RELATIONSHIPS BETWEEN DAILY HERBAGE INTAKE OF GRAZING CATTLE WITH DAILY HERBAGE ALLOWANCE AND LEAFINESS

T. Okajima[1], T. Kamijoh[2], H. Yokota[2] and M. Ohshima[2]

Department of Agrobiology, Faculty of Agriculture, Niigata University, Ikarashi, Niigata 950-21, Japan

Summary

In order to investigate the relationship between daily herbage allowance (*DHA*) and daily herbage intake (*DHI*) on the points of leaf and stem masses, grazing experiments were carried out on the pasture of tall fescue (*Festuca arundinacea* Schreb.). The experiments consisted of four 3-days' grazing periods which were from August 14 to 17, August 17 to 20, October 12 to 15 and October 15 to 18 in 1990. The value of *DHA* was 32.1 to 84.3, and the value of *DHI* was 9.9 to 27.0. The index of leafiness (leaf to stem ratio, *LSR*) was 0.74 to 3.06. The relationship between *DHI* and *DHA* was quadratic. Both relationship of daily leaf intake (*DLI*) to daily leaf allowance (*DLA*) and that of daily stem intake (*DSI*) to daily stem allowance (*DSA*) were likely to be asymptotic forms, although *DHI* did not show any significant relationships to *DLA* nor to *DSA*. The relationship between *DLI* and *LSR* was quadratic, and a negative relationship was found between *DSI* and *LSR*. From the relationship of *DLI* to *LSR* and that of *DSI* to *LSR*, the relationship of daily intake of leaf and stem (*DLSI*) to *LSR* was derived as quadratic and the *LSR* value at which the maximum *DLSI* was attained was estimated. The *DHA*, *DHI*, *DLA*, *DLI*, *DSA*, *DSI* and *DLAI* were expressed as the same unit of g/kg live body weight/day.

(**Key Words** : Cattle, Daily Herbage Allowance, Daily Herbage Intake, *Festuca arundinacea* Schreb. Grazing, Leafiness)

Introduction

On the grazed pasture, daily herbage allowance is one of the most important factors affecting daily herbage intake. The relationship between herbage intake and herbage allowance is an asymptotic form on the short grass swards dominated by perennial ryegrass (Gibb and Treacher, 1976, Baker et al., 1981), and the relationship between digestible organic matter intake (g/day) and total dry matter available (kg/ha) is an asymptotic form in a tropical grass pasture (Arnold and Dudzinski, 1967). Available herbage allowance and available leaf allowance were defined as herbage mass and leaf mass of 5 cm above the ground level by Takahashi et al. (1981), and they showed that herbage intake had an asymptotic relationship both with available herbage allowance and with leaf allowance in an orchardgrass (*Dactylis glomerata* L.)/tall fescue (*Festuca arundinacea* Schreb.) sward in Japan. Okajima and Kasaya (1988), however, reported herbage intake was affected by the amount of stem mass rather than leaf mass on the pasture of tall fescue.

The herbage on the grazed sward is made up of leaf, stem, weeds and standing dead materials, and grazing cattle prefer green living parts of plant (leaf and stem) to standing dead materials. And Stobbs (1973) reported the rate of herbage intake is sensitive to the leaf density in the sward canopy. In this paper, therefore, daily herbage intake and daily herbage allowance were investigated in relation to the contributions of leaf mass and stem mass to the herbage intake, using the index of leafiness (leaf to stem ratio), on the pasture of tall fescue.

Materials and Methods

1. Outline of experimental pasture

The grazing experiment was carried out on the pasture of the Nagoya University farm. Before the experiment the pasture had been rotationally grazed by steers and heifers

[1] Address reprint requests to Dr. T. Okajima, Department of Agrobiology, Faculty of Agriculture, Niigata University, Ikarashi, Niigata 950-21, Japan.

[2] Laboratory of Grassland Science, The Farm, School of Agricultural Science, Nagoya University, Togo, Aichi 470-10, Japan.

Received December 12, 1995
Accepted June 5, 1996

from March to July under the conventional management of the farm. The dominant species of the pasture was tall fescue, accompanied by Italian ryegrass (*Lolium multiflorum* Lam.) in spring, fingergrass (*Digitaria adscendens* Henr.) in summer and autumn, and white clover (*Trifolium repens* L.) throughout seasons. Chemical fertilizer was applied in March and July as a topdressing (total amount, N:112, P_2O_5:80, K_2O:104 kg/ha).

2. Experimental design

The experiments consisted of four 3-days' grazing periods which were from August 14 to 17, August 17 to 20, October 12 to 15 and October 15 to 18 in 1990. At each grazing period, three levels of daily herbage allowance (*DHA*, g/kg live body weight/day) were set by the changing of the paddock size according to the herbage mass per unit area measured beforehand in the pasture. Each paddock was enclosed by electrical fence. As shown in table 1, the paddock areas of low (L), medium (M) and high (H) *DHA* levels were 211, 321 and 421 m^2, respectively, both in August 14 to 17 and in October 12 to 15. And those were 184, 298 and 397 m^2, respectively, both in August 17 to 20 and in October 15 to 18. The paddocks of three levels were grazed by two cattle (Holstein steer or heifer), but they grazed other paddocks as one herd except for the experimental period. So, the pairs were replaced experiment by experiment and the experimental paddocks were not grazed consistently by the same pair of cattle. Cattle were weighed just before and after the grazing period, and means of these values were used for calculations of herbage allowance and intake. Total live body weights of a pair of cattle are shown in table 1 and they were in the range of 462 to 599 kg.

TABLE 1. GRAZING PERIOD, PADDOCK AREA AND TOTAL LIVE BODY WEIGHT OF A PAIR OF CATTLE

Grazing period	Aug. 14-17			Aug. 17-20			Oct. 12-15			Oct. 15-18		
Grazing No.	1	2	3	4	5	6	7	8	9	10	11	12
DHA[1] level	L	M	H	L	M	H	L	M	H	L	M	H
Paddock area (m^2)	211	321	421	184	298	397	211	321	421	184	298	397
Body weight (kg)[2]	599	502	507	594	503	498	462	477	542	465	475	539

[1] Daily herbage allowance. L, M and H indicate low, medium and high allowance, respectively.
[2] Total weight of a pair of cattle, mean value of before and after the grazing period.

3. Sampling methods and statistics

Herbage mass of each paddock was measured before and after each grazing period. Three 50 cm × 50 cm quadrats were set in the paddock and those places in the paddock had been selected using the Pasture Probe (DE-8208, Design Electronics Ltd.). Namely, the quadrats were set on the places where showed almost same reading to the mean of 40 readings measured beforehand within all over that paddock. Then herbage was cut at 5 cm above the ground level. A part of the herbage sample was oven-dried at 80℃ for more than 48 hours to determine the dry matter weight. The other part of the herbage sample was separated into leaf, stem (including leaf sheath, petiole and ear), weeds and standing dead materials, and then dried and weighed.

The value of *DHA* was calculated by dividing the product of herbage mass (g/m^2) and paddock area (m^2) with the product of live body weight (kg) and number of days in each grazing period, and both the daily leaf allowance (*DLA*, the same unit as *DHA*) and the daily stem allowance (*DSA*, the same unit as *DHA*) were calculated in a similar manner to the *DHA*. Herbage consumption was derived as the difference of herbage mass between before and after grazing. Both leaf and stem consumptions were also estimated as the difference of leaf and stem mass between before and after grazing. And then the daily herbage intake (*DHI*, the same unit as *DHA*) was calculated by dividing herbage consumption with body weight and number of days in each period. Both the daily leaf intake (*DLI*, the same unit as *DHA*) and the daily stem intake (*DSI*, the same unit as *DHA*) were obtained in a similar manner to the *DHI*. Correlation and regression analyses were performed by the SAS procedures (SAS Institute, 1985) using the Nagoya University Computation Center and the Niigata University Integrated Information Processing Center.

Results and Discussion

Herbage mass (g/m^2) of total, leaf, stem, weeds and standing dead materials of each paddock before grazing for each experimental period are presented in table 2.

TABLE 2. HERBAGE MASS OF TOTAL, LEAF, STEM, WEEDS AND STANDING DEAD MATERIALS, AND LEAF TO STEM RATIO (*LSR*) OF EACH PADDOCK JUST BEFORE GRAZING

Grazing No.[1]	1	2	3	4	5	6	7	8	9	10	11	12
Herbage mass (g/m^2)[2]												
Leaf	145	172	163	139	205	199	100	124	70	136	158	101
Stem[3]	107	87	70	184	90	65	114	102	188	103	67	136
Weeds	8	27	21	22	21	36	2	17	3	1	1	39
Dead	13	25	11	10	33	18	35	47	43	36	50	20
Total	273	311	265	355	349	318	251	290	304	276	276	296
LSR	1.36	1.98	2.33	0.76	2.28	3.06	0.88	1.22	0.37	1.32	2.36	0.74

[1] See table 1.
[2] Herbage mass of 5 cm above the ground level.
[3] Including leaf sheath, petiol and ear.

Total herbage mass ranged from 251 to 355 g/m^2, and leaf mass which was mainly leaves of tall fescue and fingergrass from 70 to 205 g/m^2. Stem mass which was mainly stems of fingergrass ranged from 65 to 188 g/m^2. Weeds mass ranged from 1 to 39 g/m^2 and main species of weeds was Amaranth (*Amaranthus lividus* L.). Standing dead mass ranged from 10 to 50 g/m^2, because the growth stage of tall fescue was near the end of the heading stage in the middle of August. So the tall fescue pasture used in this experiment contained considerable amount of weeds and dead materials and that pasture before grazing was not homogeneous in composition. The values of *DHA* in levels L, M and H were 32.1 to 38.2, 57.8 to 69.3 and 72.7 to 84.3, respectively. The values of *DHI* in levels L, M and H were 12.9 to 19.0, 16.2 to 27.0 and 9.9 to 17.1, respectively. The relationship between the *DHI* and the *DHA* in this experiment was quadratic [figure 1 and equation (1)]:

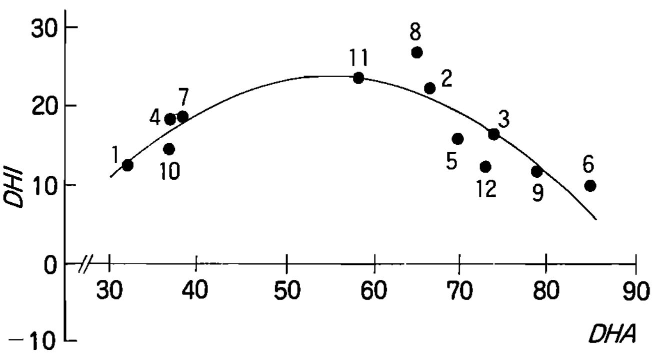

Figure 1. The relationship between daily herbage allowance (*DHA*, g/kg live body weight/day) and daily herbage intake (*DHI*, the same unit as *DHA*). Numbers in the figure are the grazing No. shown in table 1.

$$DHI = 24.1 - 0.0201\ (55.0 - DHA)^2\ (r^2 = 0.759) \cdots (1)$$

The maximum value of *DHI* estimated from the equation (1) was 24.1 at *DHA* value of 55 and this *DHI* value was similar to some results published (Hodgson et al., 1977, Jamieson and Hodgson, 1979, and Forbes and Hodgson, 1985). The *DHI* at level H was depressed in the range of *DHA* over the optimum value of 55. Meijs et al. (1982) have pointed out that, since the herbage may also grow during the grazing period, sward sampling methods to estimate herbage intake are mainly applicable in systems where the grazing periods are relative short and where grazing pressures are high. Therefore, the estimated herbage intake at the level H might be underestimated, because there might be a vigorous sward growth during the 3-days' grazing period.

Gibb and Treacher (1976) described the relationship between herbage allowance and daily intake of herbage in perennial ryegrass and red clover sward grazed by lambs with an asymptotic equation. The *DHI-DHA* relationship may differ with different types of swards, and grazing is more difficult on the swards with short sward height and low sward bulk density than those with tall sward height and high sward bulk density (Combellas and Hodgson, 1979). Though herbage mass was made up of leaf, stem, weeds and standing dead materials, animals preferentially grazed leaf mainly from the top of the sward (Chacon et al., 1978; Hirata et al., 1986). The *DHI* did not significantly related to the *DLA* nor to the *DSA* in this experiment. Assuming that cattle graze green living parts of the grass, the *DHI* can be divided into the *DLI* and the *DSI*. The relationships between the *DLI* and the *DLA* and between the *DSI* and the *DSA* are presented in figures 2a and 2b, respectively. On account of the sward was not grazed evenly within the paddock and stem mass after grazed was occasionally greater than that before grazing,

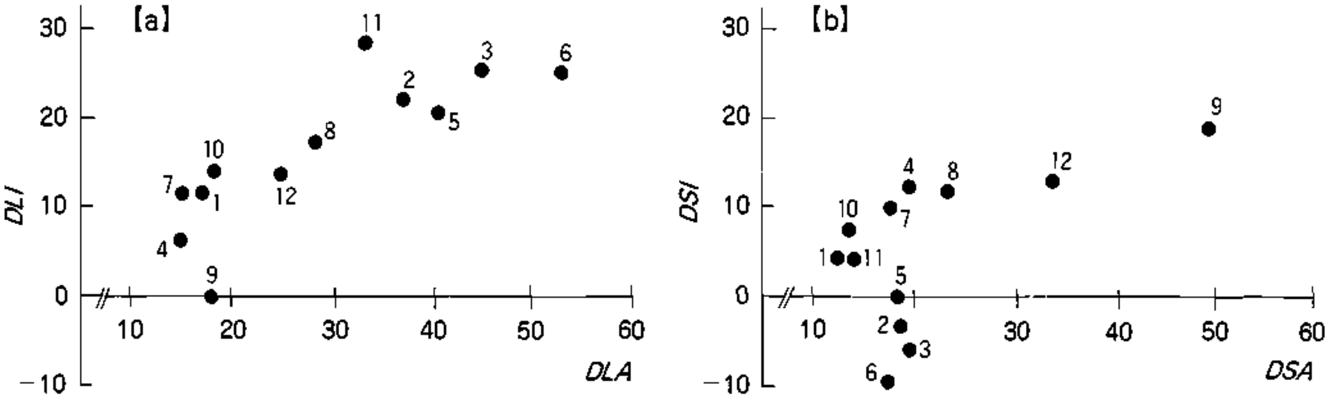

Figure 2. The relationships between [a] daily leaf allowance (*DLA*, g / kg live body weight / day) and daily leaf intake (*DLI*, the same unit as *DLA*), and [b] daily stem allowance (*DSA*, the same unit as *DLA*) and daily stem intake (*DSI*, *the same unit as DLA*). Numbers in the figures are the grazing No. shown in table 1.

values of stem intake sometimes showed negative values. However, excepting three negative and one nearly zero values, the *DSI-DSA* relationship showed a similar pattern to the *DLI-DLA* relationship, and both relationships of the *DLI-DLA* and the *DSI-DSA* in this experiment were likely to be asymptotic forms. Leaf is the most important component of the sward in grazing, and leaf yield, leaf to stem ratio, and bulk density of green material (leaf and stem) are also the important sward factors for grazing animals (Chacon and Stobbs, 1976). Stobbs (1973) reported that the rate of herbage intake is also sensitive to the leaf density in the sward canopy, and Takahashi et al. (1981) showed that the daily available leaf allowance has an asymptotic relationship with the *DHI*. On the other hand, Okajima and Kasaya (1988) reported that herbage intake was affected by the amount of stem mass rather than leaf mass on a tall fescue pasture. The ratio of sward leaf density to sward stem density in the three uppermost layers of the sward shows high positive correlation coefficient with bite size in the tropical pastures (Stobbs, 1973). And also the growth of steers grazing in tropical grass pasture is greatly influenced by the spatial distribution of herbage (leaf bulk density and leaf to stem ratio) and the nutritive value of herbage (Chacon et al., 1978). Then, from the results of this experiment, the contributions of leaf mass and stem mass to the herbage intake were investigated. Both the *DLI* and the *DSI* were presented as the function of leafiness (leaf to stem ratio, *LSR*). The relationship between the *DLI* and the *LSR* is presented in figure 3a) and it was quadratic [equation (2)] :

$$DLI = 25.4 - 3.58\ (2.93 - LSR)^2\ (r^2 = 0.875) \cdots\cdots (2)$$

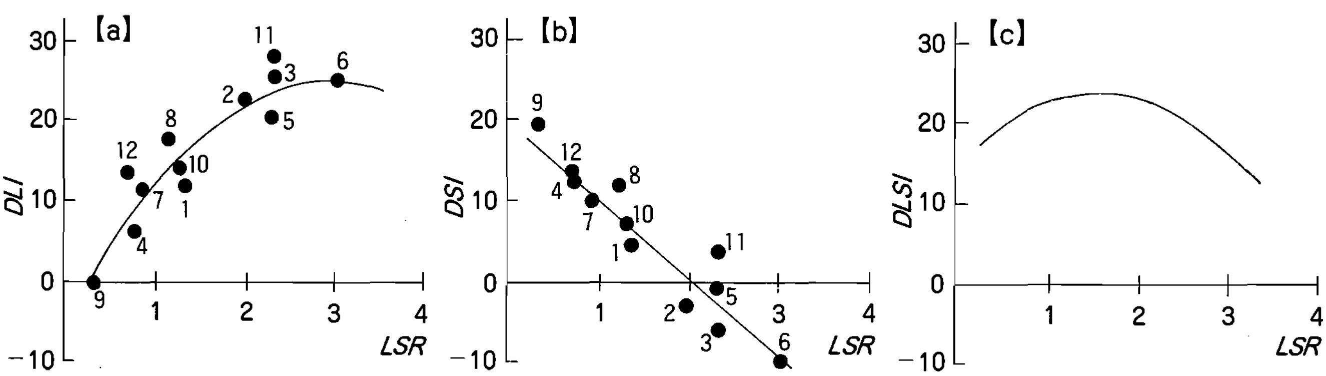

Figure 3. The relationships between [a] daily leaf intake (*DLI*, g / kg live body weight / day) and leaf to stem ratio (*LSR*), [b] daily stem intake (*DSI*, the same unit as *DLI*) and *LSR*, and [c] estimated daily leaf and stem intake (*DLSI*, the same unit as *DLI*) and *LSR*. Numbers in the figures are the grazing No. shown in tabel 1.

The relationship between the *DSI* and the *LSR* is presented in figure 3b) and it indicated a negative correlation [equation (3)]:

$$DSI = 20.7 - 9.83LSR \quad (r^2 = 0.876) \cdots\cdots\cdots\cdots\cdots\cdots (3)$$

The equation (2) indicates that the *DLI* increases to the maximum value of 25.4 until the *LSR* value of 2.93 and then decrease, but it is not appropriate to extrapolate the *DLI* when the *LSR* value is more than 3.0. The equation (3) or figure 3b) indicates that the *DSI* decrease with an increase in the *LSR* value and when the *LSR* is more than 2.1 stem is not grazed. Arnold and Dudzinski (1967) reported that herbage intake was depressed and stem was consumed when leaf became scarce. In the present experiment, a relationship between the daily intake of leaf and stem (*DLSI*) and the *LSR* was derived from the equations (2) and (3) [figure 3c)].

$$\begin{aligned} DLSI &= DLI + DSI \\ &= (25.4 - 3.58\,(2.93 - LSR)^2) + (20.7 - 9.83\,LSR) \\ &= 24.2 - 3.58\,(1.56 - LSR)^2 \cdots\cdots\cdots\cdots\cdots\cdots\cdots (4) \end{aligned}$$

The equation (4) indicates that the maximum daily green herbage intake was attained at the *LSR* value of 1.56, and the maximum value of *DLSI* was nearly the same value as *DHI* estimated from the equation (1).

In this experiment of tall fescue pasture the *DHI* was not sufficient when the *DHA* was less than 55 (figure 1). As the values of *DHA* at level L were lower, and those at level M were slightly higher than that value, cattle in the paddocks of level L and level M would graze to the lower part of the sward than those in the paddock of level H. Hirata et al. (1986) reported that higher utilization of the lower part of the sward elevated the total utilization of herbage mass. As the level of the *DHA* in this experiment was set by the paddock size, the level of the paddock size might also affect the *DHI*. The values of *DHA* at level H were 1.5 times of that optimum value of the *DHA*, and cattle might have more chance for selective grazing in the paddock of level H than those in the paddocks of the other levels. Because of the difference in the independent variable between equations (1) and (4), and because the correlation coefficient between the *DHA* and the *LSR* was very low, it might be doubtful to make the direct comparison between the *DHI* from equation (1) and the *DLSI* from equation (4). And although considerable amount of weeds and standing dead materials existed in the sward canopy in this experiment, those masses were excluded from the calculations of both the *DLI* and the *DSI*. Then, the differences between estimates of the *DHI* and those of the *DLSI* might be partly due to the contributions of weeds and standing dead materials.

Acknowledgements

The authors are grateful to Messrs. T. Harada, T. Nagatomo, M. Tsuge and N. Inagaki for their technical assistances.

Literature Cited

Arnold, G. W. and M. L. Dudzinski. 1967. Studies on the diet of the grazing animal. 2. The effect of physiological status in ewes and pasture availability on herbage intake. Aust. J. Agric. Res. 18:349-359.

Arnold, G. W. and M. L. Dudzinski. 1967. Studies on the diet of the grazing animal. 3. The effect of pasture species and pasture structure on the herbage intake of sheep. Aust. J. Agric. Res. 18:657-666.

Baker, R. D., F. Alvarez and Y. L. P. Le Du. 1981. The effect of herbage allowance upon the herbage intake and performance of suckler cows and calves. Grass and Forage Sci. 36:189-199.

Chacon, E. A. and T. H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. Aust. J. Agric. Res. 27:709-727.

Chacon, E. A., T. H. Stobbs and M. B. Dale. 1978. Influence of sward characteristics on grazing behaviour and growth of Hereford steers grazing tropical grass pasture. Aust. J. Agric. Res. 29:89-102.

Combellas, J. and J. Hodgson. 1979. Herbage intake and milk production by grazing dairy cows. 1. The effects of variation in herbage mass and daily herbage allowance in a short-time trial. Grass and Forage Sci. 34:209-214.

Forbes, T. D. A. and J. Hodgson. 1985. Comparative studies of the influence of sward conditions on the ingestive behaviour of cows and sheep. Grass and Forage Sci. 40:69-77.

Gibb, M. J. and T. T. Treacher. 1976. The effect of herbage allowance on herbage intake and performance of lambs grazing perennial ryegrass and red clover swards. J. Agric. Sci., Camb. 86:355-365.

Hirata, M., Y. Sugimoto and M. Ueno. 1986. Energy and matter flows in bahiagrass pasture. 3. Herbage consumption by grazing cattle in relation to canopy structure. J. Japan. Grassl. Sci. 32:267-277.

Hodgson, J., J. M. Rodriguez Capriles and J. S. Fenron. 1977. The influence of sward characteristics on the herbage intake of grazing calves. J. Agric. Sci., Camb. 89:743-750.

Jamieson, W. S. and J. Hodgson. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive hehaviour and herbage intake of calves under strip-grazing management. Grass and Forage Sci. 34:261-271.

Meijs, J. A. C., R. J. K. Walters and A. Keen. 1982. Sward Methods. In: Leaver J. D. (ed). Herbage intake handbook. British Grassland Society, Berkshire, England. pp. 11-13.

Okajima, T. and M. Kasaya. 1988. The relationship between herbage allowance and herbage intake at the grazing pasture. The Tokai Journal of Animal Production 36:81-87(In Japanese only).

SAS Institute. 1985. SAS user's guide: Basics and Statistics. 5th ed. SAS Inst., Inc., Cary, N.C.

Stobbs, T. H. 1973. The effect of plant structure on the intake of tropical pastures. 2. Differences in sward structure, nutritive value, and bite size of animals grazing *Setaria anceps* and *Chloris gayana* at various stage. Aust. J. Agric. Res. 24:821-829.

Takahashi, S., T. Akiyama, T. Okubo and M. Shiyomi. 1981. Effect of herbage allowance on herbage intake of grazing heifers. J. Japan. Grassl. Sci. 27:114-120(In Japanese with English summary).