バヒアグラス(Paspalum notatum Flugge)放牧草地を利用した黒毛和種育成牛飼養システムの解析(1)

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Analysis of a Japanese Black Cattle Rearing System Utilizing a Bahiagrass (*Paspalum notatum* Flügge) Pasture

1. Variations in the factors considered to affect animal production

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Synopsis

HIGASHIYAMA, M. and M. HIRATA (1995) : Analysis of a Japanese Black Cattle rearing system utilizing a bahiagrass (*Paspalum notatum* Flügge) pasture. 1. Variations in the factors considered to affect animal production. *Grassland Science* 41, 104–113.

In a Japanese Black Cattle rearing system utilizing a bahiagrass pasture in coastal Miyazaki, various factors considered to affect animal production were measured for 3 years, and their variations with the year, season and progressive grazing were examined.

The air temperatures increased from May to July/August, and decreased from August/September to October. The solar radiation and rainfall showed different seasonal variations with the years. The intake of supplementary feed varied almost similarly to the level of supplementary feeding.

The sward height and herbage mass tended to increase from May to July/August and decrease thereafter, except for some sudden drops by the mowings. As a paddock was progressively grazed, the sward height and herbage mass sometimes increased, though they mostly decreased. The sward bulk density showed different seasonal variations with the years. The dry matter digestibility of bahiagrass leaves and pasture decreased from May to August and leveled off thereafter. The animal liveweight, except for some drops with changes in herd composition, always increased. The herbage allowance, except for the first year, showed similar seasonal variations to the herbage mass.

The percentage grazing time showed different seasonal variations with the years. The biting rate and the number of bites tended to decrease from May to July/August and increase thereafter. The dry matter digestibility of hand-plucked herbage showed similar seasonal variations to the pasture digestibility.

For clarifying the mechanisms of such factor variabilities and characterizing the system, an analysis of the relationships between the factors was considered to be important.

Key words : Bahiagrass, Grazing behavior, Japanese Black Cattle, Pasture characteristics, Supplementary feed.

Introduction

Animal production in grazing system is directly or indirectly affected by a number of factors which can be classified into such categories as meteorology, pasture, animal, ingested feed, *etc.*[22,29] To clarify how these factors are related to each other and to the animal production is important for characterizing the system and optimizing the animal production.

Bahiagrass is one of the most widely-used tropical species for permanent pastures in southwest Japan, especially in the low-altitude areas of Kyushu. Several studies have been made into the grazing systems with bahiagrass pastures in Japan, focusing on such aspects as pasture production and utilization, herbage quality, grazing behavior and animal production[13,14,23,28,33,34]. However, no studies have analyzed the systems in the above-mentioned way.

In this series of studies, a Japanese Black Cattle rearing system utilizing a bahiagrass pasture in coastal Miyazaki was selected as a research object, and animal production (liveweight gain) and various factors considered to affect it were measured for 16 months covering a 3-year period. This paper, as a first paper of the series, describes the variations in the factors, giving attention to the effects of the year, season and progressive grazing.

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Materials and Methods

The investigation was made in July–October of 1991 and May–October of 1992 and 1993 into a Japanese Black Cattle rearing system with a bahiagrass pasture in the Sumiyoshi Livestock Farm, Faculty of Agriculture, Miyazaki University. The Farm is located in a coastal dune area of southern Kyushu (31° 59′ N, 131° 28′ E, about 2 km from the coast line and about 10 m in altitude). The soil type is the Sand-dune Regosols[23]. Climatically, the summers are warm and humid, and the winters are cool and rather dry (Table 1). The mean annual rainfall is about 2300 mm.

1. Pasture and animals

(1) Pasture

The system utilized three paddocks of a Pensacola bahiagrass (*Paspalum notatum* Flügge) pasture established in 1988. The areas of paddocks 1, 2 and 3 were, respectively, 0.18, 0.18 and 0.37 ha in 1991, and 0.37, 0.36 and 0.61 ha in 1992 and 1993. Paddock 3 in 1992 was oversown with Italian ryegrass (*Lolium multiflorum* Lam.) in the autumn of 1991. All the paddocks in 1993 were oversown with Maku lotus (*Lotus pedunculatus* cv. Grasslands Maku) and Shaw creeping vigna (*Vigna parkeri* Bak. ssp. *maranguënsis* (Taub.) Verdc. cv. Shaw) in the spring of 1993.

The paddocks, in addition to grazing, were cut for hay once or twice a year (Fig. 1). The cuttings were made in June (not shown in Fig. 1) or July in 1991, and in May or June and in August in 1992 and 1993. The pasture was fertilized in early spring (late February to mid-March) and just after the cuttings except for the second cuttings in 1992. On both the occasions, N, P_2O_5 and K_2O were applied as chemical fertilizer. Annual rates of N, P_2O_5 and K_2O were respectively 89, 38 and 38 kg ha^{-1} in 1991 and 1992, and 75, 149 and 175 kg ha^{-1} in 1993. The early-spring fertilization also included 10 t ha^{-1} poultry manure in 1991 and 1992.

(2) Animals

The system carried a herd of 15–17 Japanese Black Cattle (11–14 heifers and 3–6 steers). Almost all the animals were replaced by new younger animals every May. Furthermore, when a health problem occurred in some animals during the investigation, they were removed from the herd or replaced by new animals. The animal liveweights at the start of the every-year measurements were 235–473 kg (mean = 323 kg) in 1991, 187–378 kg (mean = 271 kg) in 1992 and 126–292 kg (mean = 165 kg) in 1993 (Fig. 8).

The animals grazed the three paddocks rotationally in the daytime of July–October in 1991 and May–October in 1992 and 1993, with the grazing periods of 1–13 days and the rest periods of 6–24 days (Fig. 1). The daytime grazing started between 9 and 10 a.m. and ended at 4 p.m. The animals spent the rest of the day in a barn.

The animals were supplemented in the barn before (1991) or after (1992 and 1993) the grazing. The supplement was a combination of wheat bran and one of the following roughages ; corn silage, Italian ryegrass silage, Italian ryegrass haylage, Italian ryegrass hay and rhodesgrass hay. Wheat bran, on an average, formed 28% of the supplement on a dry matter (DM) basis. The level of supplementary feeding was varied experimentally (Fig. 2).

Table 1. Long-term means of meteorological factors (1981–1990).

Factor[a]	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean or total
T_{MAX}	12.7	13.4	16.1	20.4	23.9	26.8	30.7	30.9	28.2	24.1	19.7	15.3	21.9
T_{MEAN}	6.6	8.2	11.3	16.0	19.7	22.9	26.5	27.0	24.0	18.9	14.0	8.8	17.0
T_{MIN}	1.1	3.1	6.4	11.3	15.3	19.5	23.4	23.6	20.6	14.3	8.9	3.0	12.5
SR	10.0	11.0	12.1	15.0	15.9	15.6	17.9	17.8	13.3	12.2	9.4	9.3	13.3
RF	42	97	205	215	232	324	284	267	327	178	64	30	2,264

[a] Factors are maximum (T_{MAX}), mean (T_{MEAN}) and minimum (T_{MIN}) daily air temperatures (℃), daily total short-wave solar radiation (SR, MJ m^{-2} day^{-1}), and rainfall (RF, mm). Monthly and annual means are shown for T_{MAX}, T_{MEAN}, T_{MIN} and SR, and monthly and annual totals are shown for RF.

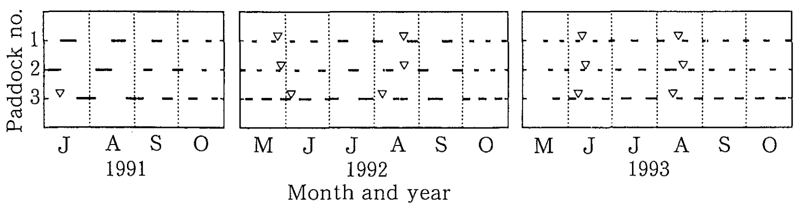

Fig. 1. Grazing periods (——) and mowing dates (▽) at the three paddocks.

2. Measurements

(1) Meteorology

The maximum, mean and minimum daily air temperatures, daily total short-wave solar radiation and rainfall were measured at the Farm.

(2) Intake of supplementary feed

The intake of supplementary feed was measured every day. Dry matter contents of the supplementary feeds were measured 2–4 times a month.

(3) Pasture

Pasture measurements were made 4–9 times a month, when the animals grazed paddocks 2 or 3. In 1991, ten 50 cm×50 cm quadrats were randomly placed in the paddock. In 1992 and 1993, five 50 cm×50 cm quadrats whose herbage mass was estimated to be similar to the mean herbage mass of the paddock were chosen with a Pasture Probe™ (Mosaic Systems Ltd., New Zealand), an electronic capacitance meter.

For each quadrat, the sward height was determined as a mean of natural heights of upper leaves of five non-heading and non-booting tillers. Then, the aboveground plant materials were sampled at a height of 5 cm above the ground surface. The samples were separated into species categories. Moreover, in 1992 and 1993, the bahiagrass samples were separated into leaf (lamina), stem (with ear and leaf sheath) and dead materials. Dry weights of the samples were determined after 48-hour oven-drying at 85℃. The sward bulk density was calculated by dividing the herbage mass (g DM m^{-2}) by the sward height (cm) less 5 cm.

(4) Animal liveweight

The animals were weighed every month in 1991 and 1992, and every half month in 1993, after an overnight period (more than 12 hours) of no feed and water. The liveweights between the measurements were calculated assuming linear liveweight changes.

(5) Grazing behavior

Grazing behavior of the animals was recorded on the same occasions as the pasture measurements. During a daytime grazing, the number of eating animals and their biting rates were recorded every 15 minutes. The biting rate was recorded from August 1991 onward, by measuring the time required for 20 prehension bites with at most five arbitrary animals. The percentage grazing time was calculated by dividing the total number of eating animals by the total number of animals summed over the daytime measurements. The biting rates recorded were averaged to produce the mean rate over the daytime grazing. The number of bites at pasture was calculated from the duration of daytime grazing, percentage grazing time and mean biting rate, using a calibration equation (unpublished).

(6) Hand-plucked herbage

Hand-plucked herbage samples were collected to indirectly estimate the diet quality. During the recording of grazing behavior, the manner of canopy grazing by the animals was carefully observed, and the herbage samples were hand-plucked simulating the animal grazing.

(7) Digestibility

In vitro dry matter digestibilities of pasture samples, Italian ryegrass haylage, Italian ryegrass hay and rhodesgrass hay were measured with a pepsin/cellulase technique, and were corrected by a calibration equation to give predicted *in vivo* dry matter digestibilities[10]. Dry matter digestibilities of wheat bran, corn silage and Italian ryegrass silage were derived from the digestible energy contents listed in the Standard Tables of Feed Composition in Japan[35], assuming that the feeds have a gross energy content of 4.4 kcal (g DM)$^{-1}$ and the dry matter digestibility equals the energy digestibility. The digestibility of pasture was calculated from the digestibilities and proportions of the pasture components (species and plant parts).

Results and Discussion

1. Meteorology

The ten- or eleven-day means of maximum, mean and minimum daily air temperatures were in ranges of 20.7–34.3℃, 16.2–29.3℃ and 10.3–25.5℃, respectively, and increased from May to July or August and decreased thereafter (Fig. 3 a). The ten- or eleven-day means of daily solar radiation ranged between 8.1 and 23.4 MJ m^{-2} day^{-1}, and showed different seasonal variation patterns with the years (Fig. 3 b). The ten- or eleven-day totals of rainfall, ranging between 0 and 520 mm, also showed different season-

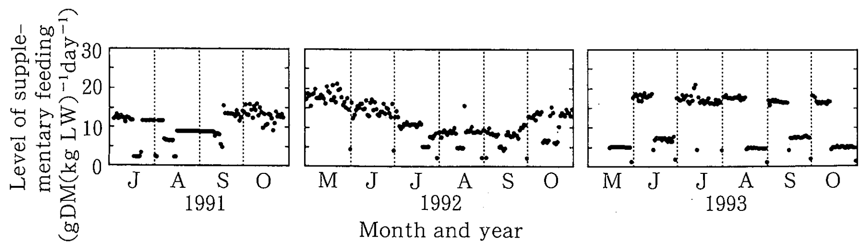

Fig. 2. Variations in level of supplementary feeding.

al variations with the years (Fig. 3c). The third year, 1993, had lower air temperatures and solar radiation in July than the other two years, and higher rainfall in June-August than the long-term mean (Table 1). The rainfall in May-October 1993 totaled to 3,172 mm.

2. Intake of supplementary feed

The intake of supplementary feed was 1.2-20.9 g (kg LW)$^{-1}$ day^{-1} on a DM basis (Fig. 4a) and 1.0-14.0 g (kg LW)$^{-1}$ day^{-1} on a digestible dry matter (DDM) basis (Fig. 4b). Their seasonal variation patterns were similar to that of the level of supplementary feeding (Fig. 2). Wheat bran, on an average, formed 29% of the ingested supplement on a DM basis.

3. Pasture characteristics

(1) Botanical composition

Bahiagrass, though it gave relatively low percentages (57-73%) in May, accounted for 84-98% of the yield in the other months (Fig. 5). The main unsown species in May were *Poa annua* L., *Veronica arvensis* L. and *Geranium thunbergii* Sieb. et Zucc. NADA and SAWAMURA[25], in a bahiagrass pasture in Kyushu, also observed lower percentage of bahiagrass in May (67%) than in June-November (87-98%). Such a reduced dominance of bahiagrass in May is regarded as one of the characteristics of the tropical pasture species growing in this region.

In paddock 3 in May 1992, Italian ryegrass oversown in the previous autumn formed 32% of the

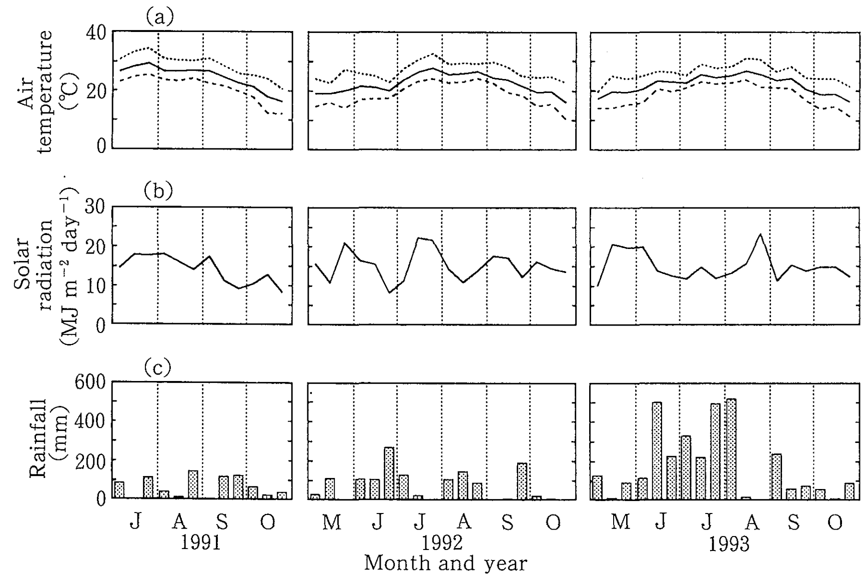

Fig. 3. Variations in air temperature (a), solar radiation (b) and rainfall (c).
(a) Ten- or eleven-day means of maximum (········), mean (——) and minimum (----) daily air temperatures.
(b) Ten- or eleven-day means of daily total short-wave solar radiation.
(c) Ten- or eleven-day totals of rainfall.

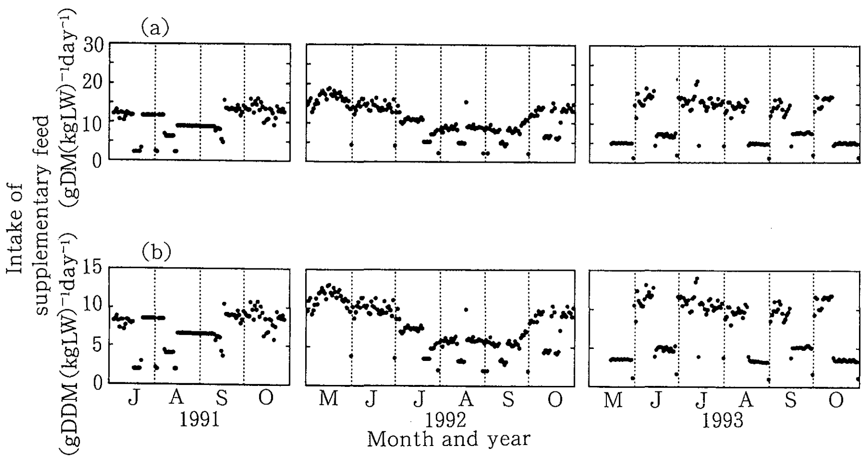

Fig. 4. Variations in dry matter intake (a) and digestible dry matter intake (b) of supplementary feed.

yield (Fig. 5). Owing to this, the percentage of unsown species was lower in paddock 3 (11%) than in paddock 2 (28%). Over-seeding of Italian ryegrass into bahiagrass pasture is a practice recommended for earlier initiation of spring grazing[27]. The present result demonstrates that this practice also has an advantage of depressing the growth of unsown species in spring. Maku lotus and Shaw creeping vigna oversown in 1993 rarely contributed to the yield.

In bahiagrass, the leaf percentage tended to be lower in July–August than in the other months (1992 and 1993 in Fig. 5). The stem percentage showed a reverse tendency. The percentage of dead materials gradually increased from July to October.

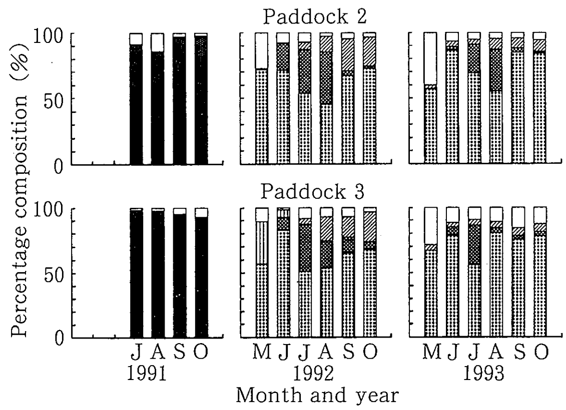

Fig. 5. Variations in percentage composition of plant species and plant parts of bahiagrass in pasture (on a dry matter basis).
Bahiagrass (■) and other species (□) in 1991. Leaf (▦), stem (▩) and dead materials (▨) of bahiagrass, Italian ryegrass (▥) and other species (□) in 1992 and 1993.

(2) Sward height and herbage mass

The sward height and herbage mass were in ranges of 7–40 cm and 5–360 g DM m^{-2}, respectively, and tended to increase from May to July or August and decrease thereafter, except for some sudden drops by the mowings (Figs. 6 a and 6 b). HIRATA *et al.*[15] reported that the before-grazing sward height of bahiagrass pasture was between 14 and 51 cm. HIRAKAWA *et al.*[12] reported that the herbage mass of bahiagrass pasture above a height of 5 cm was between 140–460 g DM m^{-2}. Thus, the sward height and herbage mass in the present system tended to be lower than those in the past studies. This is considered to be mainly due to the high stocking rate and mowings in the present system.

When a paddock was successively grazed, the sward height and herbage mass sometimes increased with the progress of grazing, though they mostly decreased (Figs. 6 a and 6 b). This result partly disagrees with the observations in other pastures[4,9], where the herbage mass always decreased with progressive grazing. However, the sward height and herbage mass can increase under grazing when herbage growth overwhelms herbage consumption by animals.

(3) Sward bulk density

The sward bulk density ranged from 3 to 24 g DM m^{-2} cm^{-1}, and showed different seasonal variation patterns with the years (Fig. 6 c). Since the mean herbage mass in a 0–5 cm layer was 230 g DM m^{-2}

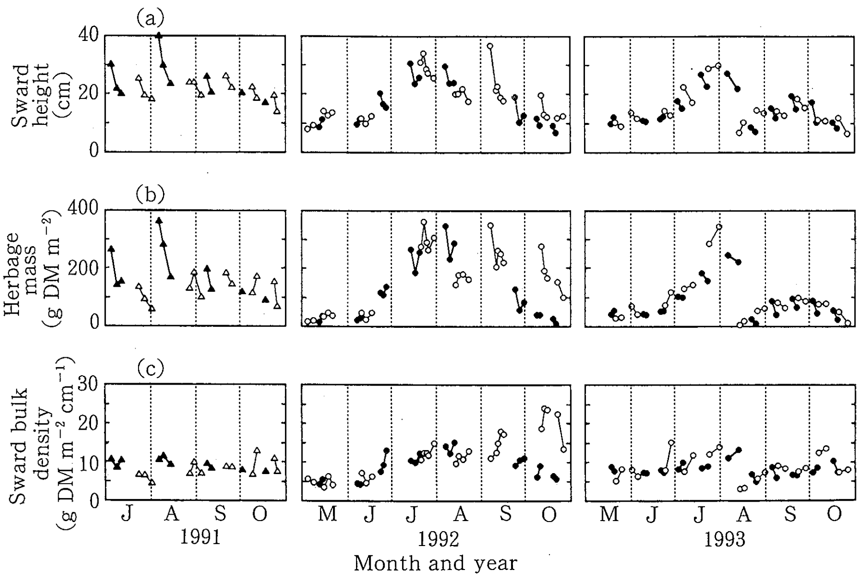

Fig. 6. Variations in sward height (a), herbage mass (b) and sward bulk density (c).
Paddocks 2 (▲) and 3 (△) in 1991, and paddocks 2 (●) and 3 (○) in 1992 and 1993.
Symbols connected by a line or lines are the data from a successive grazing period in one paddock.

(unpublished), the sward bulk density above ground level was estimated at 14–37 g DM m^{-2} cm^{-1}. According to CHACON *et al.*[5] and STOBBS[30–32], the aboveground sward bulk density of pangolagrass, rhodesgrass and *Setaria anceps* pastures were 9–37 g DM m^{-2} cm^{-1}, 1–17 g DM m^{-2} cm^{-1} and 3–33 g DM m^{-2} cm^{-1}, respectively. Thus, the aboveground sward bulk density in the present system was higher than that of rhodesgrass pastures, and similar to those of pangolagrass and *Setaria anceps* pastures.

As a paddock was progressively grazed, the sward bulk density showed variable responses in 1991, and generally tended to increase in 1992 and 1993 (Fig. 6 c).

(4) Digestibility

The dry matter digestibility of bahiagrass leaves, ranging between 0.52 and 0.67 g DM (g DM)$^{-1}$, decreased from May to August and leveled off thereafter (Fig. 7 a). The digestibility of Italian ryegrass, in a range of 0.62–0.77 g DM (g DM)$^{-1}$, decreased from May to July. The digestibility of pasture, which takes the digestibilities and proportions of the pasture components into account, decreased from May to August and leveled off thereafter, in a range between 0.50 and 0.73 g DM (g DM)$^{-1}$ (Fig. 7 b). In May to early June, the pasture digestibility usually maintained high values of more than 0.6 g DM (g DM)$^{-1}$.

Two facts contributed to this high digestibility of pasture in May–early June. First, bahiagrass leaves, which accounted for more than 50% of the yield (Fig. 5), maintained relatively high digestibility (Fig. 7 a). Second, in paddock 3 in 1992, the pasture contained a highly-digestible Italian ryegrass component (Figs. 5 and 7 a). When the contribution of Italian ryegrass was excluded, the pasture digestibility was in a range of 0.50–0.65 g DM (g DM)$^{-1}$, which lies almost in the middle of the variation range of the digestibility of tropical species[24].

4. Animal liveweight

The mean liveweight of animals was in ranges of 323–340 kg head^{-1}, 271–357 kg head^{-1} and 165–220 kg head^{-1} in 1991, 1992 and 1993, respectively (Fig. 8). The liveweight, except for some drops with changes in the herd composition, always increased. The liveweight gain was 34 kg head^{-1} in 1991 (118 days), 86 kg head^{-1} in 1992 (184 days) and 51 kg head^{-1} in 1993 (170 days). An analysis on the liveweight gain will be made in a future study.

In the present system, changes in the animal liveweight are the index of animal production. At the same time, the animal liveweight itself is a factor affecting the animal production. For example, the animal liveweight is considered to affect the animal production through the pasture/animal balance such

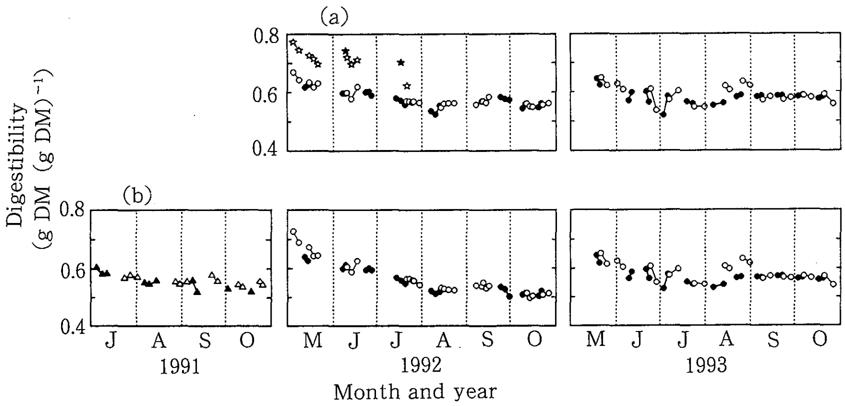

Fig. 7. Variations in dry matter digestibility of bahiagrass leaves and Italian ryegrass (a), and of pasture (b).
For the digestibility of pasture, refer to the text.
(a) Bahiagrass leaves in paddocks 2 (●) and 3 (○), and Italian ryegrass in paddocks 2 (★) and 3 (☆). Symbols connected by a line or lines are the data from a successive grazing period in one paddock.
(b) Symbols are the same as in Fig. 6.

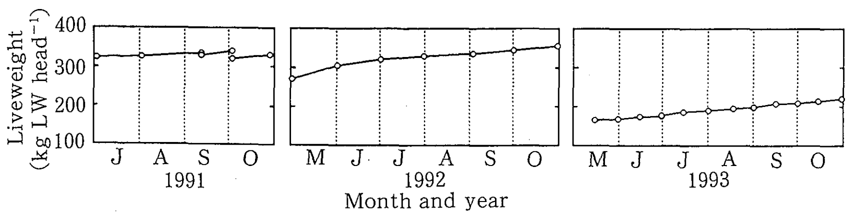

Fig. 8. Variations in mean liveweight of animals.

as herbage allowance.

5. Pasture/animal balance

The herbage allowance ranged between 6 and 740 g (kg LW)$^{-1}$ on a DM basis (Fig. 9 a) and between 3 and 400 g (kg LW)$^{-1}$ on a DDM basis (Fig. 9 b). In 1991, the herbage allowance always maintained low values. In 1992 and 1993, the allowance tended to increase from May to July or August and decrease thereafter, except for some sudden drops by the mowings.

When a paddock was successively grazed, the herbage allowance generally decreased with the progress of grazing, though it sometimes increased (Figs. 9 a and 9 b). The occurrence of the increase and decrease coincided with that of the herbage mass (Fig. 6 b). This is because both the animal liveweight (Fig. 8) and pasture digestibility (Fig. 7 b) did not vary greatly during each grazing period.

6. Grazing behavior

(1) Percentage grazing time

The percentage grazing time ranged from 23 to 87%, and showed different seasonal variation patterns with the years (Fig. 10 a). Kurosaki *et al.*[19] investigated behavior of Holstein cows grazing in the daytime a bahiagrass pasture at the Sumiyoshi Livestock Farm, and recorded a percentage grazing time of 58–100%. Thus, the percentage grazing time in the present system tended to be smaller than that reported by Kurosaki *et al.* As a reason for this, differences in the meteorological conditions, pasture characteristics, intake of supplementary feed and cattle breed would be listed[1,3].

As a paddock was progressively grazed, the percentage grazing time either increased or decreased (Fig. 10 a). According to Chacon and Stobbs[4], the grazing time of cattle on *Setaria anceps* pastures was

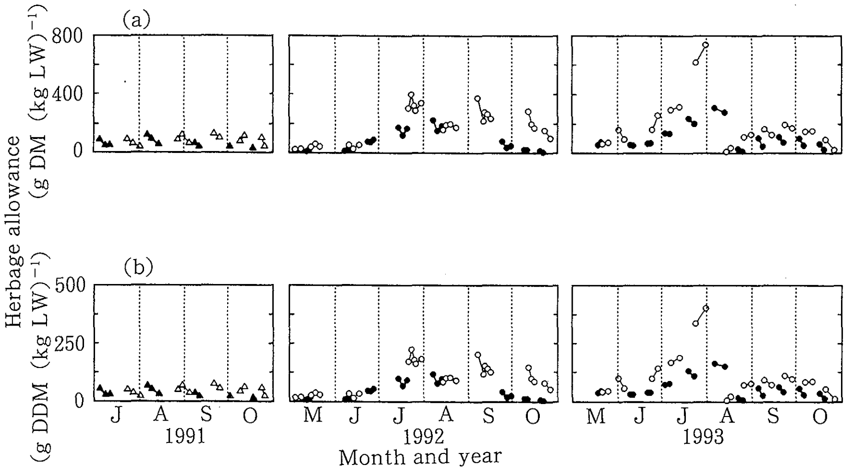

Fig. 9. Variations in herbage allowance on a dry matter basis (a) and on a digestible dry matter basis (b). Symbols are the same as in Fig. 6.

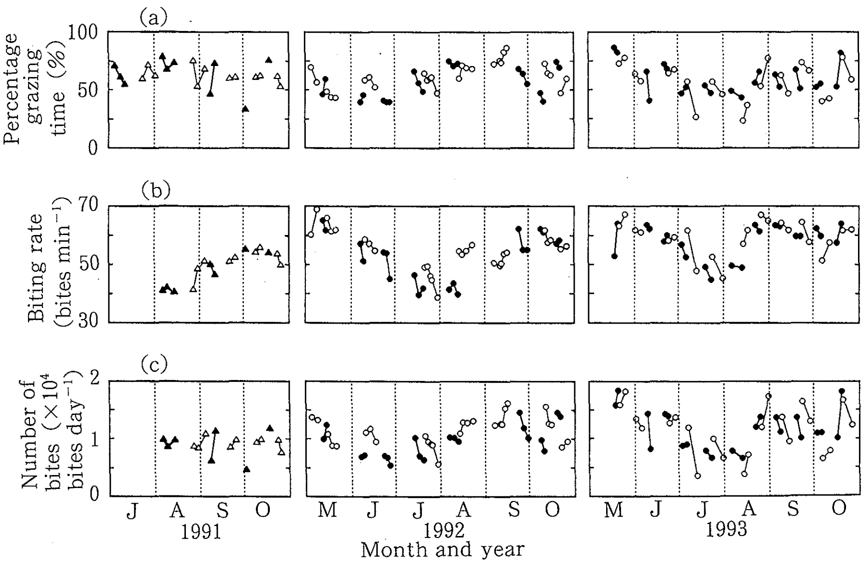

Fig. 10. Variations in percentage grazing time (a), biting rate (b) and number of bites at pasture (c). Symbols are the same as in Fig. 6.

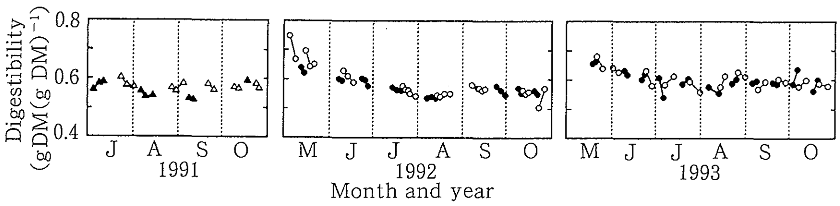

Fig. 11. Variations in dry matter digestibility of hand-plucked herbage. Symbols are the same as in Fig. 6.

shortest on the first day of a 10 or 14-day grazing period, increased in the mid-period and decreased thereafter. OLSON *et al.*[26] reported that the grazing time of cattle on crested wheatgrass pastures did not change or increased with progressive grazing of 2-3 days. Thus, there is a considerable variability in the grazing time response to progressive grazing.

(2) Biting rate and number of bites at pasture

The biting rate and the number of bites at pasture were in ranges of 39-69 bites min^{-1} and 3,600-18,400 bites day^{-1}, respectively, and tended to decrease from May to July or August and increase thereafter (Figs. 10 b and 10 c). In the literature, the biting rates of cattle grazing swards of *Setaria anceps*[4], temperate grasses[2,8,11,16-18,20,26] and alfalfa[6-8] are in ranges of 51-62 bites min^{-1}, 19-66 bites min^{-1} and 16-35 bites min^{-1}, respectively. Thus, the biting rate in the present system was in the ranges of grass swards and higher than that in alfalfa swards.

As a paddock was progressively grazed, the biting rate either increased or decreased (Fig. 10 b). This result partly disagrees with those from *Setaria anceps*[4] and crested wheatgrass[26] pastures, where the biting rate of cattle generally tended to increase with progressive grazing.

7. Hand-plucked herbage

The dry matter digestibility of hand-plucked herbage, ranging between 0.51 and 0.75 g DM (g DM)$^{-1}$, decreased from May to August and leveled off thereafter (Fig. 11). The digestibility of hand-plucked herbage was generally similar to or higher than the pasture digestibility (Fig. 7 b), and, on an average, the former was 0.02 g DM (g DM)$^{-1}$ higher than the latter. It is well accepted that grazing animals generally select high quality herbage from pasture. According to LUDLOW *et al.*[21] and STOBBS[31], diet digestibility of cattle grazing tropical grass pastures was 0.02-0.17 unit (on a DM or organic matter basis) higher than pasture digestibility.

As a paddock was progressively grazed, the digestibility of hand-plucked herbage showed variable responses (Fig. 11). This result disagrees with that from crested wheatgrass pastures[26], where the diet digestibility of cattle always decreased with progressive grazing.

Conclusions

All the factors investigated in this study showed a considerable variability with the year, season and/or progressive grazing. These factors, except for the meteorological factors and the level of supplementary feeding, are considered to be not independent of each other, but to have direct or indirect influences on each other. The meteorological factors and the level of supplementary feeding are regarded as factors exerting one-way influences on the other factors. Therefore, an analysis of the relationships between the factors is important for clarifying the mechanisms of the factor variabilities and characterizing the system. This analysis is made in the next paper.

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要　旨

東山雅一・平田昌彦 (1995)：バヒアグラス (*Paspalum notatum* Flügge) 放牧草地を利用した黒毛和種育成牛飼養システムの解析. 1. 家畜生産に影響を及ぼすと考えられる要因の変動. *Glassland Science* **41**, 104-113. 宮崎大学農学部草地畜産学講座 (889-21 宮崎市学園木花台西 1-1)

バヒアグラス放牧草地を利用した黒毛和種育成牛飼養システムにおいて，家畜生産に影響を及ぼすと考えられる様々な要因（気象，補助飼料，草地植生，家畜生体重，草地/家畜バランス，放牧行動，模擬採食草に関する要因）の変動を3年にわたり調査した。そして，各要因の変動範囲や年，季節および1つのパドックにおける放牧経過日数に対する反応などについて検討することにより，対象システムの特徴の一端を明らかにした。さらに，要因の変動の機作を理解し，システムの特徴を明らかにするうえでの要因間の関係の解析の重要性について指摘した。

キーワード：黒毛和種，草地植生，バヒアグラス，放牧行動，補助飼料.