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Nutritive value of willow (*Salix* sp.) for sheep, goats and deer

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SUMMARY

Voluntary intake and apparent digestibility of tree willow (*Salix matsudana* × *alba*) and of osier willow (*Salix viminalis*) were measured with male sheep and goats and voluntary intake only with male deer. Both willow species had been selected for extremely rapid growth, and were grown in coppices on high fertility soil. In a first experiment spring primary growth of both willows was fed to sheep, goats and deer in early summer, whilst in a second experiment summer regrowth (i.e. secondary growth) of osier willow was fed to sheep and goats in autumn.

Although the ratio of readily fermentable to structural carbohydrate (0·51–0·70) and total N concentration (18–24 g/kg D.M.) in primary growth of the willows was less than normally found in high quality fresh temperate forages, the values were similar to those of many dried forages normally used as supplements. Averaged over sheep and goats, voluntary intake of digestible D.M. was 22% less for osier than for tree willow, this being associated with higher concentrations of lignin (197 *v.* 182 g/kg D.M.) and of condensed tannin (66 *v.* 29 g/kg D.M.) in the osier willow. The lower digestible dry-matter intake was attributable to both lower voluntary intakes and lower digestibility of the D.M. (0·57 *v.* 0·64). Both voluntary intake and apparent digestibility of secondary growth willow were lower than that of primary growth.

When expressed as functions of the amount required for maintenance, voluntary metabolizable energy intake of goats was approximately double that of sheep, both for primary growth (2·2 *v.* 1·1) and for secondary growth (1·8 *v.* 0·7) willow. This was attributable to consistently higher voluntary D.M. intakes/kg $W^{0·75}$ by goats, and to a trend for higher digestibility than sheep, which attained significance in Expt 2 but not in Expt 1. The ratios of dry-matter intake/kg $W^{0·75}$ per day for sheep:deer:goats fed primary growth willow were 1·0:1·5:1·9, with deer thus being intermediate between the other two species. There were no differences in voluntary intake (g/kg $W^{0·75}$ per day) of sheep, goats and deer fed a high quality lucerne hay.

It was concluded that willows grown during spring and summer could adequately be used as supplementary feed during summer droughts and that willow could be used most effectively if fed to goats, followed by deer, with sheep being the least efficient. Tree willow is a preferred choice to the osier willow used here, and it was further concluded that like *Lotus pedunculatus*, high concentrations of lignin and condensed tannin, both of which are produced by the same biochemical pathway, are likely to be limiting nutritive value of the more leafy osier willow.

INTRODUCTION

Both the goat and deer industries in New Zealand (NZ) have expanded rapidly in recent years in response to increased demand for mohair and cashmere, and for venison production. Studies by Gihad, El-Bedawy & Mehrez (1980); Wilson (1977); Gamble & MacIntosh (1981); Watson & Norton (1982); Alam, Poppi & Sykes (1983, 1985); and Doyle, Egan & Thalen (1984), suggest that while there is no difference between goats and sheep in voluntary intake (per unit metabolic body size) and digestion of good quality feeds, goats have a greater digestive ability on low quality feeds. Such feeds are high in fibre and/or low in nitrogen (< 10 g/kg D.M.). It appears that red deer have a lower digestive ability and shorter mean retention time than sheep (Kay & Goodall, 1976; Milne *et al.* 1978). Accordingly intakes are greater for deer than for sheep. Deer have a pronounced seasonal pattern of voluntary intake, with maximum values in summer and minimum values in winter (Kay & Staines, 1981; Milne, 1980; Kay, 1985), thus the differences between the two species is greatest when the deer's appetite is at its maximum.

In NZ, deer and goat production systems have been implemented along similar lines to sheep production systems using grazed ryegrass–clover pastures. Thus all three face common limitations in the ability of grazed ryegrass–clover pastures to meet feed demand at certain times; in parts of NZ production can be restricted by regular droughts during the January–March (i.e. summer) period. In response to this, there has been a recent increase in the use of small trees and shrubs as animal feeds, particularly during summer droughts. The aim is to build a bank of feed in spring which will continue to grow and remain green when pastures have succumbed to water stress, and which is of reasonable nutritive value to ruminants. Objectives of the present study were to measure the nutritive value of two species of willow for ruminants, and to see whether goats and deer could utilize these fibrous feeds more efficiently than sheep.

MATERIALS AND METHODS

Two experiments were conducted, with Expt 1 measuring the nutritive value of two types of willow (osier and tree) by sheep, goats and deer; Expt 2 measured the nutritive value of osier willow only by sheep and goats.

Diets

Experiment 1

Lucerne hay (*Medicago sativa*) was chaffed into 30–70 mm lengths and fed to all animals for an initial period of 14 days. The two willow species, *Salix matsudana* × *alba* 'Wairakei' (tree willow) and *Salix viminalis* 'Gigantea' (osier willow) were grown at the Ministry of Works and Development Soil Conservation Centre, Aokautere in Manawatu fine sandy loam soil under high fertility conditions. They were established in 0·4 ha coppiced areas in August 1980, with plant spacing of 0·25 m within rows and 1·25 m between rows. Both cultivars had been selected for extremely rapid growth characteristics. Each winter the plants were cut back to near ground level. In September 1985 they were mowed to a height of 100 mm and sprayed with fungicide.

At harvesting in January 1986, the plants were about 1·5–2·0 m high, at an immature to pre-bloom stage of maturity. Leaf and stem material of less than 5 mm diameter was harvested daily by hand, guillotined into segments of 50–100 mm length, and fed fresh to the animals each day. The material fed was thus primary growth of willow, grown in spring and fed in summer.

Experiment 2

The area of osier willow cut in January 1986 was alllowed to regrow during the summer and was harvested for animal feeding again in autumn (April 1986) when it was approximately 0·75 m high. Harvesting was completed just before the lower leaves turned yellow, prior to the autumn leaf fall. Harvesting of this secondary (i.e. summer) growth material was as described for Expt 1.

Animals

Six castrated Romney male sheep, six castrated Angora × Feral male goats and six entire male red deer aged 14–19 months were used in Expt 1. Castrated male sheep and goats aged approximately 20 months were used in Expt 2. Prior to the start of each experiment all animals were drenched to remove any internal parasites (Nilvern, Coopers Animal Health (NZ) Ltd). The sheep and goats were housed in metabolism crates, whilst the deer were kept in concrete and wire netting pens of approximately 6 m^2. Water was freely available to all animals.

Experimental design

Experiment 1

Voluntary intake of lucerne hay was first measured, with the objective of using this as a covariate for analysing the voluntary intake of willows. Beginning on 6 January 1986, animals were fed on chaffed lucerne hay for 2 weeks. Animals were offered the hay *ad libitum*, with that offered being 1·15 of the previous day's dry-matter intake. Sheep and goats were fed twice daily at about 09.00 and 16.00 h; deer were fed once daily at about 11.00 h. Voluntary intake was measured in the last 7 days, once intakes had stabilized.

Each of the two willow species was randomly allocated to three animals of each species. During the 2-week willow-feeding period, animals were offered the fresh material *ad libitum*, with that offered being 1·3 of the previous day's dry-matter intake. Sheep, goats and deer were fed twice daily at about 12.00 and 18.00 h. Feeding was in the afternoon because it took all morning to harvest, guillotine and weigh out the day's feed. The higher level of residue was adopted, to try to ensure that all animals ate similar diets. At lower levels of feeding, leaves were observed in the residues of goats but not of sheep. Feed offered was therefore increased to 1·3 of the previous day's intake, which resulted in residues of all the animal species containing some leaf and being of similar appearance.

Voluntary intake of willows was measured in the last 9 days and digestibility was measured, for goats and sheep only, in the last 8 days, with faeces being collected using a bag and harness. During the digestibility period, all faeces were collected daily and bulked for each animal at 4 °C.

All animals were weighed, after a 24 h fast, immediately before and at the end of the period of willow feeding, with the deer first being lightly

tranquillized (Rompun; Bayer NZ Ltd). The mean of these weights for each animal was used in the calculation of intake per unit metabolic size (kg $W^{0.75}$) and per unit live weight (kg $W^{1.0}$).

Experiment 2

Six sheep and six goats were fed chaffed osier willow in Expt 2. After 2 days of initially feeding on lucerne hay, the animals were changed to willow and maximum voluntary intake had been achieved after a further 6 days. Voluntary intake and apparent digestibility were then measured over the next 6 days as described in Expt 1. Two of the sheep completely refused to eat this secondary growth willow, and had to be excluded from the experiment.

Sampling procedures

Duplicate samples of feed and residues were taken daily and dried at 100 °C for 20 h to determine dry-matter proportion; subsamples of pooled faeces were dried for 48 h. During the measurement periods for voluntary intake and digestibility, duplicate samples of feed and residue were also taken each day and pooled at −20 °C. These samples, together with subsamples from the bulked faeces, were then freeze-dried and ground through a 1 mm screen, before being used for laboratory analyses. Unfortunately, owing to an oversight in Expt 1, the residue samples were discarded and so digestibility could not be determined for organic matter, energy and fibre. Consequently, only feed samples were analysed for these constituents in this experiment.

Laboratory analyses

Freeze-dried samples were analysed for organic matter by ashing for 18 h at 500 °C, for heat of combustion by adiabatic bomb calorimetry, for total nitrogen by the Kjeldahl method, and for individual carbohydrate constituents by the fractionation procedure of Bailey (1967). Condensed tannins were determined by the vanillin HCl procedure (Broadhurst & Jones, 1978). Fresh material was used for condensed tannins analyses, which was then pulverised in liquid N, before extraction of the tannins with acetone: water (70:30).

Statistical methods

Experiment 1 was analysed as a 3 × 2 factorial, with three species of animal and two species of willow. In the analyses involving voluntary intake of dry matter and digestible dry matter, voluntary intake of lucerne dry matter was used as the covariate. The covariate had the effect of lowering the error mean square, and, therefore, of increasing the precision with which treatment effects could be estimated. As none of the

Table 1. *Chemical composition (g/kg* D.M.) *and leaf:stem distribution (proportion total* D.M.) *of the feeds offered*

	Experiment 1			Experiment 2
	Lucerne hay (*Medicago sativa*)	Osier willow (*Salix viminalis*)	Tree willow (*Salix matsudana* × *alba*)	Osier willow (*Salix viminalis*)
		Chemical composition		
Dry matter (g/kg wet matter)	868	321	299	376
Organic matter	911	924	904	940
Soluble carbohydrate (*A*)	60	94	78	ND
Pectin (*A*)	51	44	48	ND
Hemicellulose (*B*)	71	67	66	78
Cellulose (*B*)	216	134	184	129
Ratio (*A*/*B*)*	0·39	0·69	0·50	ND
Lignin	105	197	182	202
Total cell wall	392	398	432	409
Nitrogen	31·2	24·3	17·8	19·3
Gross energy (MJ/kg D.M.)	18·61	19·69	19·04	19·45
Condensed tannin	ND	66	29	ND
		Leaf:stem distribution		
Leaf		0·77	0·60	ND
Small stem (< 3 mm)		0·01	0·14	ND
Large stem (3–5 mm)		0·22	0·26	ND

* Readily fermentable carbohydrate/structural carbohydrate.
ND, not determined.

Table 2. *Experiment* 1. *Voluntary intake and digestibility of dry matter in spring primary growth willow by sheep, goats and deer*

		Sheep	Goats	Deer	S.E.
Mean live weight	(kg)	49·6	32·4	89·3	2·41
Lucerne hay					
Voluntary intake	(kg per day)	1·29	0·99	2·19	0·083
	(g/kg W per day)	26·2	30·7	24·6	2·09
	(g/kg $W^{0·75}$ per day)	69·4	73·0	75·4	5·03
Willow					
Voluntary intake	(kg per day)	0·84	1·22	2·05	0·104
	(g/kg W per day)*	17·5	35·2	24·1	1·23
	(g/kg $W^{0·75}$ per day)*	46·6	88·8	68·6	3·82
Digestibility		0·597	0·617	—	0·0120
Digestible intake	(kg per day)	0·50	0·74	—	0·057
	(g/kg W per day)*	10·6	22·3	—	1·05
	(g/kg $W^{0·75}$ per day)*	27·1	53·8	—	2·74

Mean values with S.E. for six animals per treatment group.
* Adjusted by analysis of covariance, using D.M. intake per kg W and per kg $W^{0·75}$ measured during period of feeding lucerne hay as the covariate.

Table 3. *Experiment* 1. *Voluntary intake and digestibility of dry matter in spring primary growth of two willow species*

	Osier willow (*Salix viminalis*)	Tree willow (*Salix matsudana* × *alba*)	S.E.
Voluntary intake (g/kg $W^{0·75}$ per day)*	64·1	69·6	5·40
Digestibility	0·572	0·642	0·0120
Digestible intake (g/kg $W^{0·75}$ per day)*	36·5	44·4	2·74

Mean values for three goats and three sheep fed each diet.
* Adjusted by analysis of covariance using D.M. intake per kg $W^{0·75}$ measured during period of feeding lucerne hay as the covariate.

Table 4. *Experiment* 2. *Digestibility and voluntary intake of secondary (summer) grown willow by sheep and goats*

	Sheep		Goats	
	Mean	S.E.	Mean	S.E.
Mean live weight (kg)	36·8	1·56	32·3	1·52
Digestibility				
Dry matter	0·454	0·0423	0·564	0·0346
Organic matter	0·496	0·0380	0·588	0·0310
Energy	0·452	0·0416	0·522	0·0339
Voluntary intake				
Dry matter (g/kg $W^{0·75}$ per day)	36·6	4·24	59·9	3·46
ME (MJ/kg $W^{0·75}$ per day)	0·271	0·0518	0·527	0·0423
ME concentration (MJ/kg D.M.)	7·20	0·662	8·80	0·541

interactions between animal species and plant species even approached significance ($P > 0·05$), main effects only are quoted in the results section.

Differences between sheep and goats in Expt 2 were assessed using one-way analysis of variance.

RESULTS

Chemical composition

Experiment 1

Primary growth of both of the willow species was higher in soluble sugar content and lower in cellulose and hemicellulose than lucerne hay (Table 1), and consequently had higher ratios of readily fermentable carbohydrates to structural carbohydrates, particularly *Salix viminalis*. The willows contained much greater concentrations of lignin than did lucerne hay, but lower concentrations of total N. Condensed tannin was present in both willow species, at a higher concentration in osier than tree willow.

Leaf formed a greater proportion of the dry matter

offered in *Salix viminalis* than in *Salix matsudana* × *alba*, which may account for the greater concentration of nitrogen in the *Salix viminalis* diet.

Relative to primary growth, secondary growth *Salix viminalis* contained lower concentrations of total N but slightly higher concentrations of total cell wall and lignin.

Differences between sheep, goats and deer (Experiment 1)

When fed a standard diet of lucerne hay, there were no significant differences between the three animals species in voluntary intake (Table 2) once it had been corrected for live-weight differences (either $W^{1.0}$ or $W^{0.75}$).

There was a marked decrease in voluntary intake (g D.M./kg $W^{0.75}$) by sheep when the diet was changed from lucerne hay to willow; at the same time, however, deer showed little change and goats showed an increase in their voluntary dry-matter intakes. Thus, on the willow diets, intake per unit metabolic size was greater for goats than for deer ($P < 0.05$) and was greater for goats and deer than for sheep ($P < 0.001$). Expressing intake in terms of g/kg $W^{1.0}$ maintained the ranking of goats > deer > sheep, but it increased the magnitude of the difference between goats and deer and decreased the magnitude of the difference between deer and sheep.

The small increase in digestibility of goats over sheep failed to attain significance ($P > 0.05$), but because of their greater voluntary dry-matter intake, goats had a higher digestible dry-matter intake than sheep in terms of both kg $W^{0.75}$ and kg $W^{1.0}$ ($P < 0.001$).

Differences between Salix viminalis *and* Salix matsudana × alba (*Experiment* 1)

Goats and sheep had higher voluntary intake and digestibility of tree willow than of osier willow (Table 3), with the values attaining significance for digestibility ($P < 0.01$) and voluntary intake of digestible D.M. ($P < 0.10$).

Differences between sheep and goats (Experiment 2)

When fed secondary growth osier willow during autumn (Table 4) goats had both higher digestibility ($P < 0.10$) and voluntary intake ($P < 0.01$) than sheep. Metabolizable energy concentration (MJ/kg D.M.) of this willow was also higher for goats than for sheep ($P < 0.10$).

DISCUSSION

Chemical composition

Chemical composition of the willow diets fed in the present experiments have been compared with the composition of a range of temperate forages in Table 5. The ratio of readily fermentable : structural carbohydrate in primary growth was substantially less than found for white clover and forage kale, but of similar magnitude or greater than found for fresh or dried ryegrass. Total N concentration tended to be low, but was still substantially above the levels where N concentration limits voluntary intake of adult ruminants (< 13 g N/kg D.M.; Leng, 1982).

The willow diets differed markedly from most of the temperate forage diets in that they contained extremely high concentrations of lignin, and contained medium to high concentrations of condensed tannin. In this respect they most closely resembled diets of *Lotus pedunculatus*, but contained lower concentrations of total N and slightly lower concentrations of ME. Osier willow contained higher concentrations of both lignin and condensed tannin than did tree willow, which is explainable by both compounds having a common precursor and being synthesized by similar biochemical pathways (Swain, 1979). In *Lotus* species the positive correlation between the concentrations of lignin and condensed tannins has been noted previously (Barry & Manley, 1986). Because of the similarity in composition, it is reasonable to suppose that the nutritional problems with willow diets will be similar to those encountered previously with *Lotus pedunculatus*.

Secondary growth of osier willow tended to be slightly more lignified than primary growth, and in fact lignin concentration in both the primary growth willow diets tended to be higher than found in primary growth gorse (Table 5).

Nutritive value of willow species

In terms of apparent D.M. digestibility and voluntary intake of digestible D.M., osier willow had a lower nutritive value than tree willow. This occurred despite osier willow having a higher ratio of readily fermentable : structural carbohydrate, higher nitrogen concentration and leaf forming a greater proportion of the diet, all of which would suggest that the osier willow diet should have been of higher nutritive value than the tree willow diet. The lower nutritive value of osier willow can probably be explained by its high concentration of condensed tannin and lignin.

Increasing concentrations of condensed tannins in *Lotus* species from 2·5 to 106 g/kg D.M. linearly increases duodenal flow of non-ammonia nitrogen/total N intake but concentrations in excess of about 35 g/kg D.M. markedly depress rumen digestion of structural carbohydrate, apparent digestibility and voluntary intake (Barry & Duncan, 1984; Barry & Manley, 1984; Barry, Manley & Duncan, 1986; Waghorn *et al.* 1987). It therefore seems that concentration of condensed tannin was close to optimum in the tree willow diet and should have improved the efficiency of N digestion, thus counter-

Table 5. *Chemical composition of willow compared with that of temperate forage and other browse diets*

Species	Author	Readily fermentable carbohydrate: Structural carbohydrate	Condensed tannin (g/kg D.M.)	Lignin (g/kg D.M.)	Total nitrogen (g/kg D.M.)	M/D value (MJ ME/kg D.M.)*
		Forage diets				
Forage kale (whole plant)	Barry, Manley & Duncan (1984)	2·60	ND†	32	26·3	12·8
Vegetative white clover (summer and autumn average)	Ulyatt & MacRae (1974)	1·26	ND†	25	39·0	11·9
Vegetative perennial ryegrass (summer and autumn average)	Ulyatt & MacRae (1974)	0·34	ND†	20	42·0	11·5
Vegetative *Lotus pedunculatus*	Barry & Duncan (1984)					
Low tannin		0·78	46	132	41·3	10·9
High tannin		0·82	106	152	31·6	10·2
Dried S.23 ryegrass	Waite, Johnson & Armstrong (1964)					
Young leafy		0·44	ND†	27	29·8	13·2
Late leafy		0·34	ND†	36	24·3	11·9
Head emerging		0·31	ND†	43	22·1	11·8
Seed setting		0·24	ND†	73	15·4	9·9
Lucerne hay	Present study	0·38	ND†	105	31·2	ND
		Browse diets				
Tree willow	Present study (primary growth)	0·51	29	182	17·8	10·0
Osier willow	Present study (primary growth)	0·70	66	197	24·3	9·2
Osier willow	Present study (secondary growth)	ND	ND	202	19·3	8·8
Gorse (*Ulex europaeus*)	Howe *et al.* (1988) (primary growth)	ND	0	171	29·0	10·6

* M/D value calculated as: gross energy × 0·82 × digestibility of energy (or digestibility of dry matter if energy value not available).
ND, not determined.
† Probably zero.

Table 6. *Voluntary of willow by sheep, goats and deer, expressed relative to that of lucerne hay, and expressed as a function of the quantity of intake (ME) required for maintenance*

Author		Voluntary D.M. intake expressed relative to lucerne hay as unity		
		Salix matsudana × alba	*Salix viminalis*	*Salix reichardtii*
Present study (Expt 1)	Sheep	0·71	0·60	
	Goats	1·34	1·18	
	Deer	0·85	1·00	
M. J. Ulyatt (personal communication)	Sheep	0·87	0·80	0·45

		Voluntary ME intake expressed as levels of maintenance*		
		Experiment 1		Experiment 2
		Salix matsudana × alba	*Salix viminalis*	*Salix viminalis*
Present study (Expt 1)	Sheep	1·22	0·98	0·70
	Goats	2·33	2·05	1·85
	Deer	1·08	1·22†	

* ME for maintenance taken as 0·39 MJ ME/kg $W^{0·75}$ per day for both sheep (Agricultural Research Council, 1980) and feral NZ goats (Holmes & Moore, 1981) and 0·57 MJ ME/kg $W^{0·75}$ per day for deer (Kay & Staines, 1981; Fennessy *et al.* 1981). Digestibility of energy assumed to be the same as for D.M. and 1·0 MJ digestible energy = 0·82 MJ ME (Agricultural Research Council, 1980).
† Digestibility for deer assumed to be the same as the mean for sheep and goats.

acting the somewhat lower content of total N. Based upon experiences with *Lotus penduculatus*, the higher concentration of condensed tannin in osier willow may have been a major factor in its digestibility and voluntary intake being lower than that of the tree willow diet.

In NZ, lucerne hay is frequently used as a feed supplement during summer droughts, and the relative voluntary intake of primary growth willow has been compared with that of lucerne hay in Table 6. On this basis, willow was a superior feed to lucerne hay for goats, but was inferior to lucerne hay for sheep, and was of approximately similar value to deer. Tree willow was again of superior feeding value to osier willow, and in the one comparison made, pussy willow (*Salix reichardtii*) was of much lower feeding value than either tree or osier willow, and does not deserve serious consideration as a forage willow.

Goats v. sheep

The relative voluntary intake (g D.M./kg $W^{0·75}$ per day) of goats compared with sheep was dependent upon the diet offered, with there being no difference for the lucerne hay diet but goats being markedly superior to sheep when consuming the willow diets. When the intakes are expressed as functions of the amount of ME required for maintenance (Table 6), the ME intakes of goats are approximately double those of sheep, for both primary and secondary growth willow. This is attributable mainly to higher voluntary intake of willow by the goats, but the higher digestibility by goats also contributed when secondary growth willow was fed. From a comprehensive literature survey involving 40 comparisons of goats and sheep fed forage diets, Howe, Barry & Popay (1988) concluded that in some situations, mainly involving diets low in N and high in fibre, goats had superior digestive efficiency to sheep, especially of the fibre fraction. There was no evidence in the survey of goats having superior voluntary intake (g D.M/kg $W^{0·75}$ per day) than sheep. However, the lignin concentration in the willow diets fed in the present study (182–202 g/kg D.M.) greatly exceeded that in the forage diets (62–88 g/kg D.M.) surveyed by Howe *et al.* (1988), and it therefore appears that goats are vastly superior to sheep in utilizing highly lignified diets such as willow. Howe *et al.* (1988) reached the same conclusion when comparing utilization of the shrub weed gorse (*Ulex europaeus*) by goats and sheep. It is well known that in natural habitats, goats show a preference for woody species which sheep will reject (Wilson, Leigh, Hindley & Mulham, 1975).

Ulyatt *et al.* (1986) showed that particles in the rumen have to be reduced to below a critical diameter (sheep < 1 mm; cattle < 2 mm) before they can leave the rumen through the reticulo-omasal orifice, and hence the rumen can empty and voluntary intake increase; chewing and rumination were the processes equally responsible for reduction in particle size in sheep fed fresh and dried forages. With sheep, Weston (1985) showed that as the cell wall (i.e. cellulose + hemicellulose + lignin) content of the diet increased, then voluntary intake decreased and time spent ruminating increased. It is possible that goats are more efficient than sheep in reducing particle size by chewing–rumination in highly lignified browse diets, and research is required in this area.

Goats show longer mean retention times (MRT) in the rumen than sheep fed comparable forage diets (Watson & Norton, 1982; Alam *et al.* 1983; Doyle *et al.* 1984). Extrapolation of these findings to browse diets such as gorse and willow poses problems, as reduced voluntary intake would be expected, whereas in the present study and in the study of Howe *et al.* (1988) goats consumed more of these diets than did sheep. There is thus a need to measure MRT, rumen

volume and digesta load in sheep and goats fed browse diets high in lignin.

Deer v. sheep

Milne *et al.* (1978) found that the voluntary D.M. intake (g/kg $W^{0.75}$ per day) of deer was similar to that of sheep when fed high-quality forages, such as chaffed or pelleted dried grass, but that deer had greater intakes of poor quality hill forages that were low in N and high in fibre. Similar results were obtained in the present investigation, with voluntary intakes between the two animal species not differing on lucerne chaff, but deer having a higher intake of willow. However, because of the greater requirements of ME for maintenance of deer compared with sheep (0·57 *v.* 0·39 MJ/kg $W^{0.75}$ per day), the diets of primary growth willow fed in the present experiments sustained similar levels of ME intake (1·1 × maintenance) in deer and sheep, which was approximately half that achieved by goats (2·2 × maintenance; Table 6).

Deer have a marked seasonal cycle of voluntary intake, with maximum intake in summer and minimum intake in winter (Kay, 1985; Fennessy, Moore & Corson, 1981). The comparison with sheep and goats reported in this study was made in summer, and it is possible that deer may compare less favourably with these other species as daylength declines, such as for secondary growth willow fed in autumn.

Practical conclusions

The present experiments suggest that coppices of willow, cut in the young immature stage as in these experiments, could adequately be used as a supplement during periods of reduced pasture growth caused by summer drought. Because of the higher ME intake/kg $W^{0.75}$, willows can be used most effectively by goats, followed by deer and then sheep. Secondary regrowth can be adequately utilized by goats, but will give submaintenance intakes if utilized by sheep.

Tree willow would be the preferred choice to the osier willow used here, and selections of the latter should be examined to see whether NZ varieties exist with lower concentrations of condensed tannin and lignin.

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