Selective grazing in leaf mixtures of four herbage grasses by sheep

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ABSTRACT

Grazing trials were carried out in Obihiro, Japan, in 1989 and 1990. Prehending bites were measured in leaf mixtures of four herbage grasses using hand-constructed swards, which were composed of 128 points of leaf units spaced 4 cm apart. Four grasses of the following five species were mixed in each trial: orchardgrass *(Dactylis glomerata)*, timothy *(Phleum pratense)*, meadow fescue *(Festuca elatior)*, tall fescue *(Festuca arundinacea)* and sweet vernalgrass *(Anthoxanthum odoratum)*.

The number of prehending bites, mean distance of travel between bites, traveling velocity between bites and total distance of travel for 1 min were 40-44bites/min, 8.5-8.8cm, 5.9-8.8cm/s and 3.5-3.7m/min, respectively. DM weight per bite did not differ among the four grass species. The actual area covered by one prehending bite was calculated at 18-24㎠. From the analysis of frequencies of prehending bites in a pair of grass species, sheep clearly distinguished one species from another and separately prehended each species in the combinations of orchardgrass／meadow fescue and timothy／sweet vernalgrass, With respect to the transition of prehending bites among four grasses, prehension of selected species were influenced by the species prehended at the previous bite.

Key words：Herbage grasses, Hand-constructed sward, Leaf mixture, Selective grazing, Transition.

INTRODUCTION

Pasture vegetation is composed of various plant units. Grazing animals forage quite selectively using their sense organs (ARNOLD, 1966), and definitely prefer certain herbage species, stages of growth in a given species and particular parts of individual plants (HAFEZ, 1969). Animals tend to choose plant parts which can be eaten quickly (BLACK & KENNEY, 1984：KENNEY *et al.*, 1984：O'REAGAIN, 1993). Cattle preferentially select the glabrous plants (KRUETER & TAINTON, 1988). Preference is affected by sward condition such as canopy height, plant density, and plant biomass (HODGSON, 1982：JONES *et al.*, 1994), and by

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acceptability factors such as taste, odour and feel (KENNEY & BLACK, 1984).

Preference for herbage plant species is usually expressed as a percentage of the intake of feeds using a cafeteria fashion (BELL, 1959 : HEADY & CHILD, 1994 : SALEM, *et al.*, 1994). It is suggested that preference might be better defined in terms of time spent eating rather than as amount eaten (KENNEY *et al.*, 1984). In order to clarify preference for plant species, accurate measurement of the feed components selected by the animal must be carried out at the interface between the animal and the sward (LACA, *et al.*, 1992).

The present study is carried out to investigate the selective biting of grass species in the mixed sward and to observe the discriminative ability of sheep to grass species. For this purpose, new methods were developed to measure selective biting (JONES *et al.*, 1994). In this equipment, the positions of grass species which were pulled up could be stored in the computer's memory, when animals prehend plant parts at any point.

MATERIALS AND METHODS

The experiments were conducted from June to July in 1989 and 1990. Three Suffolk wethers aged 3-4 years with a mean live-weight of 62 kg were used. Sheep were held in pens and fed an adequate diet of fresh orchardgrass harvested from the same field twice daily. Fresh feed was placed in a container outside the pen. Four days before the commencement of each trial, sheep were trained to use the hand-constructed sward, which was placed at the same position as the feed container. Sheep readily grazed the artificial swards after training. Three sheep in 1989 and two sheep in 1990 were used for each treatment. Two grazing trials using one sheep were done on each day.

The sward board used was the same as the previous report (HONGO, 1998). Four grasses of the following five species were used for hand-constructed sward : orchardgrass (OG ; *Dactylis glomerata*), timothy (TI ; *Phleum pratense*) and meadow fescue (MF ; *Festuca elatior*) as a popular herbage plants, tall fescue (TF ; *Festuca arundinacea*) as a stiff plant, and sweet vernalgrass (SVG ; *Anthoxanthum odoratum*) as an odoriferous plant. These grasses were sown as a pure stand in rows 0.6 m apart in May 1988. The swards were fertilized and harvested regularly. Before each trial, fresh grasses were cut early in the morning. Vegetative tillers of suitable size were sorted out. Two leaf blades per vegetative tiller were left and all other leaves were removed. Three tillers (6 leaves) were attached to a stainless tube (8 mm diameter and 40 mm length) with cotton adhesive tape and then covered with vinyl tape which included a slender wire. Plants were sprayed with water and stored in a polyethylene bag.

When hand-constructed swards were constructed, terminal sections of leaves were clipped to yield an uniform height of 15 cm with scissors. Grazing trials were done using the leaf mixture of OG/TI/MF/SVG in 1989 and OG/TI/MF/TF in 1990. In 1989, the following four zonal arrangements were used. Each species was arranged at random at 32 points (1 points for the species) in the first experiment, at 16 points (2 adjacent points for the species) in the second experiment, at 8 points (4 adjacent points) in the third experiment, and at 4 points (8 adjacent points) in the fourth experiment. In 1990, each species was arranged randomly at 32 points. Sheep were fasted for approximately 14 hours before a grazing trial and were allowed to graze freely for about two minutes, before the entire top horizon of the sward was grazed.

Plants with stainless pipes were weighed separately at 128 points before and after trials.

Residual plant parts above an upper board were cut and weighed after trials. From these results, herbage intake was determined. Water loss from plant surface by evapotranspiration was measured for each plant parts, which were kept near sward board during a grazing trial. Herbage weight removed was corrected for moisture loss. These plant materials were then dried to obtain DM content. DM intake per bite at each point was calculated by dividing DM consumption by the total number of bites at this point.

In the statistical analysis, animals were treated as blocks. Variables of prehending bites were analyzed using an analysis of variance (SNEDECOR & COCHRAN, 1980). Total number of prehending bites, which were obtained from twelve trials in 1989, were classified into two classes according to prehending or not in a pair of grass species. The independence of two species was tested by chi-squared method in the 2 x 2 contingency table (SNEDECOR & COCHRAN, 1980). The transition of prehending bites for four grasses was tested by chi-squared method using number of prehended points at succeeding bites in comparison with expected values (KASUYA & FUJITA, 1984).

RESULTS

The effect of bite number on bite size would be expected to decrease with increasing number, because of reduced availability of grass leaves. In the present study, results for 1 min were used in the calculation. Four zonal arrangements of four grass species did not affect selective biting, so that these treatments were included into replications.

1. Number of prehended points and DM intake

Sheep prehended 44-50% of examined 32 points per one grass species for 1 min in 1989 and 28-50% in 1990 (Table 1). In 1990, the number of prehended points of TF and MF were significantly lower than those of OG and TI, but not significant in 1989. Mean percentage of

Table 1 Number of examined and prehended points, available DM weights and grazed DM weights per point for 1 mm

Experiment	Species	Number of examined points	Number of prehended points for 1 min	Available DM weight per point (g)	Grazed DM weight per point (g/min)
Mixtures in 1989	Orchardgrass	32	16	0.18	0.10
	Timothy	32	15	0.24	0.14
	Meadow fescue	32	15	0.21	0.11
	Sweet vernalgrass	32	14	0.24	0.15
	D.F.		44	44	44
	SED[a]		1.8	0.032	0.023
		32			
Mixtures in 1990	Orchardgrass	32	16	0.24	0.14
	Timothy	32	14	0.21	0.12
	Tall fescue	32	10	0.32	0.17
	Meadow fescue		9	0.16	0.08
	D.F.		12	12	12
	SED		3.8	0.033	0.014

a) SEDs : the standard error of the mean difference.

DM weights grazed for 1 min to available DM weights at a point occupied 52-63% in 1989 and 53-58% in 1990.

2. Distance and speed of travel between bites

Fig. 1 shows a diagram tracing the center of a prehending bite. The center was calculated from an average of X and Y coordinates, when more than two points were prehended at a bite. From these coordinate results and the time, mean distance of travel between bites, traveling speed were calculated (Table 2). Almost the same results were obtained from the experiments in 1989 and 1990. Mean distance of travel between bites (8.5-8.8 cm) shows that sheep tend to skip adjacent points because of a distance of 4 cm between points.

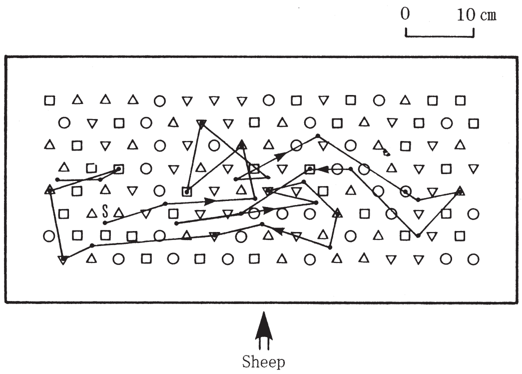

Fig. 1 Tracing of the center of a prehending bite, calculated from an average of X and Y coordinates. The first 30 prehending bites were shown in the leaf mixture of four grasses in 1990. S shows a starting point and a solid dot shows the center of a prehending bite. ○; orchardgrass, □; timothy, △; tall fescue, ▽; meadow fescue.

Table 2 Number of prehending bites for 1 min, mean distance of travel between bites, traveling velocity between bites and total distance of travel for 1 min.

Characters	1989	1990	D.F.	SED[a)]
Number of prehending bites for 1 min	40	44	14	2.4
Mean distance of travel between bites (cm)	8.8	8.5	14	0.36
Traveling velocity between bites(cm/s)	5.9	8.8	14	0.81
Total distance of travel for 1 min(m/min)	3.5	3.7	14	0.24

a) SEDs : the standard error of the mean difference.

3. Bite area and bite weight

DM weight per bite and intake rate were significantly lower in meadow fescue than in the other three grasses in 1990 (Table 3). These were not significantly different in four grasses in 1989. Numbers of prehended points per bite were an apparent estimation for bite area. In this hand-constructed swards, each point was uniformly spaced 4 cm apart and occupied 14cm². The actual area covered by one prehending bite was calculated at 24cm² in 1989 and 18cm² in 1990. Decreased bite area in 1989 resulted in reduction in DM weight per bite and DM intake rate. Numbers of points simultaneously prehended per bite were significantly correlated with bite weights (Fig. 2).

4. Frequency of prehending bites

Percent frequencies of prehending bites in six pairs of 4 grass species in 1989 are shown in Fig. 3. In the combinations of OG/TI and TI/MF, one species was independent to another species. This result means that each grass was grazed at random. Conversely, a high significance was observed in the combinations of OG/MF and TI/SVG using the chi-squared analysis. In these combinations, the presence of one species influenced prehending bite of another species because sheep clearly distinguished one species from another. Simultaneous prehension of three species at a bite was also observed in 4.3 % of total prehending bites in 1989. This analysis was not done in the result of 1990, because of insufficient number of prehending bites.

Table 3 Number of prehended points per bite, DM weights per bite and DM intake rate for 1 min

Experiment	Species	Number of prehended points per bite	DM weight per bite (mg)	DM intake rate (g/min)
Mixtures in 1989	Orchardgrass	0.45	39	1.5
	Timothy	0.43	51	2.0
	Meadow fescue	0.44	44	1.7
	Sweet vernalgrass	0.42	50	1.9
	D.F.	33	33	33
	SED[a)]	0.028	4.0	0.16
	Total	1.74±0.070	184±14.3	7.1±0.76
Mixtures in 1990	Orchardgrass	0.39	51	2.2
	Timothy	0.39	39	1.7
	Tall fescue	0.23	16	0.7
	Meadow fescue	0.24	38	1.7
	D.F.	9	9	9
	SED	0.044	4.8	0.18
	Total	1.25±0.044	144±11.7	6.2±0.43

a) SEDs : the standard error of the mean difference.

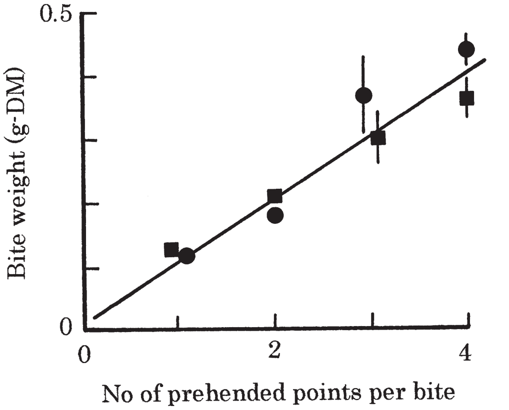

Fig. 2 Relationship between bite weight (Y) and number of prehended points per bite (X) in the mixtures of 4 grass leaves in 1989 (■) and 1990 (●). Only one observation in each number of prehended points per bite was excluded in the calculation. A vertical line attached to a symbol shows standard error. Correlation equation was as follows: $Y=0.097 \cdot X+0.020$, $r=0.961$ ($p<0.01$)

5. The transition of prehending bites

The transition of prehending bites among four grasses is shown in Table 4. Observed frequencies of transitions of OG-MF, TI-SVG, MF-OG and SVG-TI were significantly lower than expected values, and those of OG-SVG, TI-OG, MF-TI and SVG-MF were significantly higher than expected values. In these cases, selective biting of some species was influenced by another grass species prehended at the previous bite. In other cases, sheep selected grass species at random irrespective of grass species at the previous bite.

DISCUSSION

Under field conditions, it is extremely difficult to isolate the independent effects of various sward conditions on intake rate. By

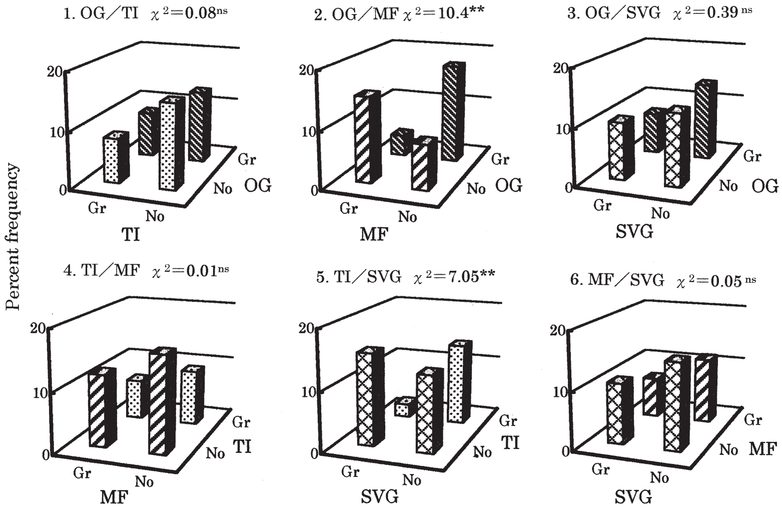

Fig. 3 Percent frequency of prehending bites for a pair of grass species. Total 484 bites of twelve trials were classified into two classes according to prehending or not in each pair of four grasses. The independence of two species was tested by chi-squared method. Zero and 1 mean no prehending and prehending of more than 1 point at each bite, respectively.
▧; OG (orchardgrass), ⚃; TI (timothy), ◪; MF (meadow fescue), ☒; SVG (sweet vernalgrass), ns; not significant, *; significant at p<0.05, **; significant at p<0.01.

Table 4 Transition of prehending bites of four herbage grasses in 1989

Prehended species		Prehended species at a succeeding bite				
		OG	TI	MF	SVG	Sum
Orchardgrass	(OG)	–	40ns	25*	52*	117
Timothy	(TI)	63**	–	41ns	17**	121
Meadow fescue	(MF)	18**	58**	–	41ns	117
Sweet vernaigrass	(SVG)	38ns	17**	50**	–	105
Sum		119	115	116	110	460

Figures show number of prehended points of four herbage grasses at a succeeding bites, when prehended species were different from those at a previous bites. Data were obtained from measurements for 1 min in twelve trials in 1989. Significant test was done using cell-by-cell test of chi-square test.
ns; not significant, *; significant at p=0.05, **; significant at p=0.01.

preparing artificial swards composed of various kinds of plant materials, it was possible to measure directly bite weight and bite area. The new system under the control of a personal computer was useful in observing biting behaviour.

There were two types of experimental errors in the overall observation (HONGO, 1998). Information recorded as biting in the computer without any DM intake occupied 4.7-6.1% of the total of 128 points in 1989 and 1990. Conversely, 10.0-13.7% were recorded as not biting in spite of DM reduction. The former type of error might be caused when plants, initially prehended, were pulled up but escaped defoliation because leaves slipped from the mouth (FLORES et al., 1993). The latter case seems to be caused mostly by the flexible characteristics of grass leaves. When tensile force by the animals is applied at a sharp angle, grass leaves may easily bend and break at an upper edge of the insertion hole, resulting in insufficient vertical force to activate switching. This experimental error was due to the structural defect of the sward board. Data of both cases were not included in these results.

The biting areas of successive bites are said to generally overlap when cattle graze across a sward horizon (UNGAR et al., 1991). In this study, biting overlap was defined as traveling distance less than 4 cm. This means that succeeding bites remain within the zone of the previous bite. Percentage of biting overlap observed for 1 min was 10.8% of total bites in 1989 and 4.4 % in 1990. Mean distance of travel between bites was 8.5-8.8 cm. This suggests that biting overlap rarely happens when sheep graze grasses in mixed swards.

In grass/clover mixtures, there are many reports that clover is usually preferred when grazed at high stocking rates (CURLL & WILKINS, 1980 : PENNING et al., 1991). In another study (BOROM & ARNOLD, 1986), some weedy species were avoided and grasses were grazed selectively between weed stubbles. In leaf/culm mixtures, sheep selected only grass leaves with a small biting area (Hongo, 1998).

The extent of preference occurring among grass species was variously reported (BAKER, 1975). In the present study, the presence of some species influenced prehension of another species in OG-MF and TI-SVG combinations. Since grazing sheep were reported to prefer OG than MF in the mixed swards (COWLISHAW & ALDER, 1960), these results seem to show the preference of one species to another in these combinations.

With respect to the transition of prehending bites among four grasses, the selected grass species were influenced by the grass species prehended at the previous bite. In another study using the same hand-constructed swards, however, sheep prehended grass leaves at random according to total frequency of each treatment (Hongo, 1998). From the result of this study, sheep may discriminate between grass species at the biting moment and tend to prehend these leaves selectively in mixed swards.

Selective biting closely relates with herbage mass per area effectively covered by one bite (FORBES, 1988: KENNEY & BLACK, 1984). Since swards were made at low density of grass leaves in this study, further studies should be done in dense swards with different herbage mass.

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REFERENCES

1) ARNOLD, G.W. (1966) The special senses in grazing animals. I. Sight and dietary habits in sheep. *Aust. J. Agr. Res.* 17, 521-529.

2) BAKER, R.D. (1975) Effect of sward characteristics on herbage intake under grazing. In *Pasture Utilization by the Grazing Animals* (Eds. by J. HODGSON and D. JACKSON). British Grassland Society. Berkshire. pp.87-92.

3) BELL, F.R. (1959) Preference thresholds for taste discrimination in goats. *J. Agr. Sci.*

52, 125-129.

4) BLACK, J.L. and P.A. KENNEY (1984) Factors affecting diet selection by sheep. II. Height and density of pasture. *Aust. J. Agr. Res.* 35, 565-578.

5) BOROM, D.M. and G.W. ARNOLD (1986) Selection by grazing sheep of pasture plants at low herbage availability and responses of the plants to grazing. *Aust. J. Agr. Res.* 37, 527-538.

6) COWLISHAW, S.J. and F.E. ALDER (1960) The grazing preferences of cattle and sheep. *J. Agr. Sci.* 54, 257-267.

7) CURLL, M.L. and R.J. WILKINS (1980) The relationship between selective grazing by sheep and the botanical composition of a grass/clover sward. *Proc. 8th Eur. Grassl. Fed.* 7, 17-23.

8) FLORES, E.R., E.A. LACA, T.C. GRIGGS and M.W. DEMMENT (1993) Sward height and vertical morphological differentiation determine cattle bite dimensions. *Agron. J.* 85, 527-532.

9) FORBES, T.D.A. (1988) Researching the plant-animal interface : the investigation of ingestive behaviour in grazing animals. *J. Anim. Sci.* 66, 2369-2379.

10) HAFEZ, E.S.E. (Ed.) (1969) *The Behaviour of Domestic Animals.* Tindall and Cassell Ltd. London. pp. 296-348.

11) HEADY, H.F. and R.D. CHILD (1994) *Range Ecology and Management.* West View Press. Boulder. pp. 39-57.

12) HODGSON, J. (1982) Influence of sward characteristics on diet selection and herbage intake by the grazing animal. In *Nutritional Limits to Animal Production from Pastures.* (Ed. J.B. HACKER).Commonwealth Agricultural Bureau. London. pp.153-166.

13) HONGO, A. (1998) Selective grazing in pure and leaf/culm mixtures of herbage grasses by sheep. *J. Agr. Sci.* 131, 353-359

14) JONES, T.A., M.H. RALPHS and D.C. NIELSON (1994) Cattle preference for 4 wheatgrass taxa. *J. Range Manag.* 47, 119-122.

15) KASUYA, E. and K. FUJITA (1984) *Statistics for Ethology.* Tokai University Press. Tokyo. pp.51-66.

16) KENNEY, P.A. and J.L. BLACK (1984) Factors affecting diet selection by sheep. I. Potential intake rate and acceptability of feed. *Aust. J. Agr. Res.* 35, 551-563.

17) KENNEY, P.A., J.L. BLACK and W.F. COLEBROOK (1984) Factors affecting diet selection by sheep. III. Dry matter content and particle length of forage. *Aust. J. Agr. Res.* 35, 831-838.

18) KRUETER, U.P. and N.M. TAINTON (1988) The effect of continuous and rotational grazing of sourveld on the selection of plant fractions by Simmental heifers. *J. Grassl. Soc. South. Africa* 5, 68-71.

19) LACA, E.A., E.D. UNGAR, N. SELIGMAN, M.R. RAMEY and M.W. DEMENT (1992) An integrated methodology for studying short-term grazing behaviour of cattle. *Grass and Forage Sci.* 47, 81-90.

20) O'REAGAIN, P.J. (1993) Plant structure and acceptability of different grasses to sheep. *J. Range Manag.* 46, 232-236.

21) PENNING, P.D., A.J. ROOK, and R.J. ORR (1991) Patterns of ingestive behaviours of sheep continuously stocked on monocultures of ryegrass or white clover. *Appl. Ani. Behav. Sci.* 31, 237-250.

22) SALEM, H.B., A. NEFZAOUI and H. ABDOULI (1994) Palatability of shrubs and fodder trees measured on sheep and dromedaries. I. Methodological approach. *Anim. Feed Sci. Tech.* 46, 143-153.

23) SNEDECOR, G.W. and W.G. COCHRAN (1980) *Statistical Methods* (7th ed.). The Iowa State University Press. Ames.

24) UNGAR, E.D., A. GENIZI and M.W. DEMMENT (1991) Bite dimensions and herbage intake by cattle grazing short hand-constructed sward. *Agron. J.* 83, 973-978.

イネ科牧草４種を混在させた人工草地におけるヒツジの選択採食

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要　　約

1989と1990年に，４㎝間隔で128 点にイネ科牧草４種を設置した人工草地を用いてヒツジの採食行動を観察した。実験にはオーチャードグラス，チモシー，メドゥフェスク，トールフェスク，スィートバーナルグラスのうち４草種を用いた。

バイト数は40～44回／分，バイト間の平均移動距離は8.5～8.8㎝，バイト間の移動速度は5.9～8.8㎝／秒，移動の合計距離は 3.5～3.7m／分であった。バイトあたりのＤＭ重は混在させた４草種の間で差はなかった。１バイトで採食した面積は18～24㎠と推察された。バイトの頻度について２草種間の関係を解析したところ，オーチャードグラスとメドウフェスク，チモシーとスィートバーナルグラスの組みあわせでは，ヒツジは明かに2草種を識別し，別々に採食する傾向にあった。ある草種を採食した後に，残りの3草種のうちどの草種を採食したのか，その推移を検討したところ，１つの草種の採食は直前に採食した草種の影響を強く受けていた。

キーワード：イネ科牧草，人工草地，混播草地，選択採食，推移.