards continued to have a lower sward height 11.7cm compared to 12.9cm for later grazed swards.

Chemical composition

There was no effect between grazing date and stocking rate for herbage chemical composition or nutritive value (Table 12). In rotation 1, grazing date significantly affected a number of chemical parameters. Early grazed swards had significantly (*P* < 0.001) lower DM content, crude fibre, NDF, ADF, but significantly higher OMD, UFL, PDIE and PDIN (*P* < 0.05) compared to late grazed swards.

In rotation 2, earlier grazed swards had significantly lower DM content (*P* < 0.001), NDF (*P* < 0.01), ADF (*P* < 0.02) but significantly higher crude protein (*P* < 0.01), OMD (*P* < 0.001), UFL (*P* < 0.001), PDIE (*P* < 0.001), PDIN (*P* < 0.01) than late grazed swards. Medium stocked swards had higher DM content (*P* < 0.04) but had no other significant effect on chemical composition.

Herbage allowance and grass utilisation

Herbage allowance

In both rotations herbage allowance (>50mm) and (>ground level) was significantly affected by grazing date (P < 0.001) and stocking rate (*P* < 0.001) (Table 13). In rotation 1, the herbage allowance allocated was 12.2, 15.3, 19.7 and 22.5kg DM/cow/day for EH, EM, LH and LM. The grass allowance (>ground level) allocated to EM and LH treatments was similar, 35.9 and 34.6kg DM/cow/day (NS).

In rotation 2, early grazed treatments were allocated 13.4, 16.0, 17.6 and 20.4kg DM/cow/day (>50mm). The herbage allowance (>ground level) was 48.6 and 45.6kg DM/cow/day for EM and LH grazing treatments (NS).

Post grazing height and herbage removed

Grazing date had a significant (*P* < 0.001) effect on post grazing sward height in both rotations. In rotation 1, early grazed swards had a post grazing height of 4.7cm compared to 7.1cm for the later grazed swards. In rotation 2, early grazed swards recorded a post grazing height of 5.0cm while late grazed swards had a post grazing height of 6.2cm. The effect of stocking rate tended towards significance (*P* < 0.09) in rotation 2, higher stocked swards had a post grazing height of 5.4cm compared to 5.8cm for medium stocked swards.

Grazing date (*P* < 0.01) and stocking rate (*P* < 0.001) had significant effects on the amount of herbage removed in both rotations. In rotation 1, cows grazing the early swards removed 14.3 *vs* 17.2 kg DM/cow/day for cows grazing the late grazed swards. Cows grazing the medium stocked swards removed 16.8 compared to 14.7 kg DM/cow/day for cows grazing at the high stocking rate. In rotation 2, cows grazing the early grazed swards removed 14.8 *vs* 16.0 kg DM cow/day for the cows grazing the late grazed swards. Cows grazing the medium stocked swards removed 16.2 compared to 14.6 kg DM/cow/day for the cows grazing at the higher stocking rate.

Herbage utilised and grazing days

In rotation 1, early grazed swards had significantly lower (-426 kg DM/ha, $P < 0.03$) grass utilisation than late grazed swards. In rotation 2, early grazed swards continued to have lower grass utilisation than the later grazed swards (-199 kg DM/ha, $P < 0.08$). Stocking rate had a significant ($P < 0.001$) effect on the number of grazing days achieved/ha in both rotations. In rotation 1, the higher stocked swards achieved 42 (rotation 1) and 20 (rotation 2) extra grazing days compared to the medium stocked swards.

Animal Performance

Stocking rate, by virtue of the fact of a lower herbage allowance allocated, significantly affected milk, fat, protein and FCM yield in both rotations. Grazing date had a significant effect (P < 0.001) on milk, fat, protein and FCM yield only in rotation 1 (Table 14). There was a significant interaction between grazing date and stocking rate for milk ($P < 0.001$), fat ($P < 0.01$), protein ($P < 0.001$) yield in both rotations and 4% fat corrected milk yield (FCM) ($P < 0.001$) in rotation 1.

In rotation 1, the interaction for milk yield was large between grazing treatments. The difference in milk, fat and protein yield (cow/day) between EM and EH treatments was +3.1 kg milk, +92 g fat, +92 g protein and +2.6 kg FCM yield. The production difference between LM and LH treatments was only +0.9 kg milk +15 g fat, +15 g protein and +0.5 kg FCM yield.

The cumulative effect of the first grazing rotation increased in the second rotation. The milk production difference (cow/day) between EM and EH increased to +4.9 kg milk, the fat and protein yield difference increased to +162 and +142 g, respectively. The difference between LM and LH remained similar at +1.0 kg milk, +18 g fat and 31 g protein yield, respectively.

The effect of stocking rate approached significance for milk fat content ($P < 0.06$) in rotation 1. Cows grazing at the high stocking rate recorded a milk fat content of 38.1 compared to 37.1 g/kg/day for medium stocked cows. There was no other significant effect on milk composition in either rotation.

Cows grazing the late grazed swards had higher bodyweight (+8kg, $P < 0.05$) than cows grazing the earlier grazed swards in the first rotation, however there was no difference in bodyweight between treatments in the second rotation. Grazing date or stocking rate had no significant effect on body condition score during the experiment. In the post experimental period, grazing date and stocking rate had no effect on either body weight or body condition score.

There was a significant interaction between grazing date and stocking rate for milk output/ha in rotation 1 ($P < 0.05$) and 2 ($P < 0.001$). The difference in milk output between EH and EM was +144 kg milk/ha (NS) in rotation 1 and was reversed in rotation 2 (-198 kg milk/ha, NS).

While the difference in milk output/ha between LH and LM was +925 (rotation 1) and +285 (rotation 2) kg milk/ha, respectively.

Grass intake and energy balance

Table 15 shows the grass DM intake and energy balance of the treatment groups. The interaction between GD and SR approached significance for GDMI. However, cows grazing the earlier grazed swards had lower -1.64 kg DM/cow GDMI than the cow grazing the later grazed swards. Lower stocked cows had higher GDMI (+1.53kg DM/cow/day) compared to higher stocked cows. The early grazed, medium SR treatment and had a higher UFL intake, which caused GD and SR to interact.

Lower stocked treatments had higher PDIE (+146), PDIN (134) and UFL (+0.78) requirement than higher stocked treatments. The interaction between GD and SR for PDI requirement was caused by the lower requirement of the EH treatment.

Early grazed treatments had significantly lower UFL balance ($P<0.05$, -0.709) and PDIE balance (-48.6) than later grazed treatments. The interaction for PDIN balance approached significance as the LH treatments had lower PDIN compared to the other treatments.

DiscussionGrass production and grass quality

The results from this study suggests that early spring grazing does not reduce the sward growth potential as there was no difference in grass growth rates between the different grazing dates. The same difference (4cm) in sward height which existed in late March after the grazing off period was present during rotation 1, this shows the compensation in growth completed by the early grazed swards. It could also be argued that the removal of higher DM yields by defoliation early in the year reduces subsequent production. Grass growth was 5kg DM/ha/day lower with the delayed grazing treatment during the second rotation even though the post grazing height was larger for these treatments. Late turnout can lead to large accumulations of herbage that can be difficult to graze. High post grazing sward heights not only reduce the efficiency of grass utilisation which results in reduced sward productivity.

The reduction in pre grazing herbage mass as a result of the early turnout treatments was large resulting in -1217 kg DM/ha in rotation 1. When the difference in pre grazing herbage mass is calculated for the early grazed treatments, on average 1230 kg DM/ha was grazed off in March, this was calculated by taking a sward density of 300 kg DM/ha for each 1cm grazed above 4cm. As the herbage mass available to the early grazed treatments was low in rotation 1, the cows grazed to low post grazing sward heights, this in turn reduced the pre grazing herbage mass further for these treatments in rotation 2 (-516 kg DM/ha) compared to the late grazed treatments.

Herbage from the early grazed swards was of higher quality (increased OMD and UFL values) than from the late grazed swards. Large differences in vitro digestibility occurred between grazing dates. Which in part reflects seasonal trends in the accumulation of dead herbage (L'Huillier, 1987) and possibly a positive change in the green leaf proportion. By delaying spring grazing, dead herbage is allowed to build up at the base of the sward because of increased tiller death rate. The problem of high senescence rates is further increased if the swards are not grazed to low post grazing sward heights.

Animal performance and grass utilisation

In rotational grazing systems limiting factors concerning herbage allowance and its effect on herbage intake and milk production are the height of the residue left post grazing. Herbage eaten by grazing animals usually contains a higher nutrient value than the sward as a whole. However differences in sward structure especially at the base of the sward and diet selected by the grazing animal lead to differences in the interpretation of grass allowance. In this study even though grass allowance (>50mm) was lower for the cows grazing the EM treatment they produced as much milk as the two later grazed treatments while achieving >100% removal, both later grazed treatments had on average 84% of grass allowance removed.

Cows grazing the EH swards grazed to low post grazing heights, because of the reduced grass allowance, it is possible they were physically restricted to grazing further into the sward horizon. Contrary to this the cows grazing the LM treatments grazed to the same post grazing height as the cows on the LH sward. While these animals had a higher grass allowance, they were at the upper limit of grass allowance for this sward type and could not graze any further. Later grazed swards had poorer sward quality as defoliation intensity and herbage mass were higher throughout the study compared to the earlier grazed swards. With a high herbage mass available to graze, the animals grazing the late swards had access to swards with lower levels of leaf and stem content. This is very evident when EM and LH treatments are compared and is confirmed by the chemical analysis and nutritive value of grass offered. Both EM and LH treatments had the same grass allowance at ground level however, it is clear that the sward structure of both swards affected animal performance. This indicates that a lower grass allowance can be tolerated with early grazed swards and can have beneficial effects on milk production performance.

The effects of grazing date in this study interacted with stocking rate for a number of milk production parameters. This interaction shows clearly that for early turnout cows grazing at the medium stocking rate performed the best. While for late turnout there was no difference between stocking rates, similar effects were found for fat, protein and FCM yield. The reason given for the higher milk performance was the higher quality of herbage consumed by the cows grazing the low herbage mass swards.

The reduced milk yield with poorer quality swards in spite of higher daily herbage allowance (DHA) (>50mm) and post grazing height clearly emphasises the conditioning effect of early turnout on sward structure. Early grazed swards had lower pre grazing herbage available, cows grazing the EH treatment had lower milk production compared to the EM treatment. An important aspect of this study was the cumulative carryover effect of the EH in rotation 2. The cows grazing the EH swards continued their milk production decline. The difference in grass removed between the two treatments was large and was on average 2.2kg DM cow/day across both rotations. The response in milk yield/kg grass removed was 1.0 kg milk/kg grass removed (rotation 1) and 1.9 kg (rotation 2). Therefore the response to the extra DM allocated was large. Cows grazing the LM swards had higher herbage allowance than cows grazing LH swards, the milk production difference was small 0.6kg (rotation 1) and 1kg (rotation 2). Therefore at high herbage masses increasing herbage allowance did not increase milk production. The level of grass removed was on average +1.5 kg DM/cow/day higher for the LM animals. The response to the extra DM offered was lower than the previous relationship 0.64kg milk/kg grass removed (rotation 1) and 0.66kg (rotation 2). With late grazed swards the approach of allowing high grass allowance maybe wasteful as the gain in milk production is low.

Conclusions

The production of grass for early grazing has particular importance for grass based systems of milk production. How this grass is used has major effects on milk production per ha. Therefore delaying grazing in spring will result in high herbage mass swards which can support higher stocking rates. Milk production per hectare will be increased at least in the short term. In the long term this study shows the benefit of earlier grazing on milk production and sward dynamics. As well as producing milk of higher value (increased milk and fat corrected milk yield) the dairy farmer is making efficient use of a low cost feed. Early spring grazing can act as a sward conditioner i.e. to avoid the build up of excessively high pre-grazing yields. It can also make grazing management easier. The high level of milk performance achieved by the cows grazing the EM treatment even with lower grass allowance than the LH and LM treatments clearly shows the benefits of early grazing on sward quality. Therefore if the land area available and soil type allow, the practice of early grazing is recommended as it has beneficial effects on cow performance and sward quality when executed at a medium stocking rate.

Table 11. Effect of grazing date and stocking rate and their interaction on herbage production, mass, allowance, sward height and density in rotations 1 and 2

	EH	EM	LH	LM	Sed	GD	SR	GD*SR
Rotation 1								
Herbage Production								
Daily grass growth (kg DM/day)	66	68	70	58	6.3	Ns	Ns	+
DM production (kg/DM/ha)	2904	3001	3051	2584	274	Ns	Ns	+
Pre-grazing herbage mass (kg DM/ha)								
> 50mm	2567	2627	4026	3602	373	***	Ns	Ns
> Between 50mm and ground level	3387	3478	2979	3254	410.9	Ns	Ns	Ns
> Ground level	5954	6105	7004	6856	649	*	Ns	Ns
Sward height (cm)								
Pre-grazing sward height	12.7	12.2	17.6	15.9	0.98	***	*	Ns
Sward Density (kg DM/ha/cm)								
Density > 50mm	336	365	321	331	17.2	**	*	Ns
Density > ground level	677	696	596	651	82.2	Ns	Ns	Ns
Rotation 2								
Herbage Production								
Daily grass growth (kg DM/day)	66	65	60	58	6.1	*	Ns	Ns
DM production (kg/DM/ha)	2075	2029	1877	1829	190	*	Ns	Ns
Pre-grazing herbage mass (kg DM/ha)								
> 50mm	2074	2117	2608	2613	248.7	***	Ns	Ns
> Between 50mm and ground level	4034	4103	3997	4154	401.9	Ns	Ns	Ns

> Ground level	6108	6220	6605	6767	535.1	*	Ns	Ns
Sward height (cm)								
Pre-grazing sward height	11.8	11.5	12.9	12.9	0.83	***	Ns	Ns
Sward Density (kg DM/ha/cm)								
Density > 50mm	302	320	331	330	25.2	Ns	Ns	Ns
Density > ground level	807	821	799	831	80.4	Ns	Ns	Ns

EH - early grazed, high stocking rate ; EM - early grazed, medium stocking rate;
LH - late grazed, high stocking rate; LM - late grazed, medium stocking rate.; Rse - Residual standard error; GD - Grazing date; SR - Stocking rate
NS - not significant; + - P<0.10; * - P<0.05; ** - P<0.01; *** - P<0.001

Table 12. Effect of grazing date and stocking rate and their interaction on herbage chemical composition (g/kg DM) in rotations 1 and 2

	EH	EM	LH	LM	Sed	GD	SR	GD*SR
Rotation 1								
Dry matter (%)	18.4	19.0	20.6	22.4	0.74	***	**	Ns
Ash	92.8	96.5	102.8	107.5	10.4	+	Ns	Ns
Crude protein	162.8	160.5	150.3	146.0	10.8	*	Ns	Ns
Crude fibre	194.5	189.0	213.0	202.5	4.88	***	**	Ns
Neutral detergent fibre	446.3	437.8	486.5	464.3	16.13	***	+	Ns
Acid detergent fibre	198.0	193.3	221.5	212.0	4.75	***	**	Ns
OM digestibilityφ	82.3	82.6	78.3	78.7	1.11	***	Ns	Ns
UFL	1.05	1.05	0.97	0.97	0.024	***	Ns	Ns
PDIE	99.3	98.5	92.3	91.5	2.28	***	Ns	Ns
PDIN	102.3	100.8	94.3	91.8	6.79	*	Ns	Ns
Rotation 2								
Dry matter (%)	16.7	17.5	18.3	19.6	1.04	***	*	Ns
Ash	100.2	90.4	95.4	93.2	10.4	Ns	Ns	Ns
Crude protein	190.0	179.8	171.6	172.8	9.91	**	Ns	Ns
Crude fibre	235.0	235.8	241.4	243.2	10.44	Ns	Ns	Ns
Neutral detergent fibre	536.0	529.4	553.0	553.0	15.3	**	Ns	Ns
Acid detergent fibre	237.2	236.8	249.6	250.4	10.97	*	Ns	Ns
OM digestibilityφ	77.7	77.4	74.5	73.5	1.23	***	Ns	Ns
UFL	0.96	0.96	0.91	0.90	0.026	***	Ns	Ns
PDIE	100.0	98.8	94.2	93.8	2.17	***	Ns	Ns
PDIN	119.2	113.0	107.8	108.8	6.16	**	Ns	Ns

Abbreviations as in Table 11.

φ Calculated from pepsin-cellulase digestibility (Aufrère and Demarquilly, 1989).

Table 13. Effect of grazing date and stocking rate and their interaction on herbage allowance and utilisation in rotations 1 and 2

	EH	EM	LH	LM	Sed	GD	SR	GD*SR
Rotation 1								
Herbage allowance (kg DM/cow/day)								
> 50mm	12.2	15.3	19.7	22.5	1.39	***	***	Ns
> Ground level	28.6	35.9	34.6	43.1	2.8	***	***	Ns
Herbage utilisation								
Grass utilisation (kg DM/ha)	2734	2675	3384	2878	323.8	*	Ns	Ns
Post grazing sward height (cm)	4.5	4.9	7.0	7.2	0.38	***	Ns	Ns
Grass removed (kg DM/cow/day)	13.0	15.6	16.5	17.9	1.13	***	***	Ns
Grazing days (days/ha)	210	172	204	158	12.9	Ns	***	Ns
Rotation 2								
Herbage allowance (kg DM/cow/day)								
> 50mm	13.4	16.0	17.6	20.4	1.63	***	***	Ns
> Ground level	40.6	48.6	45.6	53.8	3.61	***	***	Ns
Herbage utilisation								
Grass utilisation (kg DM/ha)	2133	2055	2258	2167	141.8	+	Ns	Ns
Post grazing sward height (cm)	4.8	5.2	6.1	6.4	0.42	***	+	Ns
Grass removed (kg DM/cow/day)	13.9	15.6	15.3	16.8	1.04	**	***	Ns
Grazing days (days/ha)	151	129	146	126	8.4	Ns	***	Ns

Abbreviations as in Table 11 and 12.

Table 14. Effect of grazing date and stocking rate on milk yield, milk composition, bodyweight and body condition score of grazing dairy cows

	EH	EM	LH	LM	Sed	GD	SR	GD*SR
Rotation 1								
Milk yield (kg/day)	21.1	24.2	23.9	24.8	0.24	***	***	***
Milk fat yield (g/day)	806	898	900	915	10.5	***	***	**
Milk protein yield (g/day)	597	690	693	709	7.1	***	***	***
4% FCM yield (kg/day)	20.5	23.1	23.1	23.6	0.22	***	***	***
Milk fat content (g/kg)	38.5	37.1	37.7	37.0	0.38	Ns	0.06	Ns
Milk protein content (g/kg)	28.4	28.6	29.1	28.6	0.16	Ns	Ns	Ns
Body weight (kg)	591	592	601	595	2.3	*	Ns	Ns
Milk output/ha	4351	4207	4852	3927	250.0	Ns	**	*
Rotation 2								
Milk yield (kg/day)	17.4	22.3	20.3	21.3	0.52	Ns	***	***

Milk fat yield (g/day)	659	821	770	788	20.5	Ns	***	**
Milk protein yield (g/day)	507	650	593	624	14.6	Ns	***	***
4% FCM yield (kg/day)	16.8	21.2	19.7	20.3	0.50	Ns	***	Ns
Milk fat content (g/kg)	38.3	37.1	38.0	37.0	0.486	Ns	Ns	Ns
Milk protein content (g/kg)	29.5	29.2	29.3	29.4	0.244	Ns	Ns	Ns
Body weight (kg)	585	580	589	593	3.74	Ns	Ns	Ns
Milk output/ha	2692	2890	2940	2655	118.4	Ns	Ns	***
Post Experiment								
Bodyweight (kg)	629	619	615	622	23.8	Ns	Ns	Ns
Body condition score	2.1	2.2	2.0	2.1	0.30	Ns	Ns	Ns

Abbreviations as in Table 11 & 12; FCM - Fat corrected milk yield

Table 15. Effect of grazing date and stocking rate on milk yield/intake and UFL balance

	EH	**EM**	**LH**	**LM**	**Rse**	**GD**	**SR**	**GD*SR**
Intake								
Grass	13.9	16.18	16.29	17.04	1.38	***	***	+
UFL	13.79	16.3	15.29	15.99	1.34	Ns	***	*
PDIE	1442	1644	1543	1635	137.0	Ns	***	Ns
PDIN	1750	1874	1731	1876	159.0	Ns	***	Ns
UFL requirement	14.66	15.76	15.53	15.97	0.827	*	***	Ns
PDI requirement	1296	1449	1420	1465	85.73	***	***	*
UFL balance	-0.988	0.239	-0.439	-0.234	1.079	Ns	*	Ns
PDIE balance	145.4	195.7	123.6	170.6	100.0	Ns	+	Ns
PDIN balance	449.9	428.6	310.98	412.77	118.6	*	Ns	+

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Acknowledgements

The authors wish to thank Mr. M. Feeney, F. Flynn, J. Nash, J. O'Dwyer and Ms. N. Galvin for their technical assistance and also all the Moorepark farm staff for their assistance in measurements taken during Experiments I and II. The authors would also like to thank the staff of the Mejusseaume farm (INRA, Le Rheu, Rennes) for their skilled technical input with the grazing management and measurements during the Experiment III.

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