Effects of complementary grazing by goats on sward composition and on sheep performance managed during lactation in perennial ryegrass and white clover pastures

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Abstract

The liveweight (LW) response of Gallega and Lacha ewes with their single suckling lambs when grazing with a mob of goats on perennial ryegrass (*Lolium perenne* L.)/white clover (*Trifolium repens* L.) pastures and its consequence on sward composition were analysed. From early March (turnout) to mid-June (lamb weaning), swards were grazed either simultaneously mixed in a 1:1 goat to sheep ratio or separately in a goat-first and sheep-last sequential grazing at 6 or 8 cm sward heights or in a 4-paddock rotation where goats grazed swards from 9 to 7 cm followed by sheep from 7 to 4 cm. Changes in botanical composition and in sheep liveweight performance were more significantly affected by the management and species grazing than by the sward height treatment. Swards where goats were last in had higher herbage masses, higher live clover and lower dead and stem proportions than swards where sheep and goats were mixed or sheep were last in. As a consequence of a sward clover enhancement over all treatments, ewe and lamb performances were benefited especially in the Lacha genotype, with the rotational and sequential managements having, respectively, an output of 298 and 252 kg LW/ha greater than the mixed management. These results suggest that goats could be used as a pasture management tool when integrated with sheep under these different grazing systems to enhance ovine performance during lactation. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

Based on reports performed from temperate grasslands (Clark et al., 1982; Russel et al., 1983; Grant et al., 1984), it appears that goats might be used to improve pastures for sheep production, particularly

in grass/clover swards. When goats are used exclusively, the swards tend to contain more clover than grazed by sheep (Penning et al., 1996). Using goats to increase the proportion of clover in the sward could increase the supply of high-quality feed for growing weaned lambs as it has been reported in UK by del Pozo et al. (1996), but further work with suckling lambs and lactating ewes has only been carried out in the southern hemisphere by Townsend and Radcliffe (1990) and Radcliffe et al. (1991).

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Goats require careful management in sown swards, as sward surface heights should be above 6 cm to avoid suppression of intake (Merchant and Riach, 1994). Then, managing grazing systems with breeding does and sheep will depend on the degree of competition between these species, and could involve alternative sward height managements during the grazing cycle. Osoro and Martinez (1995), working in the North of Spain, used a mixture of feral goats and native sheep to improve pasture quality and profitability of marginal areas. Sheep have also been shown to benefit when integrated with fibre-producing goats in a concurrent mixed grazing (Collins, 1989; Townsend and Radcliffe, 1990; Radcliffe et al., 1991) or separate grazing at different times on the same pasture (del Pozo et al., 1996; Bown et al., 1989). However, the suitability of these management alternatives in temperate pastures of Southern European countries is not yet defined, and managerial decisions would be better achieved if sward conditions are carefully characterized.

Therefore, the objective of this study was to examine the feasibility of sheep and goat cograzing to increase clover persistence in the sward, and improve ovine performance under rotational, sequential or mixed managements maintained at two different herbage allowances.

2. Materials and methods

2.1. Site

The current experiment was conducted in 1995 at La Mata Research Farm, Grado, located at 50 m a.s.l, in Asturias, North of Spain. Total annual precipitation averages 1032 mm (917–1380 mm range) and temperature averages 13.2°C (10.1–15.2°C range) with June, July, August and September having highest daily temperatures and lowest total rainfall amounts of the year. In November 1991, a mixture of 20 kg/ha of perennial ryegrass (*Lolium perenne* L. cv. Phoenix) plus 3 kg/ha of white clover (*Trifolium repens* L. cv. Huia) were sod seeded in the experimental area. On 25 January of the experimental year, the sward received a unique application of 40 kg N/ha, 100 kg P₂O₅/ha and 80 kg K₂O/ha.

2.2. Design

From March 7 to June 16, 10 pastures of 0.7-ha size were grazed with a herd of 54 dry Cashmere goats plus 48 autochthonous goats (30.8 ± 0.34 and 45.3 ± 0.47 kg of initial adult LW, respectively) and 42 Gallega plus 66 Lacha ewes (28.3 ± 0.32 and 32.0 ± 0.52 kg of initial adult LW, respectively) rearing their single lambs (10.8 ± 0.45 and 11.2 ± 0.41 kg of initial LW). Six paddocks were either continuously grazed under a first (goats)–last (sheep) sequential grazing or under a mixed grazing with a stock equivalence on a per head basis of 1:1 at two different available sward heights of 6 cm (Low) or 8 cm (High), whereas the remainder four paddocks were managed in a rotational management where sheep grazed swards from 7 to 4 cm (Low) after being previously grazed by goats from 9 to 7 cm (High). The different management and height treatments were randomized into the trial area and grazed by ‘core’ (tester) groups of sheep and goats balanced as far as possible on initial lamb liveweight and birth date, and on doe and lactating ewe breeds. Additional ‘put and take’ (replacement) ewes and/or goats were introduced or withdrawn to control mean sward heights.

2.3. Management

Suckling lambs born in January/February grazed with their dams from turnout until weaning. Within a sequential treatment, tester plus replacement sheep were alternated with goats between paddocks in a continuous succession of a 2-paddock system and that occurred simultaneously with the beginning of each rotation cycle in the rotational treatment on 10 April, 15 May and 16 June. Foot rot problems were controlled by using a zinc sulphate footbath, and individual animals were regularly drenched with Netobimín (200 mg/10 kg LW) to suppress internal parasites.

2.4. Measurements

2.4.1. Pasture

Air temperature and total rainfall observations were made each day by meteorological equipment located at the experimental site. Pasture height was

measured weekly with a sward stick from the Hill Farming Research Organisation (Barthram, 1986). Fifty observations of the undisturbed sward surface height were made at random per paddock. Frequencies of sward heights were fitted for each treatment following the Gibb and Ridout (1986) procedure to estimate the proportion of the shorter ('frequently') and the taller ('infrequently') grazed sample populations.

The frequency of distribution of the different herbage components within the sward canopy was determined at the beginning (7 March), at the end of the experiment (16 June) and whenever animal species end a rotational and sequential cycle (10 April and 15 May) by recording stratified contacts in 25 points taken at random per paddock with an inclined (32.5°) point quadrat apparatus (Rhodes and Collins, 1993). As the point quadrat needle, mounted on a frame, passed through the sward each contact of herbage height was noted after ground zero correction and classed using the following morphological units: perennial ryegrass (leaf, pseudostem, flower-stem or dead), white clover (laminae–petiole, stolon, flower or dead), other species and herbaceous weeds. Simultaneously to the assessments on canopy composition, herbage mass was monitored by cutting to ground level ten strips (1 × 0.2 m) per paddock. Samples were subsequently washed and oven-dried overnight at 80°C to determine dry matter content.

2.4.2. Stock

Ewe-liveweight changes were monitored by weighing of tester animals to the nearest 0.1 kg at the beginning of the experiment, at the end of the grazing season, and on each day that sward composition was determined. Body conditions were scored in ewes by the same operator and followed the 5-point scale used by Russel et al. (1969). Lambs were weighed at 1 day of age and each time that their dams were weighed. To determine overall animal production per hectare, sheep and goat stocking rates were recorded weekly having in account the animals added to or removed from paddocks to control sward height as they were weighed on and off the paddocks. Grab faecal samples were taken from all core groups of does and ewes at the beginning and end of the grazing season, and analysed immediately for faecal parasite egg concentration.

2.5. Statistical analysis

Analysis of variance was used to examine the effect of treatments on liveweight and sward composition changes occurred over the experiment by running the Genstat 5.2. statistical package (Lawes Agricultural Trust, 1990). Estimates of the variability on ewe and lamb performances were derived from the variation of the tester animals occurred within each paddock with data being analysed by a split-plot design, where animal units within a paddock were considered as blocks and grazing management × sward height × sampling date as the treatment model. Effects of treatment and sampling date were examined in herbage variables using the variance between paddocks and between sampling date as the error treatment. Faecal egg counts and the count of herbage contacts were transformed by $\log_{10} + 1$ before analysis, but only back-transformed values expressed as proportions are included in the text. A Pearson's χ^2 was used to describe the pattern of height distribution by comparing across treatments the proportion of measurements falling above 10 cm.

When variability of sheep performance was considered between management and height treatments, the data were not fully balanced. Then, overall differences that occurred between grazing managements and between height treatments within a grazing management were analysed separately for each sampling period and their level of significance determined by using Student's paired *t*-test comparisons with pooled estimates of the standard errors of difference of means (SED). Differences in sward composition due to species grazing were analysed in a similar manner as mean values were determined separately for each treatment in paddocks last grazed by goats, sheep or both species.

3. Results

3.1. Weather

The weather was abnormally dry as only 181.6 mm of rainfall occurred over the trial period. However, temperature values were average, and monthly means increased during the trial from 11°C in March till 17.2°C in June.

Table 1
Mean herbage mass (kg DM/ha) at each sampling date and proportion of sward height measurements falling above 10 cm in the sward across the different treatments during the whole experimental period

Date	Grazing management									<i>P</i> ¹
	Rotational			Sequential			Mixed			
	Sward height									
	High	Low	SEM	High	Low	SEM	High	Low	SEM	
<i>Pasture mass (n = 10)</i>										
7 March	22.39	2149 ^a	192.3	2301 ^a	2189 ^a	198.1	2289 ^a	2400 ^a	272.7	NS
10 April	2099 ^a	1532 ^b	250.0	2197 ^a	1792 ^{ab}	205.2	1700 ^{ab}	1489 ^b	253.1	<i>P</i> < 0.01
15 May	2382 ^a	1400 ^b	233.4	2299 ^a	1900 ^{ab}	213.3	1778 ^b	1525 ^b	261.4	<i>P</i> < 0.001
16 June	2200 ^a	1458 ^b	236.6	2125 ^a	1839 ^{ab}	222.2	1612 ^b	1449 ^b	243.6	<i>P</i> < 0.001
<i>Sward height proportion (n = 800)</i>										
7 March–16 June	0.02 ^a	0.01 ^a	0.013	0.12 ^b	0.05 ^a	0.010	0.07 ^a	0.03 ^b	0.021	<i>P</i> < 0.05

Means in the same row with different superscripts differs significantly (*P* < 0.05).

¹ Goat vs. sheep last grazing, NS = non-significant.

Table 2

Proportions of ryegrass leaf, ryegrass stem (pseudostem + flowerstem), dead ryegrass, live white clover (laminae + petiole + stolon + flower) and dead clover in the sward across the different treatments at each sampling date

Components	Date	Grazing management									P^1
		Rotational			Sequential			Mixed			
		Sward height									
		High	Low	SEM	High	Low	SEM	High	Low	SEM	
Ryegrass leaf	7 March	0.67 ^{ab}	0.68 ^{ab}	0.053	0.58 ^a	0.55 ^a	0.051	0.73 ^b	0.72 ^b	0.059	NS
	10 April	0.58 ^{ab}	0.29 ^c	0.048	0.60 ^{ab}	0.50 ^b	0.043	0.69 ^a	0.65 ^{ab}	0.042	$P < 0.05$
	15 May	0.55 ^a	0.53 ^{ab}	0.037	0.50 ^{ab}	0.40 ^b	0.047	0.72 ^c	0.70 ^c	0.043	NS
	16 June	0.60 ^b	0.43 ^a	0.054	0.44 ^a	0.41 ^a	0.052	0.57 ^b	0.64 ^b	0.051	$P < 0.05$
Ryegrass stem	7 March	0.13 ^{ab}	0.11 ^{ab}	0.018	0.12 ^{ab}	0.16 ^b	0.021	0.10 ^a	0.09 ^a	0.018	NS
	10 April	0.05 ^a	0.40 ^c	0.017	0.04 ^a	0.12 ^b	0.019	0.02 ^a	0.02 ^a	0.017	$P < 0.001$
	15 May	0.02 ^a	0.02 ^a	0.021	0.05 ^a	0.03 ^a	0.017	0.03 ^a	0.00 ^a	0.020	$P < 0.05$
	16 June	0.03 ^a	0.15 ^b	0.022	0.06 ^a	0.08 ^{ab}	0.016	0.15 ^b	0.13 ^b	0.022	$P < 0.001$
Dead ryegrass	7 March	0.16 ^{ab}	0.18 ^{ab}	0.024	0.18 ^{ab}	0.20 ^b	0.023	0.11 ^a	0.15 ^{ab}	0.022	NS
	10 April	0.04 ^c	0.12 ^b	0.021	0.17 ^{ab}	0.22 ^a	0.019	0.05 ^c	0.06 ^c	0.019	$P < 0.001$
	15 May	0.27 ^a	0.43 ^b	0.020	0.25 ^a	0.29 ^a	0.020	0.17 ^c	0.24 ^a	0.020	$P < 0.001$
	16 June	0.09 ^b	0.25 ^c	0.019	0.32 ^a	0.35 ^a	0.018	0.12 ^b	0.13 ^b	0.021	$P < 0.001$
Live clover	7 March	0.04 ^a	0.03 ^a	0.017	0.07 ^a	0.05 ^a	0.015	0.04 ^a	0.03 ^a	0.013	NS
	10 April	0.33 ^c	0.19 ^{ab}	0.019	0.19 ^{ab}	0.14 ^b	0.020	0.23 ^a	0.25 ^a	0.019	$P < 0.001$
	15 May	0.16 ^b	0.02 ^c	0.018	0.18 ^{ab}	0.23 ^a	0.021	0.07 ^c	0.05 ^c	0.015	$P < 0.001$
	16 June	0.26 ^c	0.15 ^{ab}	0.017	0.18 ^a	0.12 ^{ab}	0.020	0.16 ^{ab}	0.10 ^b	0.016	$P < 0.001$
Dead clover	7 March	0.00 ^a	0.00 ^a	0.005	0.00 ^a	0.00 ^a	0.009	0.01 ^a	0.00 ^a	0.006	NS
	10 April	0.00 ^a	0.00 ^a	0.004	0.00 ^a	0.00 ^a	0.008	0.00 ^a	0.00 ^a	0.005	NS
	15 May	0.00 ^a	0.00 ^a	0.007	0.00 ^a	0.02 ^b	0.007	0.01 ^a	0.00 ^a	0.004	NS
	16 June	0.00 ^a	0.01 ^a	0.009	0.00 ^a	0.00 ^a	0.008	0.00 ^a	0.00 ^a	0.007	NS

Means in the same row with different superscripts differs significantly ($P < 0.05$).

¹ Goat vs. sheep last grazing, NS = non-significant.

7 March control**16 June control****Rotational**

High
(Goat last grazing)

Low
(Sheep last grazing)

Sequential

High

Low

Mixed

High

Low

Table 3

Liveweight performance of the 'core' lambs suckling Lacha or Gallega ewes at each sampling date and grazing with goats in ryegrass/clover swards under different management and sward height treatments from turnout (7 March) to lamb weaning (16 June)

	Date	Grazing management							
		Rotational		Sequential			Mixed		
		Sward height							
		Low	SE	High	Low	SEM	High	Low	SEM
<i>Lacha</i>									
Liveweight (kg LW)	7 March	10.9 ^a	1.72	11.2 ^a	11.6 ^a	1.62	10.8 ^a	11.7 ^a	1.99
	10 April	17.0 ^a	1.78	24.7 ^b	20.3 ^c	1.54	22.3 ^{bc}	23.4 ^{bc}	2.03
	15 May	22.1 ^a	1.74	30.0 ^b	26.4 ^c	1.67	30.4 ^b	31.8 ^b	1.92
	16 June	25.7 ^a	1.80	34.8 ^b	31.3 ^c	1.60	35.6 ^b	37.9 ^b	1.90
<i>Gallega</i>									
Liveweight (kg LW)	7 March	10.5 ^a	1.79	10.4 ^a	10.7 ^a	1.58	11.1 ^a	11.3 ^a	1.91
	10 April	14.6 ^a	1.75	16.8 ^{ab}	18.9 ^{ab}	1.63	21.9 ^b	19.4 ^{ab}	1.87
	15 May	20.9 ^a	1.68	22.7 ^{ab}	25.5 ^{ab}	1.67	27.3 ^b	24.9 ^{ab}	2.01
	16 June	24.7 ^a	2.01	27.5 ^{ab}	30.7 ^b	1.76	31.1 ^b	29.4 ^{ab}	1.92

Means in the same row with different superscripts differs significantly ($P < 0.05$).

3.2. Pasture

Mean sward heights did not differ significantly between management treatments with 8.4, 8.0 and 8.1 cm being recorded in the rotational, sequential and mixed managements respectively of the high height treatments and 5.9, 6.3 and 6.1 cm being recorded in the rotational, sequential and mixed managements respectively of the low height treatments ($SED = 0.23$). However, higher proportions of sward heights above 10 cm were found on the sequential treatment than on the rotational and mixed treatments ($\chi^2 = 6.93$; $df = 2$; $P < 0.05$). The amount of residual masses existing with goat last grazing was higher than with sheep last grazing at similar height treatments in the rotational and sequential managements ($P < 0.01$), and that was accompanied in both managements with differences in the distributions of heights, since paddocks last grazed from sheep had a more skewed distribution than paddocks last grazed from goats ($\chi^2 = 4.22$; $df = 1$; $P < 0.05$). As shown by Table 1, the mixed management had fair residual mass values. Finally, the sequential and rotational managements resulted, in the high height treatments,

in higher pasture masses than the mixed management.

Table 2 shows the proportions of the perennial ryegrass and white clover components recorded in each sward treatment at each sampling date, whereas Fig. 1 displays the different sward treatment profiles at the beginning and end of the experiment.

At the beginning of the grazing period (7 March), there were no significant differences on ryegrass and clover proportions across grazing management and sward height treatments. During the trial, perennial ryegrass (*L. perenne*) was the dominant species in all the treatments comprising values always above the 0.50 proportion. In contrast, dead clover and other species as *Festuca arundinacea*, *Holcus lanatus*, *Poa annua*, *Agrostis capillaris* and *Dactylis glomerata*, and herbaceous weeds as *Cerastium arvense*, *Anthoxanthum odoratum*, *Taraxacum officinale* appeared very occasionally and were minor components ranging between 0.00 and 0.03 overall proportion.

The proportion of live white clover was the sward component most affected by the experiment. Over the whole experimental period, the mean proportion

Fig. 1. The vertical distribution of rye grass and clover components in each sward treatment and stock last species grazing management at the beginning (7 March) and end (16 June) of the experiment. Data are expressed as number of point-quadrat hits per 100 loci in each 1-cm horizon.

of clover laminae–petiole increased ($P < 0.001$) across all management and height treatments with peak increases taking place from 7 March to 10 April. Stock species grazing had a significant effect on this sward clover appearance, so that by the end of the experiment, the average presence of live clover achieved higher proportions in those paddocks most recently grazed by goats than in those most recently grazed by sheep across the rotational and sequential treatments, with the mixed management having intermediate proportions. That clover enhancement due to goat last grazing was more marked on the sward upper layers. Also, the occurrences of dead and stem ryegrass material and of clover flower component were lower and higher, respectively, in the goat-last grazed paddocks than in the sheep-last grazed paddocks.

3.3. Sheep performance

Lamb and ewe performance data are shown for both genotypes in Tables 3 and 4, respectively. Lamb growth rates were significantly affected by the grazing management ($P < 0.001$), with much lower liveweight gains recorded per head in the rotational

than in the sequential and mixed managements. These differences were much higher on lambs suckled from Lacha ewes: 147, 234, 195, 246 and 259 g LW/d (SED = 12.8) than from Gallega ewes: 141, 169, 198, 198 and 179 g LW/d (SED = 11.7) in the rotational–low, sequential–high, sequential–low, mixed–high and mixed–low treatments, respectively. Similarly, the ewe's body condition and liveweight changes were affected significantly by the different grazing strategies imposed. Sheep daily liveweight gains were ranged over the whole lactation period from 77 g to 207 g and from 91 g to 181 g on Lacha and Gallega breeds, respectively, with the sequential management recording the highest weight gains within each height treatment.

3.4. Stock productivity

The product of animal grazing days (including tester plus replacement animals) and individual rates of liveweight gain gives output of liveweight gain per hectare and is shown in Table 5. There were contrasting sheep net liveweight gains per hectare between grazing managements with the mixed treatment having lower sheep productivity per hectare

Table 4

Liveweight and body condition score of the core lactating ewes from Lacha and Gallega genotypes at each sampling date grazing with goats ryegrass/clover sward height treatments from turnout (7 March) to lamb weaning (16 June)

	Date	Grazing management							
		Rotational		Sequential			Mixed		
		Sward height							
		Low	SE	High	Low	SEM	High	Low	SEM
<i>Lacha</i>									
Liveweight (kg LW)	7 March	32.1 ^a	0.64	31.8 ^a	31.6 ^a	0.44	32.0 ^a	32.3 ^a	0.50
	10 April	38.3 ^a	0.53	43.1 ^b	40.3 ^c	.047	39.1 ^{ac}	36.6 ^d	0.43
	15 May	42.4	0.62	47.4 ^b	43.4 ^a	0.39	43.7	38.9 ^c	0.53
	16 June	44.3 ^a	0.63	52.7 ^b	45.0 ^{ac}	0.48	46.0 ^c	40.1 ^d	0.47
Initial body condition (units)		2.25 ^a	0.125	2.23 ^a	2.20 ^a	0.101	2.26 ^a	2.19 ^a	0.139
Final body condition (units)		2.26 ^a	0.114	2.98 ^b	2.51 ^c	0.099	2.92 ^b	2.30 ^a	0.127
<i>Gallega</i>									
Liveweight (kg LW)	7 March	28.3 ^a	0.42	28.4 ^a	28.7 ^a	0.22	28.5 ^a	28.1 ^a	0.32
	10 April	33.6 ^a	0.47	38.2 ^b	35.9 ^c	0.31	34.2 ^a	33.3 ^a	0.34
	15 May	36.2 ^a	0.52	42.9 ^b	38.2 ^c	0.29	36.7 ^a	35.4 ^a	0.38
	16 June	39.6 ^a	0.41	46.7 ^b	40.9 ^c	0.40	38.0 ^d	37.3 ^d	0.31
Initial body condition (units)		2.27 ^a	0.134	2.22 ^a	2.19 ^a	0.109	2.23 ^a	2.21 ^a	0.137
Final body condition (units)		2.72 ^{ab}	0.127	2.91 ^b	2.81 ^a	0.103	2.60 ^a	2.56 ^a	0.141

Means in the same row with different superscripts differ significantly ($P < 0.05$).

Table 5

Grazing days, net liveweight gain and total output for the experimental herd (core plus replacement animals) across the different treatments

	Grazing management								
	Rotational			Sequential			Mixed		
	Sward height								
	High	Low	SEM	High	Low	SEM	High	Low	SEM
<i>Grazing days (days / ha)</i>									
Ewe	—	3219 ^a	89.5	1773 ^b	2546 ^c	63.1	1400 ^d	1700 ^b	73.7
Lamb	—	2900 ^b	93.7	1700 ^b	2400 ^c	59.8	1400 ^d	1700 ^b	78.3
Doe	4498 ^a	—	125.3	2392 ^b	3338 ^c	98.8	1400 ^c	1700 ^c	113.2
<i>Liveweight gain (kg LW / ha)</i>									
Ewe	—	375 ^a	11.2	344 ^b	335 ^b	7.8	163 ^c	143 ^c	13.1
Lamb	—	418 ^a	11.8	343 ^b	472 ^c	8.8	311 ^b	372 ^d	13.0
Doe	397 ^a	—	14.5	392 ^a	355 ^b	12.2	145 ^c	110 ^c	9.1
Total output (kg LW / ha)	397 ^a	793 ^b	12.5 *	1079 ^c	1162 ^d	9.6 ⁺	619 ^c	11.7 ⁺	

Means in the same row with different superscripts differs significantly ($P < 0.05$).

* From a pooled standard error between height treatments within a management treatment.

⁺ From a pooled standard error of means between height treatments within a management treatment.

(495 kg LW/ha) than the rotational (793 kg LW/ha) and sequential treatments (747 kg LW/ha) (pooled SED = 75.3; $P < 0.01$). Additionally, goat output per hectare was the lowest in the mixed treatment. Since grazing days/ha for sheep and goats were reduced significantly in the high height treatments of the mixed and sequential managements, there was an overall extra benefit of 6 and 83 kg LW/ha in their corresponding low height treatments.

In relation to the stock health, core does carried by the end of the experiment more strongylate eggs per gram (e.p.g.) under mixed grazing than under rotational and sequential grazing (1800 vs. 1250 and 1200 e.p.g., respectively; SED = 145.2; $P < 0.001$). However, all groups of ewes had similar low egg counts (200 e.p.g.) independently of the grazing strategy.

4. Discussion

To avoid bias in determining sheep grazing behaviour within a flock, large paddocks containing at least 10 core ewes for each genotype were considered necessary for being representative (Penning et al., 1993). That increased demands on the available pasture of the experimental area, and treatment pad-

docks were not able to replicate. However, the paddock component of variance was small compared with the sampling variance in our data, and treatment effects could be assumed, as suggested by Armstrong et al. (1995), to be uninfluenced by the experimental layout design.

4.1. Sward composition

Despite mean sward surface heights being maintained close to target heights over the whole grazing trial, the distribution of the height measurements was more skewed in the sequential treatment and in those paddocks last grazed by sheep. That contrasts with the results of del Pozo and Wright (1995), but agrees well with the findings of Nicol et al. (1987), who observed a greater patchiness in a ryegrass/white clover pasture grazed by sheep than by goats. Nicol and Collins (1990) suggested that goats may browse from the top of the sward, whereas sheep tend to graze deeper resulting, therefore, in a less evenly grazed sward. Thus, alternating through a sequential procedure, the timing of sheep and goat grazing with enough length can exacerbate more the height patchiness in a pasture than if swards are grazed rotationally or concurrently mixed. Furthermore, Betteridge et al. (1994) reported on temperate grass-clover

swards that goats, when compared with sheep, left shorter heights from residual plant tillers because they grazed a larger proportion of the paddock each day. Also, differences in sward height heterogeneity due to species grazing was probably accounted for by the fact that goats seem to have greater capabilities than sheep to deal with reproductive and senescent material, and may graze them off at lower residual heights (Gurung et al., 1994). That also may explain the higher accumulation of dead and stem material that resulted through the experiment in the swards last grazed by sheep in comparison to swards last grazed by goats.

As reported by Thomson and Power (1993) on a mixed bull–goat grazing experiment and by Radcliffe et al. (1991) on a mixed sheep–goat grazing, the higher defoliation of long pasture and better elimination of pasture clumps by goats could maintain a better optimum height for canopy growth in swards grazed by goats than grazed by sheep. That could lead in the current trial to the outcome of higher herbage mass in those swards last grazed by goats. However, a binomial distribution of sward heights corresponding to ‘frequently grazed’ and ‘infrequently grazed’ components that Gibb and Ridout (1986) found under continuous cattle grazing, was not seen in this experiment because these effects, corroborating suggestions of Kiteessa and Nicol (1996), appear to be less obvious under multispecies than monospecies grazing.

Throughout the grazing trial, there was heterogeneity both horizontally and vertically in the distribution of the grass and clover morphological components. Live clover tended to have a great proportion of its leaf area on the upper layers of the canopy, and that occurred markedly in the rotational and sequential managements. del Pozo et al. (1996) achieved increases until 0.37 clover proportion in grass/clover swards grazed by lambs after being previously grazed by goats, whereas Bown et al. (1989) also showed extra clover growths when pastures were grazed rotationally by a mob of goats, sheep and cattle. Thus, different timings of sheep and goat grazings seemed to facilitate more the clover outcome through the sward upper layers than mixed species management.

Furthermore, swards last grazed by goats tended to contain higher clover and less stem and dead

proportions than swards last grazed by sheep, and that was accompanied by very marked visual differences. As suggested by Gong et al. (1993), these conflicting findings on sward clover content may result from the interaction of the feeding style of goats and sheep, with the position of clover within the vegetation strata relative to the grazing horizon of the animal. Goats, unlike sheep, seemed to not actively select *Trifolium* species particularly in the lower horizons, making these differences more dramatic on the sward surface (Fig. 1). That is in agreement with other results of Nicol and Collins (1990) and del Pozo et al. (unpublished) for sheep and goat cograzing, and of Milne et al. (1982) with sheep solely grazing. These authors showed that the composition of the diet in both sheep and goats were more closely related to changes in the composition of the upper layers of the sward than with the proportion of clover in the sward as a whole. However, these results cannot show that variability in diet clover is entirely explained by passive selection as Norton et al. (1990) showed in sheep, cattle and goats that their clover consumption might also differ within a season grazing.

4.2. Animal responses

Although herbage mass on offer to the experimental herd was higher in the goat-grazed swards, this is unlikely to be the major factor involved in the improvement of sheep liveweight gains with goat cograzing, as total herbage mass levels were always on this trial above the critical height levels recommended by Maxwell and Treacher (1987) for no limit in sheep weight gains. In accordance with the findings of Merchant and Riach (1994), the proportion of green leaf of ryegrass and clover components was not related in the current study to the different sward height treatments, since a relatively vegetative leafy state was maintained during most parts of the experiment. Therefore, the low appearance of grass seedheads and stems observed to occur through the experiment associated with increases of the live clover proportion appeared to influence more tangibly the lamb and ewe performances occurring in all treatments. Thus, the results obtained in sheep liveweight replenishments were much higher in this experiment than those achieved by Martinez and

Osoro (1995) with similar local breeds and management conditions on a continuous mono-grazing system. In their experiment, sward surface heights were maintained between the 5.5–6.0 cm range, and lambs and ewes reached gains of 170–180 and 30–40 g LW/d respectively. Also, when sward height was allowed to increase to 7.0–7.5 cm from the preceding spring period, they only managed to record gains of 195 vs. 220 g LW/d in lambs and 65 vs. 85 g/d in ewes from Gallega and Lacha breeds, respectively. Similarly, Radcliffe et al. (1991) reported that pre-weaning lambs grazing simultaneously with goats in a 1:1 mixture had daily liveweight gains some 28% greater than those grazing sheep-only pastures. Also, Townsend and Radcliffe (1990) showed extra lamb growth rates before weaning on a sheep–goat mixed than on a sheep solely management. Since Ulyatt (1981) postulated that clover can promote better live-weight performances in lambs and Gibb and Treacher (1983) showed that increasing the ratio of white clover to perennial ryegrass in the diet of lactating ewes seemed to increase the growth rate of their lambs during lactation without having negative effects on the rate of depletion of the ewe's body reserves, it seems reasonable to think that ewes and lambs would perform better during their lactation period when grazing grass/clover swards with goats than solely managed. However, an adequate prophylactic treatment needs to be given to both stock species, as they might be susceptible to the same internal parasites.

Finally, Tables 3 and 4 show that higher body weight replenishments occurred at the high height treatments in sheep from Lacha than from Gallega genotypes, although those differences were reduced at the low height treatments. That was also previously reported by the study of Martinez and Osoro (1995), as they found that the mean sward height at which liveweight performance was maximized in these genotypes, was higher in ewes and lambs from Lacha than from Gallega breed. As postulated by Illius and Gordon (1990), the value of alternative food patches in the sward may depend not only on the proportion of the sward, but on the size of the grazer. Then, the interaction between sheep size and sward canopy structure might also have an important practical implication on the management of sheep when grazing grass/clover swards.

5. Conclusions

These results indicate quite different opportunities for goats to complement sheep when grazing together grass/clover swards. Goat's cograzing can be used to improve the clover content of pastures and benefit sheep lactation performances following different or concurrent grazing procedures with the rotational and sequential managements, resulting in higher sheep productivity per hectare than the mixed management. However, the choice of an adequate grazing management to integrate goats with sheep is flexible and diverse through season, and further interpretation of the results to achieve more efficient management systems will only be possible once information is also available regarding diet selected, herbage intake and animal health.

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