Relationships between morphological and chemical characteristics of perennial ryegrass varieties and intake by sheep under continuous stocking management

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Abstract

Plots of five intermediate-heading varieties of perennial ryegrass (*Lolium perenne* L.) [AberDove, Belramo and Glen (diploid); Twins (tetraploid); and AberExcel (tetraploid hybrid)] were continuously stocked with sheep to maintain a target sward surface height of 40–50 mm. Daily dry matter (DM) intake was significantly different (F-value = 0·032) between the varieties, with the tetraploid hybrid AberExcel having the highest values for daily DM intake and intake rate during eating. Amongst the diploid varieties, intake rate tended to be higher for sheep grazing Glen. The varieties comprised a wide range in potential growth habit, from the relatively prostrate, highly tillered Glen to the more-erect AberExcel and there were differences between them in the vertical distribution of leaves within the sward canopy. The leaves of AberExcel weighed 3·6 mg DM cm^{-2} leaf area in contrast to the other varieties (4·3–5·3 mg DM cm^{-2} leaf area) resulting in a high leaf area index (LAI) in relation to the green leaf mass. Intake rate was not significantly correlated with extended tiller and sheath tube lengths, partition of herbage mass, number of tillers per square metre or LAI. However, canonical variates analysis showed that there were significant differences between the varieties for the morphological and chemical factors examined. Other factors also need to be explored to explain these differences in ingestive behaviour in order to identify plant traits that are correlated with herbage intake rate. These are needed for varieties destined for grazing use, both during the breeding programme and their subsequent evaluation.

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Received 29 May 2003; revised 25 January 2004

Keywords: perennial ryegrass, intake, sward morphology, continuous stocking, sheep

Introduction

Orr *et al.* (2003) identified marked differences between perennial ryegrass (*Lolium perenne* L.) varieties in their intake characteristics when continuously stocked with sheep in a 2-year experiment. Compared with the mean in each year, the ranges in values for daily dry matter (DM) intake were proportionately 0·81–1·24 in 1998 and 0·80–1·19 in 1999. Intake attributes are not assessed by UK national testing procedures (Ministry of Agriculture, Fisheries and Food, 1998) for those varieties featured on the Recommended Lists (National Institute of Agricultural Botany, 1998). Evaluation procedures consider yield under simulated grazing management (measured by frequent cutting), mid-season digestibility, ground cover, winter hardiness and disease resistance. Ideally, there is a need for evaluation under grazing but Hazard *et al.* (1998) suggested that the use of animal trials in routine evaluation of grass cultivars under grazing was expensive and time-consuming. They indicated a need to identify morphological traits of cultivars that enhance animal production under grazing (Hodgson, 1985; Baumont *et al.*, 2000) which could be used to evaluate grass cultivars in breeding programmes. Here it is explored whether the differences in grass intake measured by Orr *et al.* (2003) were related to morphological and chemical characteristics (Diaz *et al.*, 2001; Liu *et al.*, 2002) that could be targeted for those varieties destined for use under grazing management (Stone, 1994).

Materials and methods

Sward treatments

The experimental grazing treatments were imposed between 8 March and 9 June 2000 at the Institute of

Grassland and Environmental Research (IGER), North Wyke (50°46′N, 3°56′W).

Five intermediate-heading varieties of perennial ryegrass were chosen from the fifteen that had been sown in September 1997 and grazed by sheep in 1998 and 1999 (Orr *et al.*, 2003) to give a wide range in intake characteristics. The varieties chosen were either diploid (AberDove, Belramo and Glen), tetraploid (Twins) or tetraploid hybrid (*Lolium* × *boucheanum* Kunth) (AberExcel). Fertilizer supplying 40 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} was applied to the swards on 30 March 2000, followed by an application of 40 kg N ha^{-1} on 5 May 2000.

Animals and grazing management

Core groups of three non-pregnant, non-lactating (dry) Welsh Mountain ewes [live weight (s.e. of mean), 33 (0·2) kg] were continuously stocked on the same five replicate paddocks (0·1 ha) of each grass variety that were grazed in 1998 and 1999 (i.e. the third grazing year for each paddock). Each core group comprised one ewe aged 2 years and two ewes aged 3 years.

A target sward surface height (SSH) of 40–50 mm was maintained on each of the twenty-five paddocks using a put-and-take system, with additional ewes added to or removed from the paddocks as required.

Measurements

Morphological measurements

Sward surface height was measured each week using a sward stick (Barthram, 1986), with twenty-five contacts per paddock. Herbage measurements were made on each of the five blocks in succession on 23 and 24 May; 24 and 25 May; 30 and 31 May; 31 May and 1 June; 1 and 2 June. Herbage mass, composition and the number of tillers per square metre were measured within 50 cm × 25 cm quadrats. The herbage was cut to ground level using scalpels and sub-samples of grass were separated into live leaves, live 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 80°C for 20 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.

Extended tiller lengths (ETL) and sheath tube lengths of the youngest and oldest fully expanded live leaves were measured on all the tillers in each subsample (approximately sixty tillers per paddock). LAI (leaf area per unit ground area) was measured by passing leaves from these tillers through a planimeter before they were dried, which allowed dry weights per unit leaf area to be calculated.

The vertical distribution of leaves within the swards was estimated using an inclined point quadrat (IPQ) as described by Grant (1981). This device works by passing a needle from the surface of the sward, at an angle of 32·5°, down to the soil level. This angle was determined (Warren Wilson, 1963) from consideration of the grass foliage angle (inclination of foliage to the horizontal). Turves (10 cm × 20 cm) were cut, taken indoors and placed on a bench where the measurements were made. Twenty-five descents were made on each variety and each contact with leaves was recorded from a graduated scale so that the height above ground level could be calculated by trigonometry.

Daily intake, eating time, intake rate and ruminating time

Grass intake was measured using a modification of the *n*-alkane method of Dove and Mayes (1991). The three core sheep in each paddock were dosed with Captec™ *n*-alkane slow-release devices (FERNZ, Manurewa, Auckland, New Zealand). Following an initial acclimatization period, the boluses were designed to release C_{32}-alkane (dotriacontane) within the rumen at a constant rate between days 8 and 16 after dosing. Eight days after dosing, any spare ewes were removed for 48 h and marked areas (15 m × 2 m) within each paddock were cleared of all faeces. This was done on 23, 25 and 31 May, 1 and 7 June for the five replicate blocks in succession. Faeces samples were collected, from within the cleared areas, 24 and 48 h after clearing. This procedure ensured that only samples from dosed animals were collected.

Herbage samples (snipped samples), designed to be representative of the material eaten, were cut with scissors from the grazed horizon in the top third of the sward (Orr *et al.*, 1997) at the same time as the initial faeces clearance. Mean daily DM intake by the group was calculated from the assayed release rate of C_{32}-alkane (44·9 mg d^{-1}) and the concentrations of C_{32}- and C_{33}-alkane (tritriacontane) in herbage and faeces (Dove and Mayes, 1991).

Jaw movements were recorded over 24 h for one core ewe on each of the twenty-five paddocks, using automatic behaviour recorders (Rutter *et al.*, 1997). Recordings were subsequently analysed using the GRAZE™ software (Rutter, 2000) to distinguish periods of eating, ruminating and idling and thus allow the calculation of eating time (Gibb, 1998). Intake rate during eating was calculated from intake (g DM d^{-1}) and eating time (min d^{-1}). Rumination chews were identified, and the number of chews per minute and per bolus were calculated.

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 ten jaw movements. Jaw movements that did not satisfy these criteria were broadly designated as 'other activities' e.g. drinking, grooming, vocalization, etc. The patterns of meals throughout the day were examined by joining eating bouts with a minimum inter-meal interval of 6 min (Penning *et al.*, 1993) to create grazing bouts as defined by Gibb (1998), which included intra-meal intervals of ≥3 s–6 min duration. Individual rumination bouts associated with the eructation of each bolus were joined using a minimum inter-rumination bout interval of 20 s.

Chemical analyses

The snipped grass samples were analysed for digestibility of 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 group of three core ewes was used as the experimental unit for statistical analysis of animal variables (i.e. all the analyses were based on $n = 25$, with sixteen residual d.f. as the five treatments were allocated to five blocks) as the behaviour and performance of the individuals were not regarded as independent (Rook and Penning, 1991). Data were analysed by one-way analysis of variance with randomised blocks using GENSTAT (GENSTAT, 1987). In addition to the overall effect of variety, the effects of ploidy (diploid vs. tetraploid) and hybridisation (tetraploid vs. tetraploid hybrid) were also examined using orthogonal contrasts (see Tables 1–3). Correlation analyses between ingestive behaviour and plant factors were performed using values for individual plots (i.e. $n = 25$). Canonical variates analysis, using the CVA directive in GENSTAT, was used to find linear combinations of the original variables that maximized the ratio of between-variety to within-variety variation, thereby giving functions of the original variables that could be used to discriminate between the varieties. The CVAPLOT procedure was then used to plot the mean scores of the first two latent vectors of the canonical variates analysis and to display 95% confidence limits. Dendrograms were plotted of levels of similarity between the varieties using

Table 1 Grass morphology and chemical composition for diploid and tetraploid perennial ryegrass varieties continuously stocked with sheep.

	Diploid			Tetraploid			*F* probability		
	AberDove	Belramo	Glen	AberExcel†	Twins	s.e.d.	Overall	Ploidy	Hybridisation
Morphological factors									
SSH (mm)	46·7	48·9	45·2	45·1	45·4	2·62	0·579	0·332	0·928
ETL (mm)	54·3	50·8	50·4	61·6	52·0	4·71	0·171	0·129	0·062
ETL:SSH ratio	1·16	1·04	1·12	1·37	1·15	0·104	0·169	0·126	0·111
Sheath tube length (mm)									
Oldest fully expanded live leaf	14·7	15·2	13·8	16·6	13·3	2·32	0·647	0·827	0·171
Youngest fully expanded live leaf	23·8	25·0	20·7	28·4	20·2	3·61	0·195	0·619	0·037
Leaf mass (kg DM ha^{-1})	1321	905	1307	1216	1242	176·4	0·169	0·655	0·882
Pseudostem (kg DM ha^{-1})	1289	1151	1046	1109	872	156·7	0·159	0·109	0·149
Leaf:pseudostem ratio	1·05	0·78	1·30	1·15	1·41	0·181	0·027	0·056	0·163
Tillers (in thousands m^{-2})	39·7	31·1	43·2	31·1	25·7	7·18	0·149	0·055	0·461
Leaf weight (mg DM cm^{-2} leaf area)	4·4	4·6	4·3	3·6	5·3	0·65	0·172	0·950	0·017
Leaf area index	3·1	2·0	3·2	3·5	2·6	0·73	0·292	0·521	0·217
Chemical factors									
WSC (g kg^{-1} DM)	213	177	193	186	249	19·0	0·012	0·077	0·004
DOMD (g DOM kg^{-1} DM)	735	711	720	719	745	7·4	0·002	0·047	0·003
Nitrogen (g kg^{-1} DM)	40	40	38	44	37	2·6	0·138	0·681	0·017

†Hybrid.

DM, dry matter; DOMD, organic matter in the DM; ETL, Extended tiller length; SSH, Sward surface height; WSC, water-soluble carbohydrate.

Table 2 Daily intake, eating time and intake rate for sheep continuously stocked on diploid and tetraploid ryegrass varieties.

	Diploid			Tetraploid			*F* probability		
	AberDove	Belramo	Glen	AberExcel†	Twins	s.e.d.	Overall	Ploidy	Hybridisation
Daily intake (g DM ewe^{-1})	603	765	734	904	616	93·4	0·032	0·345	0·007
Eating time [min (24 h)$^{-1}$)	616	707	642	664	628	61·6	0·619	0·818	0·576
Intake rate (mg DM min^{-1} eating)	978	1089	1165	1390	1004	188·8	0·239	0·340	0·057
Number of meals (24h^{-1})	7·4	5·8	7·2	7·6	7·2	1·60	0·810	0·571	0·806
Meal duration (h)	1·73	2·43	1·67	1·85	1·69	0·484	0·503	0·592	0·747

†Hybrid.

Table 3 Ruminating time, number of boluses per 24 h, chews per 24 h, chews per minute and chews per bolus for sheep continuously stocked on diploid and tetraploid ryegrass varieties.

	Diploid			Tetraploid			*F* probability		
	AberDove	Belramo	Glen	AberExcel†	Twins	s.e.d.	Overall	Ploidy	Hybridisation
Ruminating time (min 24 h^{-1})	332	387	304	350	278	47·7	0·242	0·397	0·154
Number of boluses (24 h^{-1})	451	489	418	470	422	54·6	0·650	0·844	0·390
Ruminating chews (24 h^{-1})	26047	30937	24561	29536	21348	5412·4	0·429	0·625	0·150
Ruminating chews (min^{-1})	77·1	79·6	80·0	83·4	74·8	6·74	0·764	0·971	0·221
Ruminating chews (bolus^{-1})	56·7	63·6	57·9	62·5	48·9	7·33	0·322	0·443	0·082

†Hybrid.

hierarchical clustering procedures in GENSTAT. The IPQ data were analysed by fitting asymmetrical s-shaped curves for each paddock and from analysis of variance on the inflection points and upper asymptotes.

Results

Morphological traits

Mean sward surface height (Table 1) when the measurements of intake were made was within the target range of 40–50 mm for all five varieties. Within the tetraploid varieties, extended tiller length tended to be greater ($P = 0{\cdot}062$) for AberExcel (hybrid) than Twins. The ratio of extended tiller length to sward surface height, along with sheath tube lengths of the oldest and youngest fully expanded live leaves, tended to be greater for AberExcel than the other varieties but these trends were not significant between the five varieties. Within the tetraploid varieties, the length of the sheath tube of the youngest fully expanded leaf was greater ($P = 0{\cdot}037$) for AberExcel than Twins (28·4 mm vs. 20·2 mm) at the same sward surface height.

The mean number of IPQ leaf contacts in each horizon is shown in Figure 1. Above 40 mm from the root–shoot interface, the variety AberExcel, in particular, together with the Glen and AberDove varieties, had more contacts than the Twins and Belramo variety. The variety Glen tended to have most leaf contacts in total and the variety Belramo had the least, but these effects were not significant.

Leaf and pseudostem masses, and the number of grass tillers per square metre, were not significantly different between the five varieties, although Belramo had a much lower green leaf mass (Table 1). Leaf:pseudostem ratios were significantly different ($P = 0{\cdot}027$) between the five varieties and tended to be higher ($P = 0{\cdot}056$) for the tetraploid than the diploid varieties.

The swards were all very highly tillered, particularly the diploid variety Glen, as a result of the continuous stocking management with sheep. Comparing the effects of ploidy, the diploid varieties tended ($P = 0{\cdot}055$) to have greater numbers of tillers per square metre than the tetraploid varieties. Within the tetraploid varieties, the leaves of AberExcel had significantly lower ($P = 0{\cdot}017$) weights per unit leaf area than Twins (3·6 mg DM cm^{-2} vs. 5·3 mg DM cm^{-2}). This resulted in the variety AberExcel tending to have a high LAI in relation to the green leaf mass.

Chemical composition

There were significant differences between varieties (Table 1) in water-soluble carbohydrate concentration ($P = 0{\cdot}012$) and DOMD value ($P = 0{\cdot}002$) but not in N concentration. The tetraploid varieties had significantly higher DOMD values ($P = 0{\cdot}047$) than the diploids and, within the tetraploid varieties, Twins had a significantly

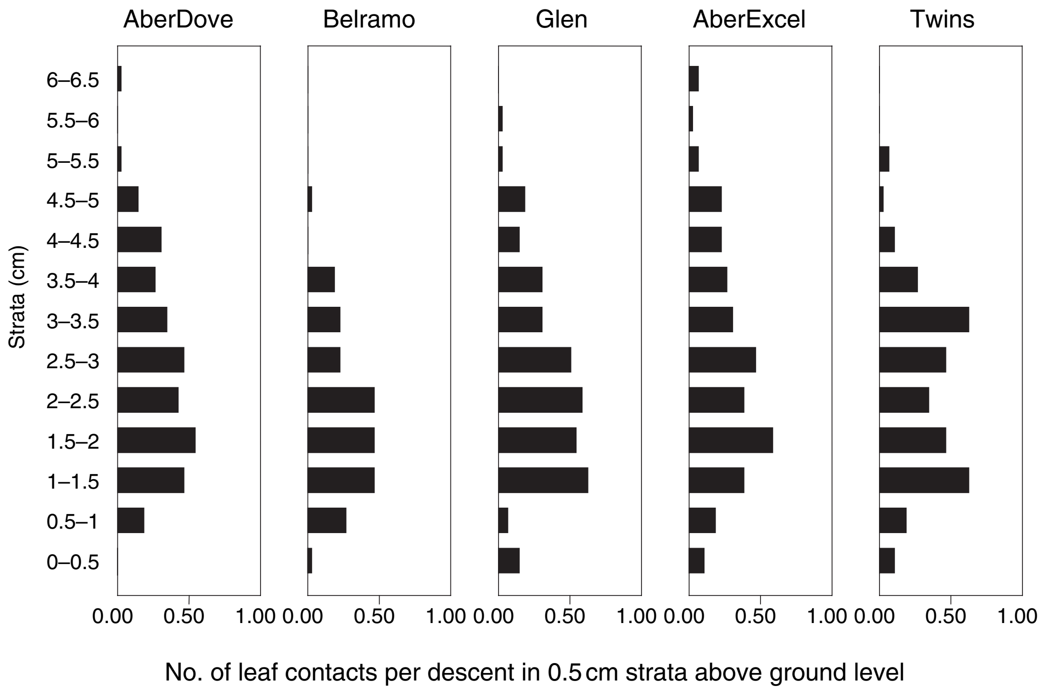

Figure 1 Number of leaf contacts per descent in 0.5 mm strata above ground level for perennial ryegrass varieties grazed by sheep.

higher DOMD value ($P = 0{\cdot}003$), higher WSC concentration ($P = 0{\cdot}004$) and lower N concentration ($P = 0{\cdot}017$) than AberExcel.

Daily intake, eating time and intake rate

Daily DM intake (Table 2) was significantly different ($P = 0{\cdot}032$) between the varieties. Within the tetraploid varieties daily intake was higher ($P = 0{\cdot}007$) for ewes grazing AberExcel than for those grazing Twins, and intake rate also tended to be higher ($P = 0{\cdot}057$). Eating time was not significantly different between the five varieties [mean: 652 min (24 h^{-1})]. Examination of the patterns of meals for individual ewes made on each of the five replicate paddocks for each variety indicated that most of the grazing occurred between sunrise (05:00 h) and sunset (21:45 h). Whilst the number of meals per day tended to be lower on the variety Belramo and the meal duration tended to be greater than on the other varieties, these were not significant (Table 2).

Ruminating time, boluses and chews

The variety Belramo tended to have the highest values for all the aspects of rumination behaviour (except rumination chewing rate) shown in Table 3 and the variety Twins had the lowest values (except for the number of boluses per 24 h, for which the value was close to that for the variety Glen which was the lowest), but these differences were not significant. The period following sunset (and the cessation of the evening meal) until approximately 09:00 h was characterized by alternating bouts of rumination and rest on all five varieties. There was some further processing of ingested grass interspersed between eating bouts, particularly in the late morning/early afternoon period, but the period before sunset (approximately 4 h) was mainly occupied by eating.

Canonical variates analysis

The canonical variates analysis for the plant factors are summarized in Figure 2a where the mean scores for latent vector 1 and latent vector 2 are plotted, along with the 95% confidence limits. The plant factors included were those listed in Table 1. The variation accounted for by latent vectors 1, 2 and 3 was 62·7, 28·5 and 5·6% respectively. The analysis clearly separated the tetraploid varieties from the diploid varieties. AberExcel differed from the other varieties in latent vector 1 score, which had a high loading for leaf:stem ratio and N concentration. Twins differed from the other varieties in latent vector 2

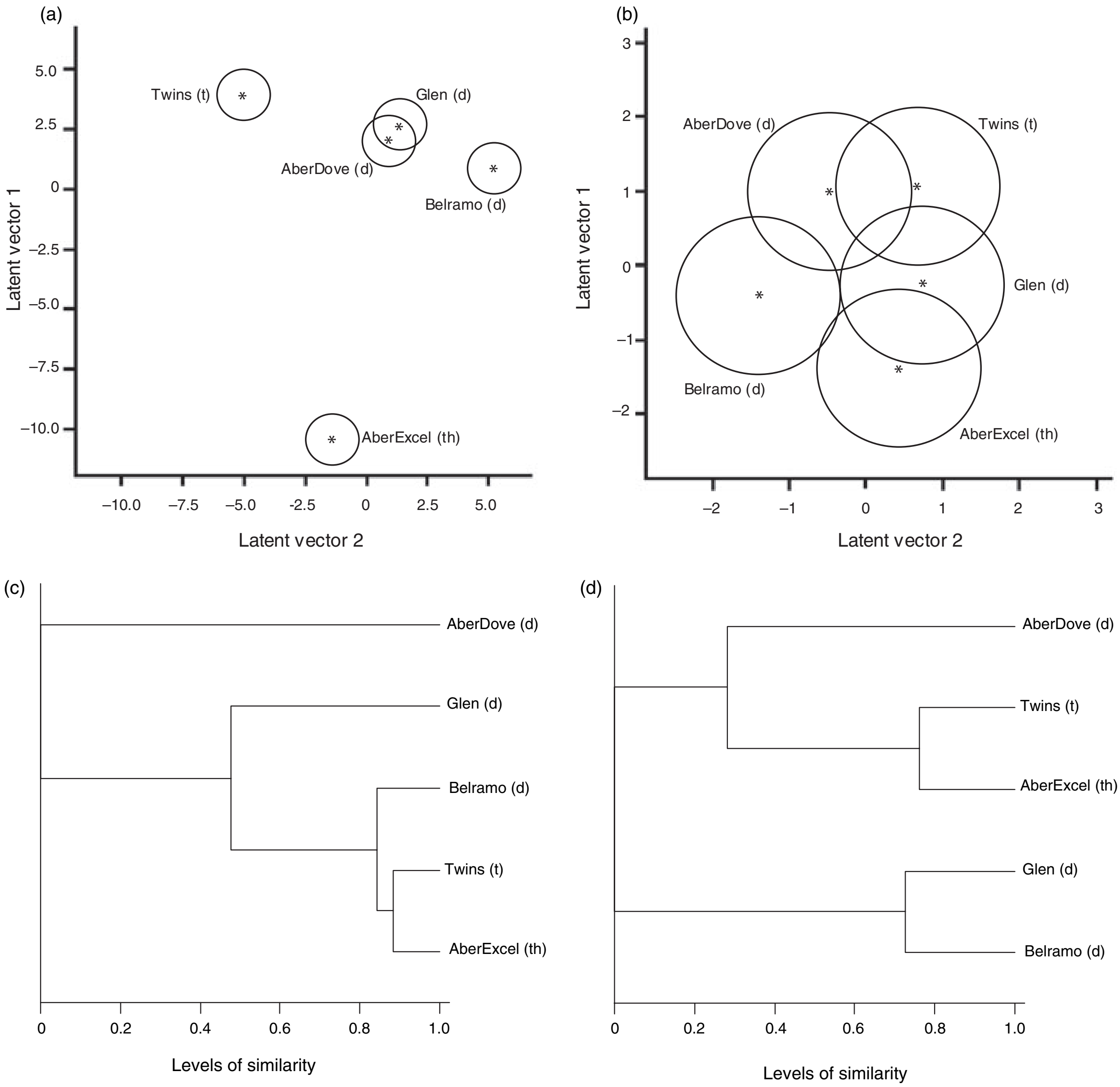

Figure 2 Canonical variates plot of (a) combined plant morphological factors: sward surface height, extended tiller length, sheath tube lengths for the oldest and youngest fully expanded live leaves, total, green leaf and pseudostem masses, leaf:pseudostem ratio, number of tillers per square metre, leaf area index, leaf weight, digestibility (DOMD), nitrogen and water-soluble carbohydrate concentrations; (b) combined ingestion and rumination factors: intake rate, daily intake, eating and ruminating times, rumination chews per minute and per bolus. Dendrograms showing levels of similarity between varieties for (c) morphological factors and (d) ingestion/rumination factors. '*', mean score for each variety; '○' indicate 95% confidence regions. d, diploid; t, tetraploid; th, tetraploid hybrid varieties.

score, which had a high loading for LAI and leaf weight per unit leaf area. Leaf:stem ratio also had a high loading for latent vector 3 (not shown in Figure 2).

The canonical variates plot of animal factors related to ingestion and rumination are shown in Figure 2b. The separation between the varieties was not as marked as for the plant factors (Figure 2a). The variation accounted for by latent vectors 1, 2 and 3 was 52·7, 41·9 and 3·9% respectively. Daily DM intake had the highest loading for latent vectors 1 and 2. Intake rate had a high loading for latent vector 2.

The dendrogram of plant factors, using information on all latent vector dimensions available, is shown in Figure 2c. As might be expected, there were close similarities between Twins and AberExcel, the tetraploid varieties. There were lesser similarities between these varieties and Belramo and Glen. AberDove did not cluster with the other varieties for plant factors. This diploid variety was only clustered with the two tetraploid varieties for animal factors (Figure 2d) at a low level of similarity. Glen and Belramo (diploids) were clustered for animal factors, as were Twins and Excel (tetraploids).

Correlations between plant and animal factors

Intake rate was not correlated with sward height, mass, sheath tube lengths or the other sward measurements shown in Table 4. Daily DM intake was not significantly correlated with eating time but was correlated with intake rate ($r = 0{\cdot}86$; $P < 0{\cdot}001$). This was to be expected as intake rate was calculated from daily intake, but the lack of correlation with eating time is worth noting.

Ruminating time was positively correlated with N concentration in grass ($r = 0{\cdot}45$; $P < 0{\cdot}05$) and negatively correlated with WSC concentration ($r = -0{\cdot}53$; $P < 0{\cdot}05$). Concentrations of WSC and N in herbage were negatively correlated ($r = -0{\cdot}82$; $P < 0{\cdot}001$).

Discussion

Morphological factors

Continuous stocking with sheep to maintain the SSH within target guidelines was intended to optimise sward and animal performance (Parsons, 1984) when the swards became adapted to this management (Penning *et al.*, 1991) in terms of tillering and leaf mass. The five varieties embraced a wide range in growth habit from the relatively prostrate, highly tillered Glen to the more-erect tetraploid hybrid AberExcel. In the present experiment, when all the swards were managed to maintain a SSH of 40–50 mm, there were still contrasts in leaf:pseudostem ratio (Table 1). Swift *et al.* (1993) compared a late-heading diploid (Contender) with a tetraploid (Condesa) perennial ryegrass variety under continuous stocking with ewes and lambs and measured tiller densities of 17 900 and 12 200 tillers m^{-2}, respectively, on average over 3 years. Mean values in May for diploid and tetraploid varieties in the current experiment were somewhat higher at 38 000 and 28 400 tillers m^{-2} respectively. Tillering will be affected by management and environmental constraints (Neuteboom and Lantinga, 1989; Gautier *et al.*, 1999) but, while there may be some overlap in the number of tillers per square metre for individual diploid and tetraploid varieties at points in time during the grazing

Table 4 Correlation matrix showing relationships between intake rate and sward parameters.

	ir													
SSH	0·28	SSH												
ETL	0·16	0·37	ETL											
Old	0	0	0·61	Old										
Young	0·13	−0·08	0·59	0·81	Young									
Mass	−0·08	0·40	0·44	0·16	0·04	Mass								
Leaf	0·09	0·36	0·38	−0·22	−0·17	0·78	Leaf							
Stem	0·06	0·34	0·52	0·51	0·49	0·68	0·32	Stem						
l:s ratio	0·05	0·04	−0·08	−0·62	−0·54	0·08	0·59	−0·57	l:s ratio					
Tillers	0·13	−0·28	−0·17	0·02	0·12	0·38	0·28	0·43	−0·14	Tillers				
LAI	0·18	0·41	0·61	0·16	0·11	0·76	0·84	0·38	0·40	0·18	LAI			
Leaf wt	−0·16	−0·22	−0·50	−0·41	−0·33	−0·42	−0·29	−0·29	0	−0·07	−0·72	Leaf wt		
DOMD	−0·28	0·01	−0·21	−0·56	−0·65	−0·08	0·18	−0·46	0·56	−0·40	−0·07	0·32	DOMD	
N	0·25	0·37	0	−0·13	0	−0·15	0	−0·13	0·11	−0·24	0·07	−0·06	0·10	N
WSC	−0·32	−0·34	0	−0·14	−0·23	0·06	0·08	−0·17	0·23	−0·12	−0·09	0·19	0·39	−0·82

$|r| > 0{\cdot}43$, $P < 0{\cdot}05$; $|r| > 0{\cdot}55$, $P < 0{\cdot}01$; $|r| > 0{\cdot}67$, $P < 0{\cdot}001$.

ir, intake rate (mg DM min^{-1} eating); SSH, sward surface height (mm); ETL, extended tiller length (mm); old and young, sheath tube lengths for the oldest and youngest fully expanded live leaves (mm); mass, weight of dry matter; leaf, weight of green leaves; stem, weight of pseudostems (kg DM ha^{-1}); l:s, leaf weight:stem weight ratio; tillers, number of tillers per square metre; LAI, leaf area index (leaf area per unit ground area); leaf wt, (mg DM cm^{-2} leaf area); DOMD, digestibility (g DOM kg^{-1} DM); N, nitrogen concentration (g kg^{-1} DM); WSC, water-soluble carbohydrate concentration (g kg^{-1} DM) for sheep grazing perennial ryegrass varieties (19 d.f.).

season, it is generally the case that tiller density tends to be higher for diploid varieties than for tetraploids (Smith *et al.*, 2001). Previously, Orr *et al.* (2003) found that the mean tiller densities over the grazing season for perennial ryegrass varieties grazed by sheep in 1998 and 1999 were 24 000 (diploids), 17 800 (tetraploids) and 17 100 tillers m^{-2} (tetraploid hybrids). A feature of the hybrid varieties is the influence of Italian ryegrass (*Lolium multiflorum* L.) and its inherent early season growth combined with the sward density attributes of perennial ryegrass.

Stratified clipping methods for measuring the vertical distribution of herbage mass were described by Barthram *et al.* (2000). Schulte and Lantinga (2002) suggested structure was an important feature affecting grazing. They modelled sward vertical structure and predicted the leaf profile and lamina density profile of perennial ryegrass from the average leaf length, the sheath tube length and either herbage mass or LAI. Barthram and Grant (1984) suggested that the different frequencies of grazing of the different classes of laminae in perennial ryegrass swards grazed by sheep could be interpreted as being a function of their frequency of occurrence within the grazed layer at the top of the sward. Orr *et al.* (2004) measured intake and plant factors every 2–3 d for rotationally stocked yearling dairy heifers grazing down perennial ryegrass pastures over two to three weekly periods. Sheath tube and leaf length measurements appeared to be useful traits that could be used to breed plants more suitable for grazing animals, i.e. to take account of intake characteristics. Bite mass was correlated with the lengths of the second and third oldest live leaves, along with the sheath tube length of the third oldest leaf as the swards were grazed down. Leaf lengths were not measured in the current experiment and intake rate was not correlated with sheath tube lengths in the continuous stocking conditions where sward state remained constant.

Chemical factors

There were significant differences between varieties in DOMD and WSC concentration (Table 1). Data have been reported previously on DOMD and N concentration in grass snips (Orr *et al.*, 2001) and on WSC concentration (Orr *et al.*, 2003) for these five varieties when grazed by sheep under continuous stocking management in 1998 and 1999. The highest mean N concentrations in grass snips taken over the grazing season were measured in AberExcel in 1998 and 1999 (45·1 g N kg^{-1} DM), with the second highest levels in Storm (44·4 g N kg^{-1} DM), which is also a tetraploid hybrid. This suggests that high N concentration of the herbage in the grazed horizon is a feature of tetraploid hybrid varieties in swards continuously stocked with sheep.

Concentrations of WSC were highest in 1998 and 1999 for AberDove (Orr *et al.*, 2003), a variety which had been bred for this characteristic. Mean WSC concentrations in that experiment were 116·4 (diploids), 127·5 (tetraploids) and 115·1 g kg^{-1} DM for tetraploid hybrids. Smith *et al.* (2001) examined WSC concentrations in diploid perennial ryegrass varieties and tetraploids that had been derived from them and concluded that the effect of tetraploidy was dependent on the genetic background of the diploid cultivars. It was not beneficial when it was imposed on cultivars which had the genetic potential for increased WSC accumulation but tetraploidy increased the WSC concentration when derived from a diploid cultivar with standard WSC concentration. Effects of ploidy were also evident in the current experiment (Table 1) where the highest concentration of WSC was measured in the tetraploid variety Twins, which also had high WSC concentrations in the previous experiment. Lee *et al.* (2001) measured higher lamb liveweight gains when ewes and their single lambs were continuously stocked on AberDove compared with AberElan (lower WSC concentration) and the former variety had a significantly higher *in vitro* DOMD. Rotationally stocked animals, consuming a higher proportion of pseudostem in their diet, may show a higher level of performance when grazing high WSC varieties because of the greater concentration of WSC in sheath and pseudostem than laminae (McGrath, 1988; Miller, 2001).

In summary, there was evidence of significant differences in some of the morphological and chemical attributes of these contrasting varieties of perennial ryegrass.

Identifying grass morphological and chemical traits correlated with ingestion and rumination

Glen and Belramo were chosen from the nine diploid varieties available, to represent high and low intake potential, respectively, as measured in 1998 and 1999 (Orr *et al.*, 2003). Similarly, AberExcel and Twins were chosen from the six tetraploid varieties available. Daily DM intake for the variety Belramo in the present experiment was surprisingly high compared with values for 1998 and 1999 (Orr *et al.*, 2003). However, intake rate for the variety Belramo was lower than for the variety Glen in May 2000. In this experiment, the ewes grazing Belramo tended to have fewer meals of longer duration (Table 2) and the DOMD of the herbage, as indicated above, tended to be low. Ewes grazing AberExcel had consistently high daily intakes, both previously and in the current experiment, and this led previously to significantly higher animal performance (Orr *et al.*, 2003) when measured over two 8-month grazing seasons. The current experiment was relatively short-term and so no animal performance data are presented here. Amongst the diploid varieties, Glen tended to have the highest intake rate per minute eating. This suggests two possible approaches which can be used to ensure the acceptability of perennial ryegrass to grazing animals. One strategy is to use prostrate diploid types with a high tiller density; another is to use more-erect tetraploid or tetraploid hybrid types with a lower tiller density. It would seem that both types may have high intake characteristics under continuous stocking management with sheep, depending on the variety chosen. The varieties AberExcel, Glen and AberDove had more leaf above 40 mm from the root–shoot interface and tended to have higher LAI values than the varieties Belramo and Twins at the same SSH. However, whilst these may be considered to be desirable attributes and there were significant differences in some aspects of sward morphology and chemistry, plant factors examined here were not correlated with intake rate.

Conclusions

In the UK, most perennial ryegrass varieties are sown in mixtures to give a blend of complementary attributes (e.g. heading dates, life expectancy and ground cover). However, this does not currently include intake characteristics despite the fact that most swards will be grazed for at least part of the year. Daily DM intake was significantly different between the five contrasting perennial ryegrass varieties examined in this study suggesting that there is considerable scope for breeding improved varieties for grazing. Intake rates were not related to the morphological and chemical measures made in this study and other factors need to be explored to identify plant traits that are correlated with herbage intake. These are needed for varieties destined for grazing use, both during the breeding programme and during subsequent evaluation.

Acknowledgments

We thank Sue Rodway-Dyer and Sue Simmons for assistance with the collection and processing of the data. This work was funded by the UK Department for Environment, Food and Rural Affairs and was carried out in accordance with the welfare standards approved by IGER's Ethical Review Procedure. IGER is supported by the UK Biotechnology and Biological Sciences Research Council.

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