

A comparative study of herbage intake, ingestive behaviour and diet selection, and effects of condensed tannins upon body and wool growth in lambs grazing Yorkshire fog (*Holcus lanatus*) and annual ryegrass (*Lolium multiflorum*) dominant swards

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SUMMARY

An experiment was carried out from August to early November 1994 to examine differences in diet selection, herbage intake, grazing behaviour and animal performance between weaned lambs rotationally grazing swards of annual ryegrass (*Lolium multiflorum*)/white clover (*Trifolium repens*) and Yorkshire fog (*Holcus lanatus*)/*T. repens* with or without *Lotus corniculatus*. There were four replicate groups of six lambs per treatment. The effects of condensed tannins (CT) on lamb production were assessed by twice-daily oral administration of 10 g polyethylene glycol (PEG; molecular weight 4000) to half the lambs on each sward. The Lotus content of all swards was very low, and results are presented here for main sward comparisons meaned over lotus treatments. Overall mean estimates of pre-grazing herbage mass and sward surface height for the annual ryegrass and Yorkshire fog swards respectively, were 5820 v. 4360 ± 190 kg DM/ha ($P < 0.001$) and 29 v. 21 ± 0.6 cm ($P < 0.001$). The coefficient of organic matter digestibility (OMD) of the diet selected and herbage intake were higher on Yorkshire fog than on annual ryegrass (0.78 v. 0.74 ± 0.080 g/kg; $P < 0.05$, and 1070 v. 860 ± 57 g OM per lamb per day, $P < 0.05$ respectively), reflecting the higher content in the diet of grass green leaf (980 v. 930 g/kg ± 14 g/kg, $P < 0.05$) and the lower content of dead material (80 v. 110 ± 15 g/kg, $P < 0.08$). Lambs grazing on Yorkshire fog swards had higher clean wool growth rate (1470 v. 1280 ± 30 mg/cm per day, $P < 0.01$) and greater fibre diameter (31 v. 29 ± 0.2 µ, $P < 0.001$), greater liveweight gain (152 v. 108 ± 5.5 g/day, $P < 0.001$), final weight (42 v. 38 ± 0.5 kg, $P < 0.001$), carcass weight gain (89 v. 69 ± 2.5 g/day, $P < 0.001$), carcass weight (19 v. 17 ± 0.3 kg, $P < 0.001$) and soft tissue thickness (GR value 11 v. 8 ± 0.5 mm, $P < 0.01$), and lower faecal egg counts (FEC; square root transformed values 9.2 v. 11.0 ± 0.4 eggs/g fresh faeces, $P < 0.01$) than lambs grazing annual ryegrass swards. Similar dietary concentrations of condensed tannins (CT) between Yorkshire fog and annual ryegrass swards (4.2 v. 3.7 DM ± 0.2 g/kg, $P < 0.08$) increased clean wool growth (1440 v. 1310 ± 32 mg/cm² per day, $P < 0.05$), fibre diameter (30.7 v. 29.5 ± 0.21 µ, $P < 0.01$) and liveweight gain (141 v. 120 ± 4.3 g per lamb per day, $P < 0.01$), although differences in carcass weight (17.9 v. 18.2 ± 0.3 kg) and FEC transformed values (9.6 v. 11.0 ± 0.6 eggs/g fresh faeces) were not significant. The effects of CT on animal performance were greater in Yorkshire fog swards. CT had no significant effects on diet selection, herbage intake and grazing behaviour patterns.

INTRODUCTION

Under high fertility conditions and either rotational or continuous grazing management, the herbage

intake and performance of sheep has generally been higher on perennial ryegrass (*Lolium perenne* L.)/white clover (*Trifolium repens* L.) swards than on Yorkshire fog (*Holcus lanatus* L.)/white clover swards (Liu *et al.* 1997; Montossi *et al.* 1997a). However, taking into account the potential value of Yorkshire fog for poorer environments (Watt 1987), and for

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control of worm parasites (Hodgson *et al.* 1996), there is a case for more comparative studies of the species covering a wider range of circumstances.

The low concentrations of condensed tannins (CT) found in the diets of sheep grazing on Yorkshire fog and perennial ryegrass swards (Montossi *et al.* 1997b) have had small and non-persistent effects on sheep production, particularly in the case of ryegrass. Taken together with evidence from other studies (Waghorn *et al.* 1990; Terrill *et al.* 1992a), these findings suggest that further moderate increases in the concentration of CT in those swards might enhance animal performance. In addition, Yorkshire fog is of particular interest for the Basaltic soils in Uruguay. This paper reports the results of studies on herbage intake, diet selection, grazing behaviour and performance in lambs grazing Yorkshire fog and annual ryegrass (*Lolium multiflorum*), species for which no comparative information is available.

MATERIALS AND METHODS

Site preparation and management

This study was carried out from August to November 1994 at Glencoe Research Unit (32° 01'S, 57° 00'W) of the INIA-Tacuarembó Research Station, Paysandú State, in an extensive region of basaltic soils in central-north Uruguay. The predominant soil types on the experimental site are silty clay loam (Typic brown-reddish and black Litosoles), shallower than 50 cm with stone content and slopes ranging from 10–25% and 1–3% respectively. These soils have a low water holding capacity with high drought risk (E. J. Berretta, personal communication).

The original phosphorus status was very low ($1.75 \pm 0.5 \mu\text{m/g}$ Resinas-P), with medium to high values of organic carbon (C) and exchangeable potassium (K) ($2.9 \pm 0.16 \text{ g/100 g}$ soil and $0.97 \pm 0.17 \text{ meq/100 g}$ soil respectively). The area received an application of 380 kg of phosphate of ammonia ($18-46-46-0$) per ha in April 1994.

Annual mean rainfall, evaporation and temperature records for the Basaltic Region are 1200 mm, 850 mm, and 19 °C respectively, increasing to the north; the mean temperature of the warmest month (January) is 27 °C and for the coldest month (July) is 14 °C. The late winter–spring 1994 was considerably wetter than that of long-run rainfall data averages. The monthly rainfall for the months of August, September, October and November 1994 was 90, 126, 161 and 66 mm respectively, compared with respective averages (6 years) of 77, 77, 96 and 92 mm.

Swards and experimental design

The swards were sown in April 1994 with annual ryegrass (*Lolium multiflorum* L. cv. 'INIA Estanzuela 284') or Yorkshire fog (*Holcus lanatus* L. cv. INIA La Magnolia), both combined with white clover

(*Trifolium repens* L. cv. INIA Estanzuela Zapicán) and with or without lotus (*Lotus corniculatus* L. cv. INIA Estanzuela San Gabriel), in plots of 0.175 ha. The sowing rates were 17, 8, 3.6 and 8.4 kg/ha for ryegrass, Yorkshire fog, white clover and lotus respectively. The trial was conducted on four 0.7 ha blocks, where each block was divided into four 0.175 ha plots by electric nets. The four sward mixtures (ryegrass/white clover/lotus, ryegrass/white clover, Yorkshire fog/white clover/lotus, and Yorkshire fog/white clover) were randomly allocated per block, giving a complete randomized block design (CRB) with four replicates. Plots were further subdivided into four 438 m² subplots, which were grazed for periods of 7 days in sequence, resulting in a rotation length of 28 days throughout the experimental period.

Ninety-six castrated Corriedale lambs, approximately 10 months old and mean liveweight $29 \pm 3.9 \text{ kg}$ at the start of the experiment, were used. The 96 selected lambs were divided into balanced groups of six lambs according to fasted initial liveweight and then assigned to the four sward treatments in each block. Additional non-experimental animals were used, as necessary, to minimize between-treatment contrasts in post-grazing sward height. At plot level, half ($n = 3$) of the lambs received a twice daily oral administration (07.30 and 17.30 h) of 10 g polyethylene glycol (PEG; MW 4000) to inactivate CT (Montossi *et al.* 1997a), whilst the remaining lambs ($n = 3$) received oral administration of an equivalent volume of water.

Sward measurements

Herbage mass and its botanical composition were estimated monthly by cutting ten 0.1 m² randomly selected quadrats in each plot to ground level before and after grazing using an electric shearing handpiece. Thirty sward surface height (SSH) readings were made before and after grazing in each plot using a common ruler. Five readings were also made inside each quadrat when herbage mass samples were collected, giving 50 readings for each plot. The bulk density of the swards before and after grazing was calculated by dividing the herbage mass estimated for each quadrat cut by the corresponding SSH average.

The vertical distribution of plant tissue within the sward canopy was measured using an inclined point quadrat (Warren Wilson 1963) set at 32.5° to the horizontal; at least 100 contacts were recorded in each plot every month. Contacts were recorded for species, morphology (leaf, stem, petiole), and state (live and dead). Point quadrat observations were expressed as the number of contacts per 5 cm of sward height.

Animal measurements

Unfasted lamb liveweight was recorded at the

Table 1. *Herbage mass (kg DM/ha) and its botanical composition (proportion, DM basis), sward height (cm), sward and green bulk densities (kg DM/ha per cm) for each treatment before and after grazing*

Sward components	Before grazing			After Grazing		
	Annual ryegrass	Yorkshire fog	S.E.M.	Annual ryegrass	Yorkshire fog	S.E.M.
Herbage mass	5820	4360	190***	4160	3340	125***
Sward height	29	21	0.6***	15	12	0.3***
Sward bulk density	201	210	5.2	290	310	12
Green bulk density	150	170	4.2*	190	180	8
Proportions						
Ryegrass	0.69	0.25	0.018***	0.65	0.25	0.028***
Yorkshire fog	0.00	0.46	0.016***	0.00	0.37	0.015***
White clover	0.02	0.03	0.011	0.002	0.002	0.003
Birdsfoot trefoil	0.005	0.011	0.002*	0.001	0.007	0.002
Weeds	0.006	0.015	0.004	0.000	0.015	0.003*
Dead material	0.27	0.22	0.008**	0.34	0.34	0.023
Green leaf	0.62	0.73	0.014**	0.40	0.56	0.026**

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

commencement of the trial and at the end of each subsequent week. Hot carcass weight and soft tissue thickness (GR) (Kirtan 1989) were recorded on both sides of the hot carcass after slaughter.

Wool growth was estimated at 6 week intervals by clipping 10 × 10 cm patches to skin level on the right midside of all the lambs while they lay on a flat surface (Bigam 1974). Mean fibre diameter was estimated using the Air Flow IWTO 6 technique (Uruguayan Wool Secretariat (SUL), personal communication). Ten fibres were taken randomly to estimate fibre length using a millimetre ruler (SUL, personal communication).

In 2-week periods during September and October, organic matter intake (OMI) measurements and grazing behaviour studies were undertaken simultaneously. OMI was calculated from estimates of total faecal output and digestibility of extrusa samples according to procedures described by Parker *et al.* (1989). Faecal output was estimated using intra-ruminal controlled release chromium capsules (65% Cr₂O₃ matrix, CAPTEC New Zealand Ltd, Auckland). Chromium release rates were determined from capsules recovered from 32 lambs (eight per treatment) slaughtered at the end of the trial. Field faecal sampling and chromium laboratory analysis procedures are reported by Parker *et al.* (1989). Faecal output values were corrected for daily PEG administration prior to calculating OMI, on the assumption that PEG is indigestible to ruminants (Barry & Duncan 1984).

Four pairs of oesophageally fistulated sheep (OF) were rotated between blocks and plots on a daily basis in a balanced sequence. Extrusa samples were col-

lected and analysed for CT and their fractions (Terrill *et al.* 1992*b*), OM digestibility (OMD) (Roughan & Holland 1977) and carbohydrates and lignin (Bailey 1967). The botanical composition of the diet selected was assessed by suspending extrusa samples in water in a gridded tray and identifying the proportions of sward components (as a proportion of total contacts) recorded at grid intersections (Clark & Hodgson 1986).

The effectiveness of the PEG (Salfed Ltd, Uruguay) used in the present trial in binding plant proteins was evaluated in the Nutrition Laboratory of INIA-La Estanzuela, Colonia, Uruguay. Rumen fistulated wethers ($n = 3$) fed on *Lotus corniculatus* L. 'INIA Estanzuela San Gabriel' receiving three daily oral doses of PEG (10 g each) had a 38% higher concentration of NH₃ in the rumen fluid than those fed on the same legume but without PEG supplementation (110 v. 71 ± 6 ppm, $P < 0.04$).

Bite weight was estimated with OF animals in each plot in the middle of each grazing period during OMI measurements, using the technique of Stobbs (1973*a, b*). Two grazing behaviour studies during daylight hours (defined as 06.30 to 20.30 h) were carried out on intact lambs during each faecal collection period, and during each study estimates of rate of biting were made using the 20-bite technique (Jamieson & Hodgson 1979) at daybreak, and after morning and afternoon PEG dosing. Only two blocks per treatment were observed in each grazing behaviour study. Further details of the grazing behaviour techniques are provided by Montossi *et al.* (1997*a*).

Before the start of the experiment, all animals were drenched with Ivermectin (Ivomec, Agroventas Ltd)

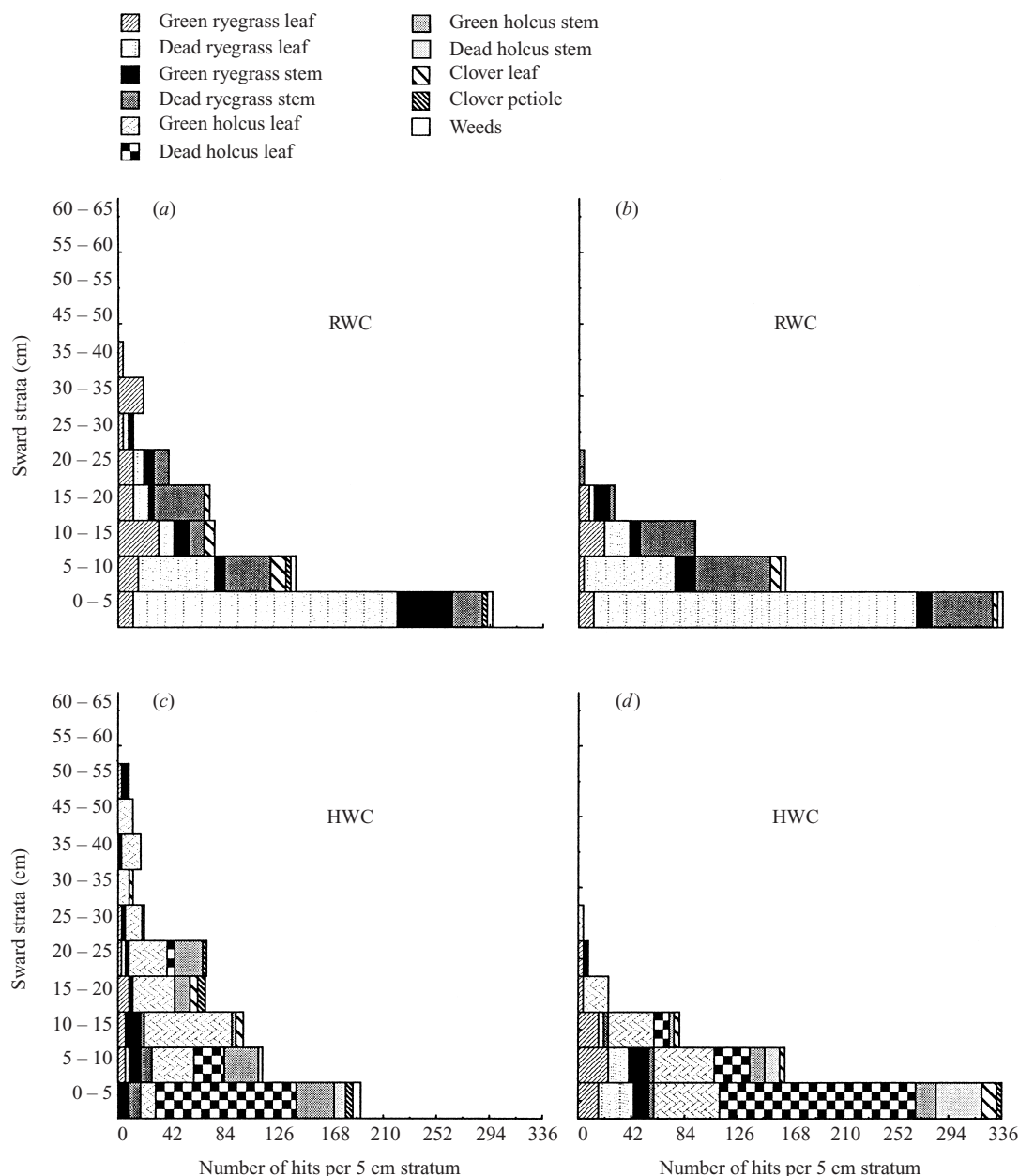


Fig. 1. Proportional distribution of plant species and morphological units in Yorkshire fog (HWC) and annual ryegrass pastures (RWC) before (a, c) and after grazing (b, d) in October, determined from point quadrat contacts.

at 1 ml/4 kg LW to control internal parasites. Faecal egg counts (FEC) were made fortnightly on two lambs per group using a modified McMaster technique (Williamson *et al.* 1994). Further drenching was specified when the average FEC of 50% of lambs rose above 1000 eggs per gram in any group (A. Mederos, personal communication).

After slaughter, the digestive tracts of four lambs per sward treatment were examined. Ligatures were made in the abomasum, small intestine and caecum. After separation of the organs, the abomasum was cut along the great curvature, the contents collected and washed thoroughly in a 5 litre container filled with water. A 500 ml sample was taken from the

container and a few drops of 10% formalin were added. The same procedure was followed for the small and large intestines (A. Mederos, personal communication). Worms were classified and counted under a stereoscope microscope as described by Ueno & Gutierrez (1983).

Statistical analyses

The pasture and animal data were analysed using the statistical package SAS (SAS 1990), based on a split-split-plot in time design using 4 blocks, with swards as the main plot arranged in a 2×2 factorial structure, grasses (ryegrass/white clover or Yorkshire fog/white clover) being one factor and lotus (presence or absence) the other factor. PEG (CT inactivated or activated) was treated as the split-plot factor, while time was used as the split-split-plot factor. Means are presented with their standard errors (S.E.M). All data were initially tested for normality and homogeneity of variance.

Liveweight gain and wool data (growth, yield, fibre diameter, fibre length) were adjusted by covariance for initial live weight and wool sample weight values. An additional group of 10 lambs was slaughtered at the commencement of the trial and their results used to provide estimates of initial carcass weights in experimental animals. Final dressing out percentages and GR measurements were evaluated using final carcass weight as a covariate.

RESULTS

Sward and animal results are summarized and presented for the entire experimental period. Given the small contribution of lotus to the experimental swards (range 0–0.016 on green DM basis) and to

the diets (range 0.004–0.009 on green DM basis) (Montossi 1996), the effects of the main grass species are averaged (means) across \pm lotus treatments.

Sward measurements

The herbage mass, proportion of dead material and sward height were all significantly greater for ryegrass swards than for Yorkshire fog swards before grazing; these differences declined with time but were still significant after grazing (Table 1). Within the green herbage mass component, the pre- and post-grazing proportions of green leaf were consistently greater for Yorkshire fog swards than for annual ryegrass, resulting in similar amounts of green leaf, with correspondingly greater proportions and amounts of green stem for annual ryegrass swards. Greater pre- and post-grazing sward and green bulk densities were observed in Yorkshire fog swards than in ryegrass swards (Table 1).

Details of the vertical distribution of plant components and their proportions in the sward profiles derived from point quadrat studies are given in Fig. 1 and in Montossi (1996). In both swards, recorded hits were concentrated below 20 cm height, where most of the dead material and green stem were located. However, higher numbers of hits of dead material and green stem above 20 cm height were recorded in ryegrass swards than in Yorkshire fog swards. Live leaf lamina was the major component of the uppermost layers (from 20 to 65 cm) of both swards, particularly Yorkshire fog. Stem frequency increased substantially from the top to the bottom in both sward canopies, but higher proportions of dead and green stems were recorded in the uppermost layers of ryegrass swards than in Yorkshire fog swards. Recorded hits of green ryegrass stem were higher than those of green ryegrass leaf, and greater numbers of

Table 2. Botanical composition of the diet selected by oesophageal fistulated sheep grazing annual ryegrass/white clover and Yorkshire fog/white clover swards, and comparative information for sward strata above 15 cm

Dietary component	Proportion in diet			Proportion in sward above 15 cm ^{††}	
	Annual ryegrass	Yorkshire fog	S.E.M	Annual ryegrass	Yorkshire fog
Live material [†]	0.890	0.920	0.0147	0.88	0.95
Grass [‡]	0.996	0.991	0.0022	0.98	0.92
Grass leaf [§]	0.928	0.977	0.0139*	0.80	0.87

[†] As proportion of total (live + dead) material.

[‡] As proportion of (grass + legume) in live fraction.

[§] As proportion of (leaf + stem) in live grass fraction.

^{††} Estimated from data shown in Fig. 1 and Montossi (1996).

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$.

Table 3. *Chemical composition (g/kg DM) and coefficient of organic matter digestibility of the diet selected by oesophageal fistulated sheep from annual ryegrass and Yorkshire fog swards*

Diet components	Annual ryegrass	Yorkshire fog	S.E.M.	Pasture effect
OM digestibility	0.740	0.780	0.008	*
NDF	490	470	7.0	NS
ADF	250	230	5.0	*
Lignin	24	17	1.0	**
Ash	156	158	3.0	NS
Free tannin	0.82	0.93	0.05	NS
Protein-bound tannin	1.61	1.98	0.02	NS
Fibre-bound tannin	1.22	1.29	0.07	NS
Total condensed tannin	3.65	4.20	0.21	NS

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$; **, $P < 0.01$.

hits of white clover, lotus and weeds were recorded, and were distributed lower in the canopy, in ryegrass swards than Yorkshire fog swards. The proportions of white clover and lotus in the canopy decreased during grazing in both swards, but the reduction was greater in Yorkshire fog swards. Clover petioles and lotus stems were distributed higher in Yorkshire fog swards than in ryegrass swards.

Animal measurements

The botanical composition of the diet selected by oesophageal fistulated wethers (OF) from ryegrass and Yorkshire fog swards is shown in Table 2. Separate identification of grass and legume species was difficult. Leaf lamina and sheath were also not

distinguished, so results are compared in terms of green versus dead material, legume versus grass, and green leaf versus green stem. Grasses made up more than 0.98 of the diets of OF on both Yorkshire fog and ryegrass swards. Diet samples from Yorkshire fog swards had less green stem ($P < 0.05$) and more green leaf ($P < 0.05$) than those from ryegrass swards. The digestibility of the herbage consumed by OF sheep was consistently higher on Yorkshire fog than on ryegrass, while ADF and lignin were significantly higher on ryegrass (Table 3). Total CT and protein-bound, fibre-bound and free fractions in extrusa samples did not differ between swards (Table 3).

Release rates of Cr_2O_3 were very similar in the slaughtered lambs for the two swards, and a common daily release rate of 187.5 mg Cr_2O_3 was used (Table 4). Herbage intakes were higher on Yorkshire fog swards than on ryegrass swards, though the difference was greater in daily intake per lamb ($P < 0.05$) than per unit of metabolic liveweight ($P < 0.07$). Effects on intake per bite, rate of biting and grazing time were not significant.

The effects of grass species and PEG administration on mean FEC values and abomasal, intestinal and total worm burdens are presented in Table 5. It was not necessary to drench the lambs in any treatment because FEC values did not reach the defined drenching criteria. Levels of FEC and digestive tract worm burdens were lower in lambs from Yorkshire fog than from ryegrass swards. The effects of PEG were not significant. Worms in the abomasum and small intestine were predominantly *Ostertagia* and *Trichostrongylus* spp.; those in the large intestine were mainly *Oesophagostomum* and *Trichuris* spp.

Lambs grazing on Yorkshire fog swards had significantly higher greasy and clean wool growth rates than lambs grazing on ryegrass swards, with a significantly greater fibre diameter ($P < 0.001$), while wool yield was similar for both treatments (Table 6).

Table 4. *The effect of pasture type and PEG supplementation on mean release rate of Cr_2O_3 (mg/day), herbage intake (g OM per lamb per day and g OM $\text{LW}^{0.73}$ /day), bite weight (mg OM/bite), rate of biting (bites/min) and grazing time (min/day)*

	Annual ryegrass		Yorkshire fog		S.E.M.	Pasture effect
	+ PEG	– PEG	+ PEG	– PEG		
Mean release rate	185	189	187	189	3.9	NS
Herbage intake	875	850	1075	1070	118	*
Herbage intake $\text{LW}^{0.73}$	60	58	71	69	7.9	NS
Bite weight	53	63	—	—	6.1	NS
Rate of biting	81	81	76	77	3.0	NS
Grazing time†	554	565	534	523	23	NS

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$.

† Within daylight hours.

Table 5. The effect of pasture type and PEG supplementation on mean faecal egg count (FEC; eggs/g fresh faeces) and on mean abomasal, intestinal and total worm burdens

Animal parameters	Annual ryegrass		Yorkshire fog		S.E.M.	Pasture effect
	+PEG	–PEG	+PEG	–PEG		
FEC†	212 (13)	135 (10)	118 (9)	108 (9)	(1.73)†	**
Worm populations in:						
Abomasum§	61 (7.6)		10 (2.8)		(1.0)	*
Small intestine§	63 (6.8)		10 (2.5)		(2.16)	NS
Large intestine§	42 (4.9)		11 (3.2)		(1.86)	NS
Total tract§	166 (12.9)		31 (5.7)		(0.67)	**

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$; **, $P < 0.01$.

† FEC and worm burdens data were normalized by square-root transformation plus 0.5 prior to analysis; normalized data in parentheses.

‡ Means of 24 animals per treatment.

§ Means of 4 animals per species, balanced for PEG effect.

Table 6. The effect of pasture type and PEG supplementation on clean wool growth ($\mu\text{g}/\text{cm}^2$ per day), fibre diameter (μ), fibre length (mm), liveweight gain (g/day), final liveweight (kg), carcass weight (kg), carcass gain (g/lamb per day), GR (mean value of left and right sides, mm) and dressing out (%)

	Annual ryegrass		Yorkshire fog		S.E.M.	Main effects and interaction		
	+PEG	–PEG	+PEG	–PEG		GRASS	PEG	GRASS \times PEG
Wool growth	1220	1343	1377	1535	30	**	*	NS
Fibre diameter	28.7	30.1	30.4	31.3	0.2	***	**	NS
Fibre length	23.5	23.8	24.5	25.2	0.5	NS	NS	NS
Liveweight gain	105	111	134	173	4.3	***	**	*
Final liveweight	37.7	38.5	41.9	43.0	0.5	***	NS	NS
Carcass weight	17.0	17.0	18.7	19.3	0.3	***	NS	NS
Carcass gain	68.0	70.0	85.9	91.7	2.5	***	NS	NS
GR	7.0	8.7	11.5	10.0	0.5	**	NS	NS
Dressing out	44.9	44.3	44.8	44.9	0.4	NS	NS	NS

S.E.M., Standard error of the mean.

Significance: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Lambs receiving PEG supplement grew less greasy and clean wool than controls (Table 6).

Lambs grew significantly faster on Yorkshire fog than on ryegrass swards ($P < 0.001$) and were significantly heavier at the end of the trial (Table 6). There was a significant interaction between the effects of pasture type and PEG, the growth reduction in response to use of PEG being substantially greater in lambs grazing Yorkshire fog than in those on ryegrass (Table 6). These differences were also reflected in heavier carcass weight, higher GR value, and higher carcass gains in favour of lambs grazing on Yorkshire fog swards. Dressing out percentages did not differ between swards.

DISCUSSION

Sward effects

Holcus swards had higher green bulk densities than ryegrass swards before grazing (Table 1), probably reflecting the higher proportion of leaves in the canopy of Yorkshire fog. The higher contents of dead material and green stem in ryegrass swards compared to Yorkshire fog swards are a consequence of the early seed head emergence of Italian ryegrass, which normally starts in early October in Uruguay, in contrast to emergence in *Holcus* in late November and early December (E. Berretta, personal communication). Similar observations on the influence of

stage of maturity on annual ryegrass biomass composition have been reported by Hume (1991) and by Jung & Shaffer (1993).

Sown grasses formed the major component of both swards before and after grazing (Table 1). No Yorkshire fog appeared in the samples from ryegrass swards, but ryegrass made a substantial contribution to Yorkshire fog swards, probably related to the presence of seed-banks associated with the previous cultivation of this species on the experimental site. Legume proportions were always low, and decreased during grazing in both swards. Weeds were a minor component of all swards.

The greater proportion of grass leaf in the samples taken by OF sheep on Yorkshire fog swards (Table 2) may be explained by the high proportion of hits of this component in the whole sward profile, particularly in the surface layers of the canopy of Yorkshire fog compared to ryegrass swards, whereas dead material was distributed higher in the sward canopy of ryegrass swards (Fig. 1). The composition of the diet selected tended to match the composition of the strata of ryegrass and Yorkshire fog swards above 15 cm height (Table 2), where most grazing was concentrated. The evidence suggests that sheep apparently discriminated in favour of the leaf component, rather than the legume component, and that they probably penetrated in some degree to the lower horizons of both sward canopies (below 15 cm) to increase the selection of leaf material.

The greater degree of lignification and lower digestibility of the diet from ryegrass than from Yorkshire fog swards reflects the greater stem to leaf ratios in the former (Tables 2 and 3). The decrease in digestibility in annual ryegrass with increasing maturity has been associated with increasing cell wall contents of both leaf and stem fractions, but the digestibility of the leaf fraction usually declines at a slower rate than that of stem (Ballard *et al.* 1990; Hume 1991). After anthesis in annual ryegrass, the poor digestibility of senescent plant material has a strong influence on whole plant digestibility (Ballard *et al.* 1990).

The greater herbage intake from Yorkshire fog than from ryegrass swards (Table 4) may reflect the greater proportion of cell wall components in annual ryegrass, associated with the early reproductive development of this species in Uruguayan conditions, resulting in a decline in digestibility and hence intake. The intake of leaf is greater than that of the stem fraction of grasses due to the shorter time leaf is retained in the reticulo rumen (Poppi *et al.* 1981*a, b*). Also, high levels of dead material in the pre-grazing pasture mass affect herbage intake due to its effect in (i) reducing the digestibility of the herbage harvested (Rattray *et al.* 1987) and (ii) increasing searching time for preferred components (e.g. green leaf) within the sward profile (Birrell 1989). Intakes per unit of

metabolic weight ($LW^{0.73}$) were lower than those recorded previously in lambs by Jamieson & Hodgson (1979) and Montossi *et al.* (1997*a*), probably reflecting the lower nutritive value of the diet selected in the present study.

Sward effects on the components of ingestive behaviour were not significant (Table 4). However, the general tendency for higher mean bite weight and lower rate of biting and grazing time recorded on Yorkshire fog swards compared to ryegrass swards is in agreement with the previous experiments in this series (Montossi *et al.* 1994; Liu *et al.* 1997; Montossi *et al.* 1997*a*).

The low FEC values recorded in this study (Table 5) are probably explained by the alternate rotation of crops and pastures in the experimental area in previous years, and by the alternate grazing of sheep and cattle. These latter management practices prevent the establishment of infective larval populations in pastures (Speedy 1980). Also, the fact that lambs were drenched onto plots, and the short-term period of the trial, limited the build-up of infective larval populations. Nevertheless, the differences between swards in FEC and abomasal and total worm burdens were of greater magnitude than those found in previous studies (Niezen *et al.* 1993, 1994; Montossi *et al.* 1997*a*).

Differences between swards in wool growth and fibre diameter, and in lamb growth and carcass parameters (Table 6) resulted principally from the effects of the higher digestibility values and intakes of Yorkshire fog swards compared to those of ryegrass (Tables 3 and 4), reflecting the higher proportions in the diet of green leaf and the lower proportions of green stem and dead material. Birrell (1992) found a curvilinear relationship between organic matter digestibility (OMD) and wool growth, where growth rates increased to an apparent optimum around 0.70 OMD. Allowing for the greater number of non-experimental animals maintained in ryegrass plots, over the whole experimental period sheep liveweight output per hectare was 28 % greater on Yorkshire fog plots than on ryegrass plots (497 v. 389 ± 33 kg/ha, $P < 0.05$).

PEG effects

There is accumulating evidence on the presence of low concentrations of CT in *Lolium* genera and in *Holcus* (Horigome & Uchida 1981; Montossi *et al.* 1997*b*). The CT concentrations observed in this study (Table 3) are higher than those generally reported for these species (Douglas *et al.* 1993; Iason *et al.* 1995; Montossi *et al.* 1997*b*), probably as a consequence of the low fertility conditions of the experiment, but similar to those reported by Terrill *et al.* (1992*a, b*). Increased concentrations of CT have been found in CT-containing legumes under environmental stress (Barry & Forss 1983; Douglas *et al.* 1993).

It is unlikely that the CT concentrations in *Holcus* or annual ryegrass swards influenced the selective patterns of the OF sheep which ate mostly green leaf from both swards, despite the significantly higher CT concentrations normally found in leaves than in stems (Douglas *et al.* 1993; Iason *et al.* 1995). Confirming the results of Terrill *et al.* (1992b) and those of Montossi *et al.* (1997a), the herbage intakes of PEG and non-PEG lambs were similar, suggesting that CT concentrations were not high enough to depress intake. PEG supplementation did not affect the grazing behaviour patterns of the lambs.

The effects of PEG drenching on FEC were small, supporting other findings (Niezen *et al.* 1993, 1994; Montossi *et al.* 1997a). This suggests that the control of worm parasites in lambs grazing on Yorkshire fog swards may reflect species differences in physical characteristics (e.g. sward canopy structure, leaf surface texture) as well as in CT concentration. More research is required in this area to determine causative relationships.

The effects of PEG on wool production (Table 6) matched very closely those of the spring trial of Terrill *et al.* (1992b), where similar CT dietary concentrations (4.7 g/kg on a DM basis) to those of the present study increased wool growth by 18%. The beneficial effects of CT on wool production have been well defined (Wang *et al.* 1994). These findings indicate that CT increases the availability and absorption of sulphur amino acids (Reis *et al.* 1990), resulting in increases in wool production, though the effects have generally been demonstrated at substantially higher CT concentrations (< 3.5% on a DM basis) than those observed in this study.

Non-PEG lambs gained significantly more liveweight than PEG lambs (Table 6), in accord with the results of the spring trial with temperate grasses of Terrill *et al.* (1992b). In agreement with the work of Montossi *et al.* (1997a), a significant grass \times PEG interaction indicated that CT in Yorkshire fog was probably more effective than CT in ryegrass in promoting increases in liveweight gain. This latter effect could be related to the slightly higher total CT and protein-bound CT concentrations in extrusa in

favour of Yorkshire fog swards. The same tendency was observed for final liveweight ($P < 0.09$), but no significant differences between PEG treatments existed for carcass weight, GR values or dressing out percentages.

CONCLUSIONS

The results of this study indicate the potential value of Yorkshire fog swards for moderate soil fertility conditions. Lower levels of parasitism were recorded in lambs grazing Yorkshire fog swards than in lambs grazing annual ryegrass under conditions of very light parasite challenge, indicating the potential advantage of *Holcus* in the biological control of worm parasites. More research is needed in this area to determine causative relationships.

Evidence of low CT concentrations in annual ryegrass and Yorkshire fog were reported for the first time in Uruguayan conditions, supporting previous evidence from New Zealand. The results indicate that CT concentrations close to 0.5% on a DM basis would be expected to provide measurable improvement in lamb performance. Given similar dietary CT concentrations, however, the impact of PEG drenching on lamb performance tended to be greater on Yorkshire fog than on annual ryegrass, which may indicate that the CT present in *Holcus* are more efficient in binding plant proteins than those in *Lolium* spp. There was no evidence that the low CT concentrations influenced diet selection, herbage intake or grazing behaviour patterns. These results indicate a promising unexplored potential to improve the nutritive value of *Lolium* spp. and *Holcus* from limited increases in CT content.

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REFERENCES

- BAILEY, R. W. (1967). Quantitative studies of ruminant digestion. II. Loss of ingested plant carbohydrates from the reticulo-rumen. *New Zealand Journal of Agricultural Research* **10**, 15–32.
- BALLARD, R. A., SIMPSON, R. J. & PEARCE, G. R. (1990). Losses of the digestible components of annual ryegrass (*Lolium rigidum* Gaudin) during senescence. *Australian Journal of Agricultural Research* **41**, 719–731.
- BARRY, T. N. & DUNCAN, S. J. (1984). The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 1. Voluntary intake. *British Journal of Nutrition* **51**, 485–491.
- BARRY, T. N. & FORSS, D. A. (1983). The condensed tannin content of vegetative *Lotus pedunculatus*, its regulation by fertiliser application, and effect upon protein solubility. *Journal of the Science of Food and Agriculture* **34**, 1047–1056.
- BIGHAM, M. L. (1974). Effects of shearing interval on fleece

- weight and wool growth on a delineated midside patch. *New Zealand Journal of Agricultural Research* **17**, 407–410.
- BIRRELL, H. A. (1989). The influence of pasture and animal factors on the consumption of pasture by grazing sheep. *Australian Journal of Agricultural Research* **40**, 1261–1275.
- BIRRELL, H. A. (1992). Factors associated with the rate of growth of clean wool on grazing sheep. *Australian Journal of Agricultural Research* **43**, 265–275.
- CLARK, D. A. & HODGSON, J. (1986). Techniques to estimate botanical composition of diet samples collected from oesophageal fistulates. Mimeograph, DSIR, Palmerston North.
- DOUGLAS, G. B., DONKERS, P., FOOTE, A. G. & BARRY, T. N. (1993). Determination of extractable and bound condensed tannins in forages species. *Proceedings of the XVII International Grassland Congress*, pp. 204–206.
- HODGSON, J., NIEZEN, J. H., MONTOSI, F., LIU, F. & BUTLER, B. M. (1996). Comparative studies on animal performance and parasite infestation in sheep grazing Yorkshire fog, perennial ryegrass, and tall fescue pastures. *Proceedings of the New Zealand Grassland Association* **57**, 89–93.
- HORIGOME, T. & UCHIDA, S. (1981). Nutritional quality of leaf protein prepared from crops containing phenolic compounds and polyphenolase. *Proceedings of the XIV International Grassland Congress*, Lexington, Kentucky, pp. 362–364.
- HUME, D. E. (1991). Primary growth and quality characteristics of *Bromus willdenowii* and *Lolium multiflorum*. *Grass and Forage Science* **46**, 313–324.
- IASON, G. R., HODGSON, J. & BARRY, T. N. (1995). Variation in condensed tannins concentration of a temperate grass (*Holcus lanatus*) in relation to season and reproductive development. *Journal of Chemical Ecology* **21**, 1103–1112.
- JAMIESON, W. S. & HODGSON, J. (1979). The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. *Grass and Forage Science* **34**, 261–271.
- JUNG, H. G. & SHAFFER, J. A. (1993). Component yields and quality of binary mixtures of lucerne and perennial, Italian or short rotation hybrid ryegrass. *Grass and Forage Science* **48**, 118–125.
- KIRTON, A. H. (1989). Principles of classification and grading. *Meat Production and Processing* (Eds R. W. Purchas, B. W. Butler-Hogg & A. S. Davies), pp. 143–158. New Zealand Society of Animal Production, Occasional Publication No. 11.
- LIU, F. Y., HODGSON, J. & BARRY, T. N. (1997). Comparative studies of herbage intake and performance of lambs grazing Yorkshire fog (*Holcus lanatus*) and perennial ryegrass (*Lolium perenne*) pastures in winter. *New Zealand Journal of Agricultural Research* **40**, 463–474.
- MONTOSI, F. (1996). *Comparative studies on the implications of condensed tannins in the evaluation of Holcus lanatus and Lolium spp. swards for sheep performance*. Ph.D. Thesis. Massey University, New Zealand. 288 pp.
- MONTOSI, F., HU, Y., HODGSON, J. & MORRIS, S. T. (1994). Herbage intake, ingestive behaviour and diet selection in sheep grazing *Holcus lanatus* and perennial ryegrass swards. *Proceedings of the New Zealand Society of Animal Production* **54**, 71–74.
- MONTOSI, F., LIU, F., HODGSON, J. & MORRIS, S. T. (1997a). A comparative study of herbage intake, ingestive behaviour and diet selection, and effects of condensed tannins upon body and wool growth in lambs grazing *Holcus lanatus* and *Lolium perenne* swards in summer. *New Zealand Journal of Agricultural Research* **40**, 449–461.
- MONTOSI, F., LIU, F., HODGSON, J. & MORRIS, S. T. (1997b). Influence of low-level condensed tannins concentrations in temperate forages on sheep performance. *Proceedings of the XVIII International Grassland Congress Canada* **8**, 1–2.
- NIEZEN, J. H., CHARLESTON, W. A. G., HODGSON, J. & WAGHORN, T. S. (1993). Effect of four grass species on lamb parasitism and growth. *Proceedings of the New Zealand Grassland Association* **55**, 203–206.
- NIEZEN, J. H., WAGHORN, T. S., KAUFAUT, K., ROBERTSON, H. A. & MCFARLANE, R. G. (1994). Lamb weight gain and faecal egg count when grazing one of seven herbage and dosed with larvae for six weeks. *Proceedings of the New Zealand Society of Animal Production* **54**, 15–18.
- PARKER, W. J., MCCUTCHEON, S. N. & CARR, D. H. (1989). Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. *New Zealand Journal of Agricultural Research* **32**, 537–546.
- POPPI, D. P., MINSON, D. J. & TERNOUTH, J. H. (1981a). Studies of cattle and sheep eating leaf and stem fractions of grasses. I. Voluntary intake, digestibility and retention time in the reticulo-rumen. *Australian Journal of Agricultural Research* **32**, 99–108.
- POPPI, D. P., MINSON, D. J. & TERNOUTH, J. H. (1981b). Studies of cattle and sheep eating leaf and stem fractions of grasses. II. Factors controlling the retention of the feed in the reticulo-rumen. *Australian Journal of Agricultural Research* **32**, 109–121.
- RATTRAY, P. V., THOMPSON, K. F., HAWKER, H. & SUMNER, R. M. W. (1987). Pastures for sheep production. In *Livestock Feeding on Pasture* (Ed. A. M. Nicol). New Zealand Society of Animal Production, Occasional Publication No. **10**, 89–103.
- REIS, P. J., TUNKS, D. A. & MUNRO, S. G. (1990). Effects of infusion of amino acids into the abomasum of sheep, with emphasis on the relative value of methionine, cysteine and homocysteine for wool growth. *Journal of Agricultural Science, Cambridge* **114**, 59–68.
- ROUGHAN, P. G. & HOLLAND, R. (1977). Predicting in vitro digestibilities of herbage by exhaustive enzymic hydrolysis of cell walls. *Journal of Agricultural Science, Cambridge* **87**, 423–432.
- SAS (1990). *SAS User's Guide: Statistics, Versions 5 and 6 Edition*. SAS Inc, Cary, North Carolina, USA.
- SPEEDY, A. W. (1980). *Sheep Production: Science into Practice*. London: Longman Scientific and Technical Publication. 191 pp.
- STOBBS, T. H. (1973a). I. The effect of plant structure on the intake of tropical pastures. *Australian Journal of Agricultural Research* **24**, 809–818.
- STOBBS, T. H. (1973b). II. The effect of plant structure on the intake of tropical pastures. *Australian Journal of Agricultural Research* **24**, 819–829.
- TERRILL, T. H., DOUGLAS, G. B., FOOTE, A. G., PURCHAS, R. W., WILSON, G. F. & BARRY, T. N. (1992a). Effect of CT upon body growth, wool growth and rumen metabolism in sheep grazing sulla (*Hedysarum coronarium*) and perennial pasture. *Journal of Agricultural Science, Cambridge* **119**, 265–273.

- TERRILL, T. H., ROWAN, A. M., DOUGLAS, G. B. & BARRY, T. N. (1992*b*). Determination of extractable and bound CT concentrations in forage plants, protein concentrate meals and cereal grains. *Journal of the Science of Food and Agriculture* **58**, 321–329.
- UENO, H. & GUTIERREZ, V. C. (1983). Manual para diagnóstico das Helmitoses de Rumiantes. Tokyo, Japan.
- WAGHORN, G. C., JONES, W. T., SHELTON, I. D. & MCNABB, W. (1990). Condensed tannins and the nutritive value of herbage. *Proceedings of the New Zealand Grassland Association* **51**, 171–176.
- WANG, Y., WAGHORN, G. C., DOUGLAS, G. B., BARRY, T. N. & WILSON, G. F. (1994). The effects of condensed tannins in *Lotus corniculatus* upon nutrient metabolism and upon body and wool growth in grazing sheep. *Proceedings of the New Zealand Society of Animal Production* **54**, 219–222.
- WARREN WILSON, J. (1963). Estimation of foliage denseness and foliage angle by inclined point quadrat. *Australian Journal of Botany* **11**, 95–105.
- WATT, T. A. (1987). A comparison of two cultivars of *Holcus lanatus* with *Lolium perenne*, under cutting. *Grass and Forage Science* **42**, 43–48.
- WILLIAMSON, J. F., BLAIR, H. T., GARRICK, D. J., POMROY, W. E. & DOUCH, P. G. C. (1994). The relationship between internal parasite burden, faecal egg count, and mucosal mast cells in fleeceweight-selected and control sheep. *Proceedings of the New Zealand Society of Animal Production* **54**, 9–13.