SHEEP PREFERENCE FOR AND EFFECT OF BROWSING ON REGROWTH OF TWO *SALIX* SPECIES AND *CHAMAECYTISUS PALMENSIS* (H. Christ) Hutch

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ABSTRACT
To evaluate the usefulness of two Salix species in pastoral systems, two experiments were conducted to determine 1) the effects of browsing intensity and frequency on the regrowth of the Salix species and Chamaecytisus palmensis (H. Christ) Hutch and 2) sheep preference for them. The species responded well to browsing but the mean regrowth of S. kinuyanagi Kimura and C. palmensis was higher than that for S. matsudana x alba clone 'Tangoio'. Across species, browsing twice during summer-autumn yielded more edible dry matter (DM) than browsing once and seemed the most practical management for the farmer. Heavy browsing increased woody stem DM in S. kinuyanagi but did not influence regrowth in S. matsudana x alba and C. palmensis. S. matsudana x alba was the most preferred species by sheep but declined dramatically in preference during autumn. It is suggested that C. palmensis must be grown alone to enhance its use while the Salix spp. could be mixed.

Keywords: *Browsing intensity, browsing frequency, condensed tannin, forage intake, preference, regrowth, Salix species, Chamaecytisus palmensis.*

INTRODUCTION

For practical purposes, woody species selected for fodder in pastoral systems should be judged on both cutting and browsing management. Browse species tend to respond differently to different methods of defoliation due to the amount and type of tissue removed. The use of either cut and carry or *in situ* browsing system depends on how accessible and acceptable the forage is to the animal, and the practical expediency to the farmer. Cutting management studies (Douglas *et al*., 1996; Oppong, 1998) have indicated the potential of *Salix matsudana* x *alba* clone 'Tangoio' and *Salix kinuyanagi* Kimura as supplementary fodder in a dry summer. Nonetheless, their response to browsing has been sparingly studied (Hathaway, 1986) and therefore needs to be investigated further. In this study, the *Salix* species were compared to *Chamaecytisus palmensis* (H. Christ) Hutch since it has received most attention in browsing evaluations (Borens and Poppi, 1990; Townsend and Radcliffe, 1990). Moreover, *C. palmensis* is the most favoured browse species because of its high edible dry matter (DM) yield and reasonable browse quality (Borens and Poppi, 1990; Douglas *et al*., 1996).

Townsend and Radcliffe (1990) found that browsed *C. palmensis* had lower edible DM yield than when cut or browsed and then trimmed. The browsed trees also became woody with fewer bud sites (Townsend and Radcliffe, 1990). The fewer potential growth buds resulted in reduced regrowth since these buds occur largely on the smaller and softer stems that were also browsed. Hathaway (1986) found increased DM yields in *S. matsudana* x *alba* when several *Salix* species had intensive browsing once a year for three years but they did not determine the effect of browsing intensity and frequency on the DM yields of the species.

Further, the feeding value of any forage is a function of its intake and nutritive value (Ulyatt, 1981). Forage intake is influenced by the preference of animals, and is modified by the availability of the forage (Hodgson, 1979). In New Zealand only a few studies on browse preferences have been conducted (Lambert *et al*., 1989; Pande *et al.* 2002). Preference ratings are useful for selecting the most acceptable browse species for inclusion into pastoral systems and such studies could be useful in formulating browsing strategies (Lambert *et al*., 1989).

Depending on the farmers' circumstances, the selection of species that are resilient to browsing may be the most convenient and economical option. Browse species that maintain productivity under browsing may be favoured by pastoral farmers. A wider use of browse fodder in well-developed pastoral systems such as those in New Zealand will require more information on the effect of browsing on and animal preferences for browse species. Two experiments were conducted to determine 1) the effect of browsing intensity and frequency on the regrowth of the *Salix* spp. and *C. palmensis* and 2) sheep preference for these browse species at different times of the day and year.

MATERIALS AND METHODS

Site description

The experiments were conducted at Frewens, Massey University, Palmerston North (grid reference; NZMS, Palmerston North 260 T24 332869). The long-term mean annual rainfall is 995 mm and the dry months are January to April. The long-term mean annual air temperature is 12.9 ^{0}C. The mean soil temperature (30 cm depth) is 14 ^{0}C (Burgess 1988). The soil is an Ashhurst silt loam, that is, a shallow and stony soil associated with yellow-grey earths and it is excessively well drained (Cowie 1976). It has medium fertility, for example, Olsen P of 20 mg/kg soil and soil pH of 5.2 (Table 1).

Experimental plants

The three browse species used were hybrid willow (*Salix matsudana* x *alba*) clone 'Tangoio', Kinuya-

Table 1: Soil nutrient levels at Frewens, Massey University, Palmerston North (sampled to 75mm depth; July 1995)[a]

			Exchangeable cations (meq/100g soil)[d]		
pH[b]	Olsen P (mg/kg)	S[c] (mg/kg)	K	Ca	Mg
5.2	20	4	0.3	0.1	0.8

[a]*Converted "quick-test" units assuming constant soil bulk density*
[b]*Determined on a 1:2.5 soil : water suspension*
[c]*CaH_2PO_4 -extractable SO_4-S*
[d]*1M ammonium acetate, pH 7*

nagi willow (*Salix kinuyanagi*) and tagasaste (*Chamaecytisus palmensis*). The same experimental plants were used in both experiments.

Plant establishment and management

The site was sprayed with glyphosate (1.1 kg ai/ha) and cultivated by chisel plough a week before planting. Stakes of the *Salix* species were planted on 8/9 September 1994 whilst seedlings of *C. palmensis* were transplanted on 21/22 September 1994. In autumn 1995 the site was sown with *Lolium perenne* and *Trifolium repens* as cover plants to control the ingress of weeds. Subsequently, the pasture within tree rows was killed with a mixture of glyphosate, terbuthylazine and terbumeton (1.1, 0.25 and 0.25 kg ai/ha, respectively). The between row pasture was mowed regularly. The species were browsed by sheep when they were aged 16 months and had the following mean heights and crown diameters; *Salix matsudana* x *alba* (1.7 m ; 1.8 m), *Salix kinuyanagi* (1.7 m ; 2.3 m) and *Chamaecytisus palmensis* (1.9 m ; 3.1 m).

Experimental treatments, procedures and design

Experiment 1

The treatments were three browse species (*Salix matsudana* x *alba*, *Salix kinuyanagi* and *Chamaecytisus palmensis*); two browsing intensities - heavy (removal of leaves and edible stem less than 5 mm in diameter) and light (removal of leaves only) browsing, and two frequencies of browsing - once (summer) and twice (summer and autumn). The 12 treatments were arranged in four randomised complete blocks with each plot (experimental unit) comprising a row of 8 trees. One row had 4 trees and was considered a missing plot. The trees had intra-row spacing of 2 m and inter-row of 4 m and each plot was enclosed with an electric fence. Four groups of six mature Romney ewes were used in the experiment with mean weights of 63 kg and 64 kg for summer and autumn, respectively. The groups were allocated randomly to the plots. The summer browsing spanned from 6 - 20 February 1996 and that of autumn, 22 - 28 April 1996. Before each browsing, the animals were kept in an adjacent paddock with the same browse species for a week, to become accustomed to them.

Experiment 2

The treatments were three browse species (*S. matsudana* x *alba*, *S. kinuyanagi* and *C. palmensis*), two browsing times and two seasons. The times were morning (9.30 - 11.30 hr) and evening (15.00 - 17.00 hr), which are peak grazing periods for sheep grazing temperate pastures (Hodgson, 1982). The two seasons were summer (February 1997) and autumn (April 1997). The experiment was a split plot design with four randomised complete blocks. The trees were cut to 1.2m above ground in late August 1996 for summer browsing and cut in February 1997 to the same height for autumn browsing. Each subplot comprised a row of 4-8 trees of each browse species, that is, three rows in an area of 192 m^2. The trees were spaced as in Experiment 1. Pasture between the trees was killed with glyphosate (1.1 kg ai/ha) about four weeks before the observation period so that the browse species were the only live forage available. Preference for the browse species by six Romney ewes (with mean weights of 56 kg and 55 kg for summer and autumn respectively) was determined with the interval sampling technique (Hodgson, 1982). The sheep were identified using coloured markers on their backsides. The animals were allowed to become accustomed to the browse species in a nearby paddock with the same forages for a week, then were held there when not on the experimental plots. The sheep were not fasted, to prevent any bias in their preference for the browse species (John Hodgson, personal communication), and were allowed free choice of all browse species in each plot. The observation period was 2 hours whilst the frequency of the observations was 2 minutes.

Measurements

Experiment 1

Two plants within each row were selected a week before browsing and their crown diameters measured at the mid-point of the tree canopy (0.8-1.0 m aboveground). Crown diameter (CD) was measured with a 7.5 m diameter tape. Tree mass of the *Salix* species was removed to a stump height of 30 cm whilst that of *Chamaecytisus palmensis* to 50 cm stump height to optimise regrowth and maintain it within reach of the browsing animal. The fresh herbage was oven dried at 80 ^{0}C for 24 hours to determine the dry matter (DM) of each species. These data were used to determine the following regression functions relating dry matter (g/tree) and crown diameter of all the species based on the techniques developed by Rittenhouse and Sneva (1977) and Rutherford (1979) using Microsoft Excel for windows version 7 programme (Microsoft Corp. 1995):

Chamaecytisus palmensis:
$DM = 119.6CD^{2.09}$ $R^2 = 83\%$ $p \leq 0.0001$

Salix matsudana x *alba* clone 'Tangoio':
$DM = 193.1CD^{1.29}$ R2 = 63% $p \leq 0.01$

Salix kinuyanagi:
$DM = 57.7CD^{2.66}$ $R^2 = 64\%$ $p \leq 0.05$

A day before summer and autumn browsing, another pair of randomly selected trees from each treatment were tagged and their crown diameters recorded. Twenty-five percent of tree mass of one of the pair was sub-sampled to estimate dry matter of leaf, edible and woody stem components. The crown diameter of the second tree of the pair was measured post-browsing to estimate dry matter not consumed, using the equations above. No regrowth yield was determined after the autumn browsing until the following spring, because the *Salix* species were dormant during winter whilst *C. palmensis* was assumed to have negligible growth during winter (Oldham *et al*., 1994). The final regrowth of trees browsed once or twice during the season was estimated at the end of the following spring (20 December 1996; Figure 1). The regrowth was estimated from a randomly selected pair of trees not previously sampled. Similarly, the crown diameters were measured for estimating regrowth dry matter and sub-sampled as before to determine leaf, edible and woody stem components.

Experiment 2

The activity of each sheep was recorded as browsing or idling (all other activities apart from browsing). Sheep activities were recorded using binoculars of 10 x 50 magnification and each animal was observed every 2 minutes. The species browsed and the number of bites on the species during this time interval was recorded. The recordings were conducted on all the animals over the entire observation period of 2 hours. The procedure was repeated for each subplot in the morning and evening and for

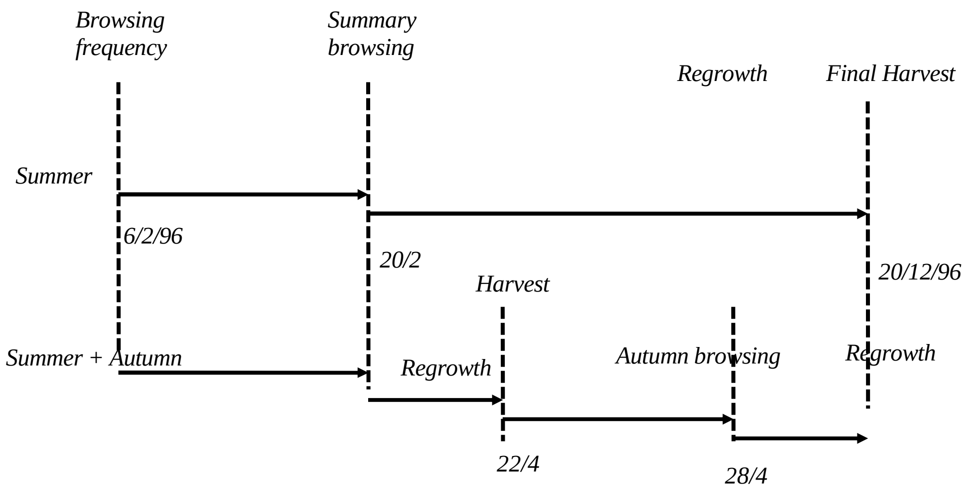

Figure 1: Schematic diagram of browsing and harvesting sequence in Experiment 1

eight subplots in each browsing season. The total number of bites on each browse species over the browsing period (four days for each season) was used to determine its preference rating.

Plant numbers, spreads (crown diameters) and mean heights per row were recorded. The foliage densities of the browse species per row were ranked visually on 1 (trees with least dense foliage in canopies) - 10 (trees with most dense foliage in canopies) scale. These variables were used to estimate relative abundance values (RAV) of each browse species in each plot (Oppong, 1998). This was expressed in terms of browse species density (Etienne, 1989). The proportion of browsing observations (PBO) for each browse species and RAV were used to calculate the browsing preference index (BPI) (Loehle and Rittenhouse, 1982), using the formula:

$$BPI = \frac{(PBO_i / RAV_i)}{{}^{n}\sum_i (PBO_i/RAV_i)}$$

Where i = individual browse species; n = all the browse species

Statistical analysis

In Experiment 1, analyses of variance were performed on leaf, edible stem, woody stem and total and edible dry matter yields, using the PROC GLM programme of SAS (SAS 1994). Pre- and post-browsing data were analysed as a split-plot over time. Data from Experiment 2 were analysed as a split-plot analysis of variance using the SAS package. Fisher's protected LSD was used to compare treatment means at $\alpha = 0.05$ (Steel and Torrie, 1980).

RESULTS

Results presented are significant ($p< 0.05$) interaction effects (species x browsing intensity; species x browsing stage; species x browsing season; browsing time x season) and main effects of the estimated variables that provided useful information. There were no significant second-order interaction effects in any of the experiments.

Effects of browsing frequency and intensity on regrowth

Regrowth of the tree species when browsed twice (summer and autumn) was in leaf, edible stem, woody stem and total and edible DM, than when browsed once (summer) (higher $p\leq 0.05$; Table 3). Regrowth of *S. matsudana* x *alba* and *C. palmensis* was not affected by browsing intensity (p^3 0.05; Table 4). Heavy browsing of *S. kinuyanagi* resulted in higher regrowth in woody stem and total DM, than light browsing ($p\leq 0.05$; Table 4).

Table 2: Effect of browsing on regrowth biomass (g DM/tree/day) of the *Salix* spp. and *Chamaecytisus palmensis* between 6 February and 20 December 1996 (Experiment 1)

	Regrowth biomass (g DM/tree/day)				
	Leaf DM	**Edible stem DM**	**Woody stem DM**	**Total edible DM**	**Total DM**
SPECIES					
Salix matsudana x *alba*	1.5^b	0.6^b	1.9^b	2.0^b	3.9^b
Salix kinuyanagi	3.7^a	0.5^b	4.9^a	4.2^a	9.1^a
Chamaecytisus palmensis	4.5^a	1.2^a	3.5^a	5.7^a	9.5^a
SEM	0.6	0.2	0.5	0.7	1.1

Means in a column followed by the same letters are not significantly different at 5% significance level

Table 3: Effect of browsing frequency on regrowth biomass (g DM/tree/day) of the *Salix* spp. and *Chamaecytisus palmensis* between 6 February and 20 December 1996 (Experiment 1)

	Regrowth biomass (g DM/tree/day)				
	Leaf DM	Edible stem DM	Woody stem DM	Total edible DM	Total DM
BROWSING FREQUENCY					
Summer only	2.3[b]	0.4[b]	2.6[b]	2.7[b]	5.4[b]
Summer and autumn	4.1[a]	1.1[a]	4.4[a]	5.2[a]	9.6[a]
SEM	0.5	0.2	0.4	0.6	0.9

Means in a column followed by the same letters are not significantly different at 5% significance level

Table 4: Effect of browsing intensity on the regrowth biomass (g DM/tree/day) of the *Salix* spp. and *Chamaecytisus palmensis* between 6 February and 20 December 1996 (Experiment 1)

SPECIES	Browsing intensity	Regrowth biomass (g DM/tree/day)				
		Leaf DM	Edible stem DM	Woody stem DM	Total edible DM	Total DM
Salix matsudana x *alba*	Light	1.4	0.6	1.8[bc]	2.0	3.8[c]
	Heavy	1.6	0.5	1.9[bc]	2.1	4.0[c]
Salix kinuyanagi	Light	2.7	0.2	3.5[bc]	2.9	6.4[bc]
	Heavy	4.7	0.8	6.2[a]	5.5	11.7[a]
Chamaecytisus palmensis	Light	5.3	1.4	4.3[b]	6.7	11.0[ab]
	Heavy	3.8	1.0	3.2[bc]	4.8	8.0[abc]
SEM		0.8	0.3	0.6	1.0	1.6

Means in a column followed by the same letters are not significantly different at 5% significance level

Pre-and post-browsing dry matter yield

Post-browsing DM yields after 7 months regrowth were significantly higher for leaf, edible stem, woody stem and total and edible DM yields, than pre-browsing DM yields (Table 5). The interaction between species and browsing stage for these variables was only significant for leaf DM yield ($p \leq 0.05$). Post-browsing leaf DM yield was higher in *S. kinuyanagi* (0.8 vs. 0.3 kg DM/tree) than pre-browsing DM yield, but similar in *S. matsudana* x *alba* (0.6 vs. 0.4 kg DM/tree) and *C. palmensis* (1.0 vs. 0.7 kg DM/tree).

Experiment 2

Sheep preference for browse species

Effect of species

Sheep biting rate when browsing *S. matsudana* x *alba* and *C. palmensis* was 11 bites/minute which was twice that for *S. kinuyanagi* (Table 6). Sheep spent more time (18%) browsing *S. matsudana* x *alba* than *S. kinuyanagi* and *C. palmensis* (12% vs. 11%), but the values were not significantly different. Sheep spent 40% of the browsing period feeding on the species and 60% of time idling (defined as a combination of resting, ruminating and feeding on dead pasture). The percent time spent browsing was higher in summer (45%) than in autumn (38%) for all three species. The browse preference indices showed that *S. matsudana* x *alba* was 3-5 times more preferred than *S. kinuyanagi* and *C. palmensis* ($p \leq 0.05$; Table 5).

Effect of time of day

The biting rate of sheep on all browse species was higher in summer than autumn for morning browsing (11 vs. 7 bites/minute) and similar ($p > 0.05$) for afternoon browsing (9 vs. 10 bites/minute). However, there were no differences between morning (16% vs. 10%) and afternoon (14% vs. 15%) browsing in each season on percent time sheep spent browsing and the preference rating of the three species (33%).

Effect of season

Sheep biting rate, percent time spent browsing and preference rating were higher in summer than autumn for *S. matsudana* x *alba* whilst for *S. kinuyanagi*, values for these attributes in autumn were considerably higher than those in summer. There was no seasonal effect (p^{3} 0.05) on the biting rate of sheep, percent time spent browsing and preference rating of *C. palmensis* although the data suggested a decline in all variables for autumn forage (Table 7).

DISCUSSION

Results from Experiment 1 showed that the browse species responded differently to sheep browsing. *S. kinuyanagi* and *C. palmensis* had higher regrowth compared to that of *S. matsudana* x *alba* and they seemed better adapted to browsing than *S. matsudana* x *alba*. Radcliffe (1982) found that *C. palmensis* responded better to browsing than *S. matsudana* x *alba* and *S. viminalis* clone 'Gigantea', an osier *Salix* species. In contrast to Radcliffe's findings, *S. kinuyanagi*, an osier, showed a similar re-

Table 5: Difference between pre- (16 months) and post-browsing biomass of the *Salix* spp. and *Chamaecytisus palmensis* between 6 February and 20 December 1996 (Experiment 1)

	BIOMASS (kg DM/tree)				
BROWSING STAGE	**Leaf DM**	**Edible stem DM**	**Woody stem DM**	**Total edible DM**	**Total DM**
Pre-browsing	0.5^b	0.1^b	0.4^b	0.6^b	1.0^b
Post-browsing	0.8^a	0.2^a	0.9^a	1.0^a	1.9^a
SEM	0.1	0.03	0.1	0.1	0.2

Means in a column followed by the same letters are not significantly different at 5% significance level

Table 6: Sheep preference for the *Salix* spp. and *Chamaecytisus palmensis* during summer (February 1997) and autumn (April 1997) (Experiment 2)

	Bite rate (bites/ minute)	**Proportion of browsing time in each browsing period (%)**	**Browsing preference indices (%)**
SPECIES			
Salix matsudana x *alba*	11.1^a	18.1	63.6^a
Salix kinuyanagi	5.4^b	12.1	24.4^b
Chamaecytisus palmensis	11.2^a	11.4	12.0^b
SEM	0.9	2.5	5.2

Browse preference indices - preference rating adjusted for browse availability; Means in a column followed by the same letters are not significantly different at 5% significance level

Table 7: Effect of season on sheep preference for the *Salix* spp. and *Chamaecytisus palmensis* (Experiment 2)

Species	Browsing season	Bite rate (bites/ minute)	Proportion of browsing time in each browsing period (%)	Browsing preference indices (%)
Salix matsudana x *alba*	Summer	14.6[a]	27.5[a]	82.4[a]
	Autumn	7.5[b]	8.9[bc]	44.8[b]
Salix kinuyanagi	Summer	1.8[c]	1.5[bc]	0.8[cd]
	Autumn	9.0[b]	22.7[a]	48.0[b]
Chamaecytisus palmensis	Summer	12.4[a]	16.1[ab]	16.8[c]
	Autumn	10.1[ab]	6.7[bc]	7.3[cd]
SEM		0.9	2.7	4.6

Browse preference indices - preference rating adjusted for browse availability
Means in a column followed by the same letters are not significantly different at 5% significance level

sponse to browsing as *C. palmensis*. This pattern of response by *S. kinuyanagi* is not well understood, but may be due to morphological differences between this species and the osier *Salix* used in Radcliffe's study. *S. kinuyanagi* has its growing buds on the main shoots and therefore escaped damage whilst in *S. matsudana* x *alba*, these buds occurred mostly on the edible stems which were browsed or damaged during browsing. Further results obtained by Oppong (1998) showed that the length and basal diameter of the dominant coppice shoot were more important for estimating DM yield in *S. matsudana* x *alba* and *S. kinuyanagi* respectively, indicating differences in morphology of the two species. There also seemed to be differences in the use and storage of carbohydrate reserves as shown in the differences in DM yield when *S. matsudana* x *alba* and *S. kinuyanagi* were first cut in mid-spring (Oppong, 1998), and this might have also affected their capacity to show compensatory growth.

There were no differences in leaf, edible stem and total edible DM regrowth between heavy and light browsing regimes in the three species. Du Toit *et al.* (1990) reported that the net annual shoot regrowth of heavily browsed *Acacia nigrescens* was not significantly different from that in lightly browsed trees. They suggested that the response was due to compensatory growth which alleviated the potential deleterious effects of tissue damage to either vegetative or reproductive organs (McNaugthon, 1983). The higher regrowth in woody stem and total DM yield resulting from heavy browsing in *S. kinuyanagi* compared to light browsing may be due to high compensatory growth. A greater proportion of this growth was woody stem which served as storage tissue for reserve carbohydrates that may provide the potential growing buds adequate nutrients for regrowth.

The *Salix* species potentially benefited from heavy browsing since there was no decline in edible DM yield (Benjamin *et al*., 1995) but in contrast, this component was reduced in heavily browsed *C. palmensis*. The decline in edible DM yield following heavy browsing in *C. palmensis* was similar to the findings of Townsend and Radcliffe (1990). Molyneux and Ralph (1992) reported that browsing was usually more damaging to evergreen than deciduous species and further supported the findings on *C. palmensis* under heavy browsing in this study. Evergreen species store carbon and nutrient reserves in their leaves whereas deciduous trees store them in stems and roots (Kramer and Kozlowski, 1979). As a result leaf removal places substantial strain on plant reserves and regrowth following browsing is greatly reduced (Molyneux and Ralph, 1992).

Across the *Salix* spp. and *C. palmensis*, browsing twice in the growing season increased regrowth compared to once. This is corroborated by Oldham *et al*. (1994) who found that *C. palmensis* trees browsed twice by cows and calves during the growing season increased forage yield due to substantial compensatory growth. In contrast to the findings of this study, Kay (1997) reported reduced browse yield after repeated browsing of *Salix* spp. by elk in Yellowstone National Park. Furthermore, Oppong (1998) showed that *Salix* trees cut in late winter and harvested once in autumn yielded more DM than trees harvested three times including autumn harvest. The results discussed here are for one year and it is suggested that this experiment should be conducted for 3 - 4 years to establish the long term response of the browse species to herbivory.

Experiment 2 showed that *Salix matsudana* x *alba* was the most preferred by sheep and that their preference for *S. kinuyanagi* and *C. palmensis* was similar. McCabe and Barry (1988) and Douglas (unpublished data) also found that *S. matsudana* x *alba* was the most preferred species compared to *S. viminalis*, and *S. kinuyanagi* and *C. palmensis* respectively. The relatively high biting rate of sheep browsing *S. matsudana* x *alba* and *C. palmensis* compared to *S. kinuyanagi* may be due to differences in condensed tannin (CT) concentration. Oppong *et al*. (1996) found that *S. kinuyanagi* had a high CT concentration which may be responsible for its reduced acceptability to sheep (Provenza and Malechek, 1984; Silanikove *et al.*, 1996) leading to the extremely low summer values for the percent time sheep spent browsing and the preference rating of the species. The summer CT concentration was higher than the autumn levels even though it was not statistically different within species (Oppong *et al*., 1997). The biting rate of sheep on temperate pastures is 31- 49 bites min^{-1} (Hodgson, 1982), about four times that obtained in the present study. The difference in leaf structure and density of the species compared to the grass/legume sward may be responsible for the low sheep biting rate on the browse species. Hodgson (1982) defined forage intake as the product of grazing time, biting rate and forage intake per bite which shows that biting rate is an important parameter in forage intake. The low values obtained with the browse species in this study may cause reduced intake and subsequent decline in animal production (Hodgson, 1990).

In all three species the biting rate of sheep was higher in the summer mornings than autumn mornings whereas in autumn afternoons it appeared to be higher than in summer afternoons. The differences might be due to behavioural responses of the sheep to variable weather conditions. The warm summer mornings offered a more conducive condition to browse than the cold and windy autumn mornings. The summer afternoons were hot and possibly this caused reduced browsing.

There were variations between seasons in biting rate of sheep, percent time sheep spent browsing and preference rating of the *Salix* species. These variations may be due to structural and chemical differences of the browse (Provenza and Malechek, 1984). *S. kinuyanagi* had higher values for the browsing variables in autumn than in summer and *S. matsudana* x *alba* showed higher values for the same variables in summer than autumn. A possible explanation for the improved autumn preference rating of *S. kinuyanagi* compared to *S. matsudana* x *alba* may be due to the new leaves which resulted from regrowth of the trees when topped after summer browsing. Owen-Smith (1993) reported that unpalatable woody species may be acceptable in the new leaf stage even though CT levels in leaves may still be high (>50 gCT/kg DM). This may be due to the high protein concentration as well as high digestibility of young leaves compared to mature leaves (Papachristou and Papanastasis, 1994).

The biting rate of sheep, percent time sheep spent browsing and preference rating of *C. palmensis* tended to be higher in summer than in autumn. The low sheep preference rating for *C. palmensis* may be related to its small and hairy leaves which influenced bite size and depressed forage intake (Hodgson, 1990). Certain morphological features such as dense pubescence and texture (Malechek and Provenza, 1983) may also reduce the acceptability to stock of plant species. Reduced intake of *C. palmensis* may also be due to increased secondary metabolites resulting from heat and water stress during summer (Edwards *et al*., 1997) as well as odour from leaves. Arnold and Hill (1972) noted that the senses of taste and smell were also responsible for preference rating of species by animals. The preference rating of *C. palmensis* in this study is similar to those of several workers (Lambert *et al*., 1989; Pande *et al.*, 2002. However, the intake of *C. palmensis* is high when provided as a sole diet and has been acclaimed as a useful fodder especially for dry summers (Borens and Poppi, 1990; Oldham *et al*., 1994).

CONCLUSIONS

All three browse species showed adaptability to browsing. Browsing twice in the growing season did not adversely affect regrowth. *S. matsudana* x *alba* was the most preferred species but preference declined dramatically in autumn. The high autumn preference for *S. kinuyanagi* suggested that a mixed plantation of both the *Salix* species might be useful. *C. palmensis* needs to be grown alone to boost its use, as it is less preferred when in association with the *Salix* spp.

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