Intake characteristics of perennial ryegrass varieties when grazed by yearling beef cattle under rotational grazing management

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Abstract

Four intermediate-heading perennial ryegrass (*Lolium perenne* L.) varieties, which in previous studies had been associated with high- or low-intake characteristics when swards containing them had been continuously stocked with sheep, were sown as monocultures. They were rotationally grazed, using 1-d paddocks, with core groups of four yearling Simmental × Holstein beef heifers in 2002 and 2003 and ingestive and ruminative behaviour, and sward factors, were measured. There were two diploid (Belramo and Glen) and one tetraploid (Rosalin) perennial ryegrass varieties and one tetraploid hybrid (*Lolium* × *boucheanum* Kunth) (AberExcel) variety. Intake rate (IR) was significantly higher in August 2003 for heifers grazing Glen than those grazing Belramo [27·5 vs. 20·6 g dry matter (DM) min^{-1}; $P = 0·019$], but there were no significant differences between varieties in two other measurement periods. This is in contrast to previous results with sheep when IR were significantly higher for Glen than Belramo and for AberExcel than Rosalin. Total jaw movement rates during grazing were significantly higher for heifers on the tetraploid swards than those on the diploid swards (87·7 vs. 83·6 jaw movements min^{-1}; $P = 0·023$) in September 2002. Ruminating time was significantly lower for heifers on the tetraploid swards than those on the diploid swards (453 vs. 519 min 24 h^{-1}; $P = 0·012$) in July 2002. Digestibility of grass snips was significantly higher on the tetraploid than the diploid swards [697 vs. 680 g digestible organic matter (DOM) kg^{-1} DM; $P = 0·042$] in September 2003 and, within diploids, was significantly higher for Glen than Belramo (696 vs. 663 g DOM kg^{-1} DM; $P = 0·014$). There were significant differences in sheath tube and leaf lengths and in the population density of tillers between and within ploidies, which might have been expected to have influenced intake characteristics, but this was not generally found under rotational grazing with cattle. In order to separate the effects of defoliation interval from those of grazing style of the different ruminant species, it is suggested that grass variety evaluations using continuously stocked cattle swards are required.

Keywords: perennial ryegrass, varieties, intake rate, rotational grazing, cattle

Introduction

The assessment of intake characteristics of grass cultivars in grazing experiments (e.g. Barrett *et al.*, 2003) is expensive in terms of land, animal and labour resources. However, the potential value of perennial ryegrass cultivars under grazing cannot necessarily be assessed from offering fresh or dried cut forage to housed animals (Hazard *et al.*, 1998). Orr *et al.* (2003) measured large differences in dry matter (DM) intake rate (IR) between fifteen intermediate-heading perennial ryegrass (*Lolium perenne* L.) varieties when they were continuously stocked with sheep and subsequently explored the extent to which, for five of these varieties, these differences could be explained by chemical and morphological traits (Orr *et al.*, 2004a). The objective of this study was to examine IR and eating times for four of the fifteen varieties, which within ploidy had low- or high-intake characteristics when grazed by sheep, to see if those attributes also held when swards containing these varieties were rotationally grazed by cattle. Sward chemical and morphological factors were also assessed.

Materials and methods

The experiment was conducted on a site at the Institute of Grassland and Environmental Research, North Wyke, Devon (50°46′N, 3°56′W). Four intermediate-heading perennial ryegrass varieties [Belramo and Glen (diploid), Rosalin (tetraploid) and AberExcel (tetraploid hybrid,

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Received 11 November 2004; revised 18 February 2005

Lolium × *boucheanum* Kunth)] were compared when rotationally grazed by yearling Simmental × Holstein beef heifers. In previous studies, daily intakes by sheep had been 810, 904, 818 and 1104 g dry matter (DM) for Belramo, Glen, Rosalin and AberExcel respectively.

Sward establishment

The four varieties were each sown on 30 August 2000 in three replicate blocks to create twelve (0·6 ha) areas. Each area was further subdivided into thirty paddocks (7·4 m × 27·0 m). A seed-sowing rate of 30 kg ha^{-1} was used for the diploids and 40 kg ha^{-1} for the tetraploid and tetraploid hybrid varieties. Fertilizer, which supplied 43 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}, was applied to the seed bed. In 2001, the whole experimental area was cut and the herbage removed on 3 June, 23 July and 18 September.

Management

The twelve treatment areas were each rotationally stocked using core groups of four heifers from 26 April to 25 October 2002 (born August 2001) and 24 April to 12 September 2003 (born August 2002). In 2003 only, there were an additional three heifers present in each group between 24 April and 26 June. This strategy was used in order to utilize some of the herbage growth in the early part of the season that was in excess of requirements for the cattle, but the group size was reduced in late June as the cattle grew larger. In 2002 and 2003, respectively, the core heifers (s.e.) had a live weight of 200 (2·5) kg and 190 (3·6) kg at the start of the grazing season and the same groups were maintained on the same treatments throughout each season. They grazed 1-d paddocks, had access to the previous day's paddock as a lie-back and moved to a new paddock at approximately 15:00 hours.

Uninterrupted spring growths were cut on two-thirds of each treatment area (0·4 ha) on 4 June 2002 and on one-third of each treatment area (0·2 ha) on 20 May 2003. Following removal of the herbage, fertilizer, supplying 100 kg N and 64 kg K_2O ha^{-1}, was applied. Each year the grazed paddocks were fertilized with five applications of 40 kg N ha^{-1} at approximately monthly intervals from March.

Measurements

Intake rate

Herbage IR was estimated throughout each year for the same two of the four heifers (chosen at random) grazing the four varieties in each replicate block on 10, 11 and 12 September 2002; on 14, 17 and 22 July 2003 and on 22, 26 and 27 August 2003 using a weighing technique (Penning and Hooper, 1985), modified for use on cattle (Huckle *et al.*, 1994). Measurements were made when the heifers, which were trained to be accustomed to the procedure, were introduced to the new paddocks.

Heifers were weighed before and after a period of grazing of approximately 1 h, during which time the jaw movements were recorded using automatic behaviour recorders (Rutter *et al.*, 1997). Recordings of jaw movement were subsequently analysed using 'Graze'™ software (Rutter, 2000) to calculate the duration of eating. Herbage samples were snipped from the grazed horizon using scissors and oven-dried at 80°C for 20 h for assessment of DM content. Herbage DM IR was calculated making an allowance for insensible weight loss, caused by evaporative and gaseous losses, determined in the preceding hour. Rate of insensible weight loss was measured by weighing heifers before and after a non-grazing period of approximately 1 h, when they were fitted with muzzles and allowed to walk within the paddock.

Eating time and ruminating time

Jaw movements were recorded over 24 h for the same two heifers that had been used for IR measurements, using the automatic behaviour recorders. Recordings were subsequently analysed to distinguish periods of eating, ruminating and idling and thus allow the calculation of eating time (Gibb, 1998). Measurements were made when the heifers moved to a new paddock at approximately 15:00 hours in each replicate block: in 2002 beginning on 1, 8 and 10 July and 29 August, 2 and 5 September, and in 2003 beginning on 6, 12 and 14 May; 15, 23 and 30 July and 28 August, 4 and 8 September. Snip samples were cut from the grazed horizon using scissors before the heifers entered the paddocks for these 24-h behaviour measurements and were rapidly frozen, freeze-dried and analysed for DM content as described below.

Data for eating time and ruminating time included pauses of <3 s between successive jaw movements (i.e. the minimum inter-bout interval was 3 s), and an eating bout and a ruminating bout each contained at least 10 jaw movements. Jaw movements that did not satisfy these criteria were broadly designated as 'other activities', e.g. drinking, grooming, vocalization, etc. Individual rumination bouts associated with the eructation of each bolus were combined using a minimum inter-rumination bout interval of 20 s.

Sward height, mass and sheath tube/leaf lengths

Compressed sward height (CSH) was measured when IR and grazing behaviour measurements were made using an Ashgrove platemeter (Ashgrove Pastoral Products, Palmerston North, New Zealand) with 25 contacts per paddock. The partition of herbage mass between live and dead material, and the tiller population density (tillers m^{-2}), were measured within circular quadrats with the same diameter (354 mm) as the platemeter when grazing-behaviour measurements were made. The grass was cut to ground level (Frame, 1981; Thomson *et al.*, 1997) using scissors and subsamples of 50–60 grass tillers were separated into green leaves, green vegetative and reproductive stems, and dead material. Reproductive tillers in the subsample were identified on the basis of internode elongation and the numbers of both reproductive and vegetative tillers in the subsample were counted. The dry weight (oven-drying at 85°C for 18 h) of the components and the number of tillers were calculated from the contribution of their weight to the total weight of the respective subsamples and the total sample weight.

Sheath tube and leaf lengths (Casey, 2000) were measured after the removal of senescent material on the tillers in the subsample, with lamina containing proportionately >0·50 of dead surface tissue being classified as dead. Sheath tube lengths were measured from the root/shoot interface.

Chemical analyses

Freeze-dried grass snips from the grazed horizon, collected in association with the 24-h behaviour measurements, were analysed for digestible organic matter in the DM (DOMD *in vitro*; Jones and Haywood, 1975), for nitrogen (N) concentration by the Kjeldahl method, with copper sulphate as a catalyst, using a Tecator 1030 auto analyser (Tecator, 1987), and for water-soluble carbohydrate (WSC) concentration (Thomas, 1977).

Statistical analysis

The results were analysed as a one-way randomized block design ($n = 12$) using GenStat (GENSTAT, 1987). The effects of ploidy and variety within ploidy were examined by using orthogonal contrasts. Mean values for the two measured heifers in each of the twelve groups were used as the unit of replication, as were mean values per paddock when analysing the herbage data.

Results

Compressed sward heights when IR was measured in September 2002, and July and August 2003, respectively, were 11·2, 10·7 and 9·3 cm and there were no significant differences in sward height between treatment paddocks.

IR and jaw movement rates

Apart from the within-diploid comparison between Glen and Belramo ($P = 0{\cdot}019$), there were no significant differences in grass DM IR (Table 1). Grass DM IR tended to be higher on the tetraploid varieties than the diploids in September 2002 and July 2003, whereas the IR was markedly higher on Glen (diploid) in August 2003 than the other varieties.

In September 2002, jaw movement rate was significantly higher for cattle grazing the tetraploids than those grazing the diploids ($P = 0{\cdot}023$). There were no significant differences between treatments in biting, chewing or total jaw movement rates in 2003. There were no significant differences between treatments in DM content of the grass snips and mean values were 224, 224 and 236 g kg^{-1} in September 2002, July 2003 and August 2003 respectively.

Eating and ruminating

There were no significant differences between varieties in daily time spent eating (Table 2). Overall mean values for diploid and tetraploid varieties were 529 and 531 min eating 24 h^{-1} respectively.

Daily time spent ruminating (Table 2) was significantly lower for heifers grazing the tetraploid varieties than the diploids in July 2002 ($P = 0{\cdot}012$), but otherwise ruminating time was similar between treatments. Overall mean values for diploid and tetraploid varieties were 467 and 442 min ruminating 24 h^{-1} respectively. There were no significant effects of variety on the rumination chewing rate or the number of chews per bolus.

Digestibility, nitrogen and WSC concentrations in grass snips

Digestibility of the grass snips taken before the heifers entered a new paddock (Table 3) was significantly higher for the diploid varieties than the tetraploids in September 2003 ($P = 0{\cdot}042$) and, within the diploids, Glen was significantly higher than Belramo ($P = 0{\cdot}014$). Overall mean values for Belramo, Glen, Rosalin and AberExcel, respectively, were 703, 719, 709 and 719 g DOM kg^{-1} DM.

Nitrogen concentrations in the grass snips were significantly higher for AberExcel than Rosalin in September 2002 ($P = 0{\cdot}013$) and tended to be higher for tetraploid than diploid varieties in September 2003. Values tended to increase as the season progressed. In 2003, however, values were higher in May than July or September. Overall mean values for Belramo, Glen, Rosalin and AberExcel were 3·2, 3·1, 3·2 and 3·4 g N kg^{-1} DM respectively.

Table 1 Intake rate, grazing jaw movement rates and grass dry matter (DM) content for the first hour following introduction of the Simmental × Holstein heifers to a new paddock at approximately 15:00 hours in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d.	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Intake rate (g DM min^{-1})								
September 2002	31·5	32·2	34·5	34·4	5·20	0·507	0·897	0·984
July 2003	19·4	21·2	22·7	22·3	1·99	0·171	0·388	0·823
August 2003	20·6	27·5	22·8	24·0	2·16	0·699	0·019	0·617
Biting rate (min^{-1})								
September 2002	65·4	65·3	68·9	69·0	2·64	0·100	0·975	0·990
July 2003	69·9	65·8	61·4	65·4	3·58	0·129	0·296	0·300
August 2003	67·1	66·9	67·1	65·6	2·06	0·705	0·932	0·493
Chewing rate (min^{-1})								
September 2002	17·1	19·4	17·8	19·7	1·96	0·722	0·280	0·382
July 2003	17·9	20·6	25·9	23·2	3·63	0·084	0·483	0·490
August 2003	20·1	18·3	19·9	20·0	2·84	0·715	0·545	0·955
TJM rate (min^{-1})								
September 2002	82·4	84·7	86·8	88·6	1·93	0·023	0·289	0·366
July 2003	87·8	86·4	87·2	88·6	1·50	0·448	0·393	0·389
August 2003	87·2	85·1	87·0	85·7	1·96	0·894	0·344	0·520
Grass DM content (g kg^{-1})								
September 2002	225	217	230	225	17·7	0·630	0·672	0·811
July 2003	226	213	229	229	16·9	0·461	0·490	0·995
August 2003	239	244	232	229	13·3	0·301	0·758	0·839

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.
TJM, total jaw movements (biting + chewing).

Water-soluble carbohydrate concentrations in the grass snips were not significantly different between the varieties and, unlike the N concentrations, tended to decrease as the season progressed. Overall mean values for Belramo, Glen, Rosalin and AberExcel were 17·5, 18·6, 17·8 and 17·9 g WSC kg^{-1} DM respectively.

Daily liveweight gain

The liveweight gains of the heifers during the grazing season were high in both years and mean values were 0·98 and 1·02 kg day^{-1} for 2002 and 2003 respectively. However, there were no significant differences in daily liveweight gain between the treatments (Table 4) in either year.

Compressed sward height, green leaf mass and the number of tillers per square metre

Compressed sward height (Table 5) at the start (IN) and end (OUT) of 24-h grazing periods, when behaviour was recorded, was significantly higher in AberExcel than Rosalin in July 2002 ($P = 0{\cdot}025$). Overall mean values for Belramo, Glen, Rosalin and AberExcel were 10·9, 11·9, 11·5 and 12·8 cm (IN) and 6·6, 7·0, 6·9 and 7·0 cm (OUT) respectively.

Green leaf mass (Table 6) was not significantly different between the varieties and declined with season. For example, overall mean values across the four varieties in May, July and September 2003 were 2027, 1239 and 1034 kg DM ha^{-1} respectively.

There were significant effects of ploidy on the tiller population density per square metre (Table 6) in July 2002 ($P = 0{\cdot}004$), May 2003 ($P = 0{\cdot}002$) and July 2003 ($P = 0{\cdot}004$) with higher values for the diploid than the tetraploid varieties. Within ploidies, Rosalin was higher than AberExcel in July 2002 ($P = 0{\cdot}025$) and Glen was higher than Belramo in May 2003 ($P = 0{\cdot}019$). Overall mean values for Belramo, Glen, Rosalin and AberExcel were 10008, 10998, 8356 and 6112 tillers m^{-2} respectively.

Sheath tube and leaf lengths

There were significant effects of ploidy on sheath tube and leaf lengths associated with live leaves (Table 7) in July each year. For diploid vs. tetraploid varieties, overall mean values for the sheath tubes were 38 vs.

Table 2 Eating time, ruminating time, ruminating chewing rate and the number of chews per bolus in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d.	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Eating time (min 24 h^{-1})								
July 2002	571	550	567	614	38·7	0·319	0·597	0·264
September 2002	521	511	515	542	35·0	0·630	0·791	0·477
May 2003	492	485	491	508	28·2	0·621	0·815	0·569
July 2003	561	567	496	551	42·2	0·224	0·891	0·238
September 2003	496	536	528	501	26·5	0·932	0·183	0·348
Ruminating time (min 24 h^{-1})								
July 2002	522	516	432	474	26·3	0·012	0·836	0·160
September 2002	477	441	411	452	42·3	0·387	0·429	0·368
May 2003	457	485	414	448	51·3	0·313	0·609	0·536
July 2003	431	407	399	446	38·1	0·892	0·558	0·262
September 2003	463	473	465	482	13·5	0·558	0·489	0·254
Ruminating chews min^{-1}								
July 2002	77·9	79·8	77·6	78·3	2·55	0·635	0·479	0·817
September 2002	73·6	75·3	71·2	71·0	2·32	0·086	0·489	0·943
May 2003	83·0	84·4	80·6	83·1	4·15	0·552	0·756	0·565
July 2003	72·9	74·0	73·5	75·1	4·47	0·803	0·813	0·730
September 2003	73·9	75·6	75·3	76·0	3·88	0·758	0·671	0·857
Ruminating chews $bolus^{-1}$								
July 2002	58·1	54·9	59·9	58·3	4·57	0·450	0·512	0·737
September 2002	58·6	57·9	56·8	63·6	5·19	0·608	0·891	0·240
May 2003	68·1	67·3	60·9	66·6	5·30	0·328	0·878	0·325
July 2003	63·2	59·5	56·8	59·8	4·06	0·333	0·391	0·494
September 2003	67·4	68·3	65·0	65·2	4·38	0·409	0·848	0·969

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.

44 mm (oldest), 56 vs. 70 mm (second oldest) and for leaf lengths were 89 vs. 100 mm (oldest fully expanded), 114 vs. 138 mm (second oldest fully expanded) and 73 vs. 85 mm (expanding leaf). There were significant differences within ploidies in July 2002. On average, over the five measurement periods, values for Glen were generally greater than those for Belramo and values for AberExcel were generally greater than those for Rosalin for each of these factors but this was not always the case (Table 7). In 2003, values were higher in May than in July or September.

Discussion

Previous studies have compared the performance of perennial ryegrass varieties under grazing, but generally have not measured intake (e.g. Swift *et al.*, 1993; McCallum and Thomson, 1994; Emile *et al.*, 2000). However, Gowen *et al.* (2003) examined heading date and ploidy effects for four cultivars on grass intake and milk yield for rotationally grazed dairy cows. They concluded that late-heading grass cultivars have a beneficial effect on milk yield, but used the individual cows as the unit of replication in their analyses. This approach was questioned by Rook and Penning (1991) who argued that the behaviour and performance of individuals cannot be regarded as being independent. In this study, IR was measured for four contrasting perennial ryegrass varieties, with three replicate groups of each, along with sward chemical and morphological traits which could potentially be used to identify lines with superior grazing characteristics.

IR in cattle and sheep

Apart from August 2003, when IR was significantly higher for cattle grazing Glen than for those grazing Belramo, there were no significant differences in IR within or between ploidies. Similarly, there were no significant differences between varieties in biting rate (mean 66·5 bites min^{-1}), chewing rate while grazing (mean 20·0 chews min^{-1}), eating times (mean 530 min 24 h^{-1}), ruminating times (mean 455 min 24 h^{-1}) and

Table 3 Digestibility (digestible organic matter in the dry matter DOMD), nitrogen (N) and water-soluble carbohydrate (WSC) concentrations in grass snip samples taken before the heifers received their daily allocation of grass in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d.	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
DOMD (g DOM kg^{-1} DM)								
July 2002	714	717	728	722	12·9	0·341	0·824	0·666
September 2002	731	715	703	733	14·7	0·642	0·340	0·088
May 2003	720	737	733	763	15·9	0·128	0·329	0·110
July 2003	689	730	687	678	22·9	0·156	0·123	0·706
September 2003	663	696	696	698	9·6	0·042	0·014	0·846
N (g kg^{-1} DM)								
July 2002	31	25	28	29	3·0	0·866	0·102	0·693
September 2002	38	38	33	45	3·3	0·740	0·995	0·013
May 2003	24	21	28	27	5·7	0·266	0·598	0·833
July 2003	31	34	29	31	3·3	0·266	0·384	0·618
September 2003	36	38	40	39	1·7	0·071	0·274	0·401
WSC (g kg^{-1} DM)								
July 2002	193	220	206	189	22·8	0·622	0·284	0·484
September 2002	131	134	129	112	8·6	0·098	0·799	0·097
May 2003	270	289	266	303	31·9	0·850	0·576	0·294
July 2003	151	149	162	152	11·9	0·460	0·858	0·451
September 2003	131	139	129	140	9·2	0·956	0·389	0·286

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.

Table 4 Daily liveweight gain (kg day^{-1}) from turnout to the end of the grazing season in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Daily liveweight gain (kg day^{-1})								
2002	1·00	1·02	0·99	0·92	0·12	0·151	0·663	0·220
2003	0·96	1·13	1·02	0·96	0·08	0·416	0·091	0·469

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.

ruminating chews (mean 76·6 min^{-1} and 61·8 $bolus^{-1}$). These measurements were undertaken over a relatively long time-scale, with three replicate areas of each variety. It can be concluded, therefore, that the lack of difference in intake characteristics is real, it can be viewed with some confidence and is supported by the animal performance data.

When the same four varieties that were used in the present experiment were grazed continuously by sheep in 1998 and 1999 (Orr *et al.*, 2003), average IR for the 2 years was markedly higher for Glen than Belramo (1555 vs. 1160 mg DM min^{-1}) and for AberExcel than Rosalin (1778 vs. 1218 mg DM min^{-1}). In a subsequent experiment, conducted in 2000, which included three of the varieties (Orr *et al.*, 2004a) IR for similar continuously stocked sheep were 1165, 1089 and 1390 (mg DM min^{-1}) for Glen, Belramo and AberExcel, respectively, i.e. the rankings were similar to the previous sheep data, although these differences were not significant in the latter experiment. However, both animal species (cattle vs. sheep) and grazing management (rotational vs. continuous stocking) changed between this and the previous studies. Therefore, there is a need to identify more closely the mechanisms involved and grass variety evaluations using continuously stocked cattle swards are required in order to separate the effects of defoliation interval from those of grazing style of the different animal species. Nevens and Reheul (2003), in a long-term study, suggested that potential differences between grass varieties were

Table 5 Compressed sward height at the start (IN) and end (OUT) of grazing periods in which grazing and ruminating behaviour was measured over 24 h in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Compressed sward height (cm)								
IN								
July 2002	10·8	13·0	11·9	16·1	1·32	0·075	0·147	0·025
September 2002	10·2	11·5	11·1	9·7	0·69	0·438	0·120	0·103
May 2003	15·9	15·2	15·7	18·4	3·62	0·591	0·871	0·512
July 2003	9·1	10·5	10·3	10·8	1·12	0·396	0·248	0·699
September 2003	8·7	9·5	8·4	9·2	0·68	0·583	0·301	0·265
OUT								
July 2002	6·6	8·0	7·7	8·8	0·48	0·032	0·036	0·074
September 2002	6·0	7·0	6·4	5·6	0·45	0·165	0·079	0·118
May 2003	8·9	7·1	8·6	9·2	0·98	0·238	0·105	0·555
July 2003	5·7	6·3	6·1	6·1	0·57	0·770	0·332	0·902
September 2003	5·9	6·6	5·6	5·3	0·68	0·144	0·328	0·660

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.

Table 6 Leaf mass and the number of tillers per square metre when heifers entered the paddocks at the start of 24-h behaviour recordings in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Leaf mass (kg DM ha^{-1})								
July 2002	1398	1809	1545	1665	209·3	0·990	0·097	0·586
September 2002	1231	1317	1265	1030	160·8	0·308	0·610	0·194
May 2003	1875	2360	2027	1847	425·5	0·570	0·298	0·688
July 2003	1025	1479	1413	1037	260·3	0·889	0·131	0·198
September 2003	902	1345	1120	769	176·1	0·200	0·046	0·093
Number of tillers (1000 m^{-2})								
July 2002	13·1	10·7	9·5	5·4	1·38	0·004	0·140	0·025
September 2002	8·2	9·8	8·7	5·6	1·57	0·141	0·343	0·090
May 2003	8·7	12·3	6·8	5·4	1·15	0·002	0·019	0·247
July 2003	10·6	13·2	8·4	8·2	1·15	0·004	0·069	0·848
September 2003	9·4	8·9	8·4	6·1	2·01	0·227	0·799	0·307

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.

strongly confounded with sward × management interactions.

There are fundamental physiological differences in the way cattle graze compared with sheep. Cattle, generally, use a prehensile tongue to 'sweep' forage into the mouth, whilst sheep rely on a split upper lip and tend to nibble swards. However, sheep can also deal effectively with tall swards (Penning *et al.*, 1994) by inserting their mouth sideways into swards and severing, at a single bite, bunches of long leaves and pseudostems which are gradually drawn into the mouth. While grazing, cattle have a lower total jaw movement rate (e.g. Orr *et al.*, 2004b) than sheep (e.g. Penning *et al.*, 1991), and sheep also have higher proportions of the grazing jaw movements (between one-half and two-thirds) as chews depending on sward height (Penning *et al.*, 1994). Yearling dairy heifers rotationally stocked on perennial ryegrass swards (Orr *et al.*, 2004b) had generally similar total jaw movement rates during the first hour on a new paddock to those in the present experiment. Values were

Table 7 Sheath tube and leaf lengths when heifers entered the paddocks at the start of 24 h behaviour recordings in 2002 and 2003.

	Variety					Level of significance		
	Belramo (d)	Glen (d)	Rosalin (t)	AberExcel (th)	s.e.d	Ploidy	Belramo vs. Glen	Rosalin vs. AberExcel
Sheath tube length (mm)								
Oldest								
July 2002	30	44	32	57	6·3	0·144	0·063	0·008
September 2002	38	42	35	31	5·2	0·106	0·562	0·403
May 2003	60	44	64	87	18·3	0·116	0·426	0·260
July 2003	24	31	40	32	4·6	0·041	0·143	0·127
September 2003	29	43	32	28	6·9	0·267	0·102	0·564
Second oldest								
July 2002	44	58	45	106	15·2	0·065	0·393	0·007
September 2002	50	55	46	47	8·1	0·334	0·577	0·971
May 2003	110	74	120	160	35·5	0·106	0·343	0·304
July 2003	35	45	54	48	5·4	0·026	0·121	0·286
September 2003	36	52	40	38	8·4	0·407	0·106	0·887
Leaf length (mm)								
Oldest FE								
July 2002	81	115	100	143	11·5	0·026	0·023	0·009
September 2002	100	99	93	87	20·3	0·516	0·984	0·772
May 2003	105	96	122	150	32·0	0·165	0·802	0·414
July 2003	62	78	87	72	11·4	0·280	0·209	0·236
September 2003	63	94	75	69	9·2	0·345	0·015	0·552
Second oldest FE								
July 2002	109	160	145	205	10·5	0·002	0·003	0·001
September 2002	126	127	127	142	17·3	0·536	0·960	0·416
May 2003	117	123	151	174	35·8	0·148	0·881	0·547
July 2003	86	105	130	107	19·1	0·139	0·378	0·269
September 2003	84	98	100	103	13·9	0·298	0·359	0·859
Expanding								
July 2002	72	95	93	132	7·6	0·002	0·024	0·002
September 2002	82	81	80	88	9·7	0·737	0·905	0·435
May 2003	68	70	93	92	15·3	0·073	0·881	0·964
July 2003	65	73	84	72	10·5	0·275	0·459	0·333
September 2003	52	71	61	54	8·6	0·523	0·071	0·469

(d) diploid; (t) tetraploid; (th) tetraploid hybrid.
FE, fully expanded.

approximately 93 jaw movements min^{-1} (76–78 bites plus 15–17 chews min^{-1}) compared with 87 jaw movements min^{-1} (67 bites plus 20 chews min^{-1}) measured in the present experiment. The biting and total jaw movement rates measured by Orr *et al.* (2004b), when the dairy heifers entered the new paddock, may have been marginally higher because the grazing periods in that experiment were of 2–3 weeks duration, so the heifers may have been hungrier (Greenwood and Demment, 1988) prior to their next move than in the present study where they moved to a new paddock each day.

Eating time, ruminating time and rumination chewing

Daily intake may be thought of as the product of IR and eating time but, while both of these factors were measured, daily intake was not calculated here because IR was only measured during the first hour of the 24 h that the heifers spent on the paddock. It is very likely that IR declined (McGilloway *et al.*, 1999; Barrett *et al.*, 2001; Orr *et al.*, 2001b) during the grazing period as the swards were grazed down. However, while we cannot be certain that there were no differences between varieties in IR over the whole 24-h grazing period, there were no significant differences in eating time (mean 521 min 24 h^{-1}), or ruminating time (mean 462 min 24 h^{-1}) – apart from significantly higher ruminating time in July 2002 for heifers grazing diploid compared with tetraploid varieties – or the number of rumination chews (mean 78 min^{-1} or 63 $bolus^{-1}$). Furthermore, it is likely that daily intakes were also similar for the four varieties because liveweight gains, which provide a very robust measure of variety performance, were not significantly different (Table 4) between the heifers grazing the four varieties. McCallum and Thomson (1994) also found that ryegrass cultivar had little effect on dairy animal performance when four cultivars were rotationally grazed with dairy calf replacements or cows in a series of tests. In contrast, Hazard *et al.* (1998) found a significant cultivar effect on intake by sheep when two intermediate-heading and two late-heading diploid perennial ryegrass varieties were rotationally grazed. These same four cultivars were rotationally grazed by cows in the following year (Emile *et al.*, 2000) and there were significant effects of cultivar on milk yield which were attributed to sward structure traits such as lamina length, sheath weight and green lamina ratio. These authors identified the need for further investigation of morphological traits which could be used as selection criteria to increase cultivar performance under grazing.

Effects of sward chemical and morphological factors on IR

Differences between grass varieties in IR by sheep have been related in part to sward factors in previous studies (Orr *et al.*, 2003, 2004a). Here, sward chemical and morphological factors (Smith *et al.*, 2001; Gilliland *et al.*, 2002) were also examined to see whether these might provide an explanation of the intake characteristics measured.

In the previous studies (Orr *et al.*, 2003, 2004a) with continuously stocked sheep there was some evidence that, in 1998 but not 1999, IR was positively correlated with nitrogen concentration and digestibility of grass snips (comprising predominantly of live leaves) designed to be representative of the material ingested by the sheep. In those studies, the tetraploid hybrid varieties had high intake characteristics and high nitrogen concentrations in the leaves (Orr *et al.*, 2001a). In the fifteen intermediate-heading varieties examined, WSC concentration was not found to be related to IR under continuous stocking conditions where the diet comprised mainly leaves, rather than sheath and pseudostem which contain higher concentrations of WSC (McGrath, 1988). In the present experiment, there were small effects of ploidy on herbage quality and for the diploid and tetraploid varieties overall mean values were 711 vs. 714 g DOM kg^{-1} DM for digestibility, 32 vs. 33 g N kg^{-1} DM for nitrogen concentration and 181 vs. 179 g WSC kg^{-1} DM for WSC concentration.

Herbage quality is widely assumed to be related to grazing intake, animal performance and protein utilization and increased digestibility has received much attention as a breeding trait (Wilkins, 1997) along with the concentrations of N, WSC and fibre (Wilkins and Humphreys, 2003). Hence, perennial ryegrass breeding programmes have focussed on these quality traits (Beerepoot and Agnew, 1997), along with plant persistence, tolerance to environmental stresses and resistance to pathogens and invertebrate pests. Armstrong *et al.* (1986) harvested herbage from five indigenous hill plant communities and from sown perennial ryegrass and white clover swards, ranging from 371 to 796 g DOM kg^{-1} OM (organic matter digestibility, OMD), which was offered to housed sheep in pens. These authors concluded that digestibility accounted for much of the variation and provided a good general index of potential intake. The range in digestibility (DOMD) values for the fifteen intermediate-heading perennial ryegrass varieties grazed by sheep in the experiment of Orr *et al.* (2001a, 2003) was much more limited (621–736 g DOM kg^{-1} DM) than the range reported by Armstrong *et al.* (1986). The same was true in the present experiment where the range in DOMD values was 663–763 g DOM kg^{-1} DM and there was no correlation between DM IR (measured in the first hour on the new paddock) and the plant and animal factors shown in Tables 1–3 and 5–7 for the three periods in which IR was measured (September 2002, July and August 2003), apart from a positive correlation ($P < 0{\cdot}001$) with DM content of the herbage (range 199–258 g kg^{-1}) in September 2002. Taweel (2004) investigated rumen capacity in dairy cows and screened six perennial ryegrass varieties for their ruminal clearance and degradation rates and concluded there was only a narrow range for selection for these factors. Moreover, feeding high-sugar grass in a comparison with four other varieties did not lead to increased DM intake or milk yield under stall-feeding or daily strip-grazing conditions.

The measurements of sheath tube and leaf lengths provided 'snap-shots' of the plant dimensions at a point in time but are difficult to interpret without information on appearance date of leaves. Sward structure of a variety is likely to change with season and this could result in differences in IR. There were significant differences in some of these attributes and in tiller population density between and within ploidies, which might have been expected to have some influence on intake characteristics, but this was not generally found under rotation grazing with cattle. Hazard and Ghesquiere (1997) found a genotype × management interaction with short-leaved genotypes giving a better yield under frequent cutting than long-leaved genotypes, but the relationship was inverted under infrequent cutting.

Conclusions

It is evident from these and previous results, obtained using the same four intermediate-heading varieties, that perennial ryegrass displays considerable plasticity under different managements. In the experiment reported here (with the exception of a within-diploid comparison in one of three measurement periods), IR were not significantly different between the varieties, nor were eating times. In order to understand further these interactions there is a need to identify more closely the mechanisms involved. As part of this process, grass variety evaluations using continuously stocked cattle swards are required in order to separate the effects of defoliation interval from those of grazing style of the different animal species. Then it will be possible to develop new varieties for grazing use which are matched with appropriate grazing-management recommendations.

Acknowledgments

This work was funded by the Department for Environment, Food and Rural Affairs of England and Wales and was carried out in accordance with the welfare standards approved by IGER's Ethical Review Procedure. IGER is supported by the Biotechnology and Biological Sciences Research Council.

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