Muhammad Mukhtar

Dry Matter Productivity & Grazing Characteristics in Dwarf & Normal Elephant Grass

DRY MATTER PRODUCTIVITY AND GRAZING CHARACTERISTICS OF DWARF AND NORMAL ELEPHANTGRASS

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PREFACE

Gratitude Praise Allah Swt. for the blessing a abundance of grace. This book shows the reported results a cultivars of dwarf elephantgrass (*Pennisetum purpure* Schumach) have recently been grown and examined for th growth characteristics in the tropical and sub-tropical regions the world.

The effects of planting density and cutting frequency dry matter productivity were compared in two years follow establishment among dwarf varieties (early-heading, DE a late-heading, DL) and normal varieties, Wruk wona (Wr) a Merkeron (Me), in the southern part of Kyushu, Japan. T planting densities examined were high (16 plants/m^2, 25 cm 25 cm of spacing), medium (8 plants/m^2, 50 cm × 25 cm), a low (4 plants/m^2, 50 cm × 50 cm) for Wr, DE and DL, and w only medium for Me. The cutting frequency was three tir with 60-day intervals in 2002 and two times with 90- intervals in 2003. Irrespective of the planting densities, dw varieties were higher in tiller number, leaf area index a percentage of leaf blade (PLB) than normal varieties, but lo in plant height and total dry matter weight at all plant densities in both years. With the increase in planting dens annual herbage dry matter yield (HDMY) increased. The ann HDMY was higher in 2002 (cut twice) than in 2003 (cut th times), and the difference in annual HDMY between the dw and normal varieties was reduced by planting at high density and cut twice. Even though the dry matter productivity was higher in the normal varieties than in the dwarf varieties at any planting density and cutting frequency, DL tended to show a stable productivity with high PLB irrespective of planting density and cutting frequency.

This book there are still many shortcomings, especially in terms of methods and approaches, is expected to itui criticism, suggestions and feedback from the readers, for the perfection of the writing of this scientific work in the future, it delivered many thanks.

Author

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1 DRY MATTER PRODUCTIVITY OF THE DWARF AND NORMAL ELEPHANTGRASSES AS AFFECTED BY THE PLANTING DENSITY AND CUTTING FREQUENCY

A. Introduction

Many cultivars of dwarf elephantgrass (*Pennisetu* *purpureum* Schumach) have recently been grown and examine for their growth characteristics in the tropical and sub-tropic regions in the world (CUOMO *et al.*, 1996; HANNA and MONSO 1988; KIPNIS and BNEI-MOSHE, 1988). Dwarf elephantgra facilitates hand-harvesting by farmers and is assessed to be mo suitable for grazing than normal variety (RUSLAND *et al.*, 199 WILLIAMS and HANNA, 1995). Dwarf varieties were differe from normal varieties in tiller number, mean tiller weight ar percentage of leaf blade in a preliminary study using the plan (ISHII *et al.*, 1998).

In order to recommend cultivation of dwa elephantgrasses to grass producing farmers in Miyazak Southern part of Japan, it is necessary to examine grow characteristics of dwarf elephantgrass as affected by planti density and cutting frequency in the year after establishment well as in the established year. In normal elephantgrass, grow and yielding characteristics such as dry matter yield, till density and leaf area index (LAI) were higher in a high-densi plot (8.2 plants/m^2) than in low-density plot (4.0 plants/m^2) by 20 – 30 % throughout the growing period (ITO *et al.*, 1989). It is natural that dry matter yield increased with the increase in planting density. However, since elephantgrass is propagated vegetatively with stem cuttings or rooted tillers (KIPNIS and BNEI-MOSHE, 1988), establishment efficiency decreases and its cost increases with the increasing planting density. Thus, it is necessary to investigate the effect of planting density on DMY and related growth characters. Cutting frequency is another important management practice for maintaining forage quality and guaranteeing the continuous regrowth of elephantgrass. It is known that the annual DMY is higher under less frequent cutting than under frequent cutting, because a larger amount of dry matter accumulates in the stem part under infrequent cutting. However, low leaf/stem ratio is associated with low forage quality such as low digestibility and low crude protein content (ISHII *et al.*, 1996b; SUNUSI *et al.*, 1997). SOLLENBERG and JONES (1989) shows that a dwarf elephantgrass of "Mott" produced excellent forage yield under the continuous grazing management and achieved the live weight gain of nearly 1 kg/day for the beef cattle in Florida, USA, which was superior to the ordinary "Pensacola" *bahiagrass*. Thus, the relationship between DMY and ratio of leaf to stem should be examined in the dwarf and normal elephantgrasses as affected by the cutting

frequency. The annual DMY of elephantgrass in the year o[f] establishment differs from that in the following year. The DM[Y] in the established year is used to increase the regrowth in th[e] following year (ITO *et al.*, 1988). The growth rate in th[e] following year (regrowing from the stubble) is higher than tha[t] in the transplanted year, if the overwintering percentage i[s] sufficiently high. In this study, only the plants in the year afte[r] establishment were used, since the productivity of elephantgras[s] in this region of Southern Kyushu island is closely correlate[d] with the overwintering ability (ISHII *et al.*, 1996a), as in som[e] tropical grasses (CAI *et al.*, 1999).

The objective of this study was to examine the effect o[f] planting density and cutting frequency on dry matte[r] productivity in the years after establishment in the dwarf an[d] normal elephantgrasses in the Southern part of Kyushu, Japan.

B. Materials and Methods

a. Plant materials

The research was carried out at the Experimental fiel[d] Station, Miyazaki University, Japan from May 2002 to Apri[l] 2003. The examined varieties were two normal varieties, Wru[k] wona (Wr) and Merkeron (Me), and two dwarf varietie[s] introduced from Thailand. Since the two dwarf varieties wer[e] definitely different in the heading date, early-heading variet[y] was termed DE and late-heading variety DL. Normal variety of Me was a leading variety in Miyazaki and used as a control variety.

As a basal dressing was fermented cattle manure at dose 600 g/m^2 and slaked lime at 400 g/m^2 applied in May. As additional dressing, 10 g of N, P_2O_5 and K_2O/m^2 of chemical compound fertilizer were applied three times in both 2002 and 2003.

In May 2003, soil at the top 5 cm layer were analyzed. The pH was measured with a pH meter (HM-7E, TOA Electronic Co. Ltd.), electric conductivity (EC) at soil : water = 1 : 5 (v/v) with an EC meter (CM- 40S, TDA Co. Ltd.) and chemical contents with a Dr. Soil kit (Fujihira Kougyou Co. Ltd.). The pH (H_2O) was 7.4, pH (KCl at pH 7) was 6.7, EC was 64.1 μS/cm^2. NO_3-N, NH_4-N and available P_2O_5 contents were estimated to be 1, 5, and 15.8 mg in 100 g soil, respectively.

b. Experimental Design

The experimental plots were arranged in a blocked design of Latin square method at three replications for each planting density. Each variety was planted at a high density (16 plants/m^2, 25 cm × 25 cm of spacing), medium density (8 plants/m^2, 50 cm × 25 cm), and low density (4 plants/m^2, 50 cm × 50 cm) except Me, which was planted only at the medium density. Plot sizes were 5 m^2 (2 m × 2.5 m), 7.5 m^2 (2.5 m × 3

m), and 12 m^2 (3 m × 4 m) for the high, medium and lo density, respectively. The plants were cut three times at abo 60-day intervals, on July 5, September 11 and November 23 2002, and two times at about 90-day intervals on July 31 ar November 3 in 2003. The cutting height was 10 cm above t ground.

c. Sampling Methods for The Growing Period

A single plant per replication (three replications f each density) was sampled and divided into herbage pa stubble part and underground part. The herbage part was cut 10 cm above the ground surface, and measured for plant heig (PLH), tiller number (TN), leaf area (LA) and dry matter weig (DMW) of leaf blade (LB), stem with leaf sheath (ST) and de part (D). The stubble part was cut at the ground surface, a measured for DMWs of LB, ST and D. The underground pa was measured for DMW of underground stem (UG) excludi roots. Fresh and dry matter yields were measured for five plar in each replication and three replications per variety.

d. Data Analysis

The data were analyzed statistically by the analysis variance and the difference in the mean value was calculated the LSD method at 5 % level.

C. Results

a. Climatic Conditions

Figure 1 shows mean air temperature, solar radiation and precipitation during the growing period in 2002 and 2003 from the data of Miyazaki Meteorological Observatory. Mean air temperature and solar radiation were generally higher in 2003 than in 2002, especially in July and August. Since the average precipitations in a normal year are 288 mm in July and 294 mm in August, the amount of rainfall was much larger, and mean air temperature and solar radiation were lower in July and August in 2002 than those in a normal year. In 2003, mean air temperature and solar radiation from late June to middle July were higher than in a normal year.

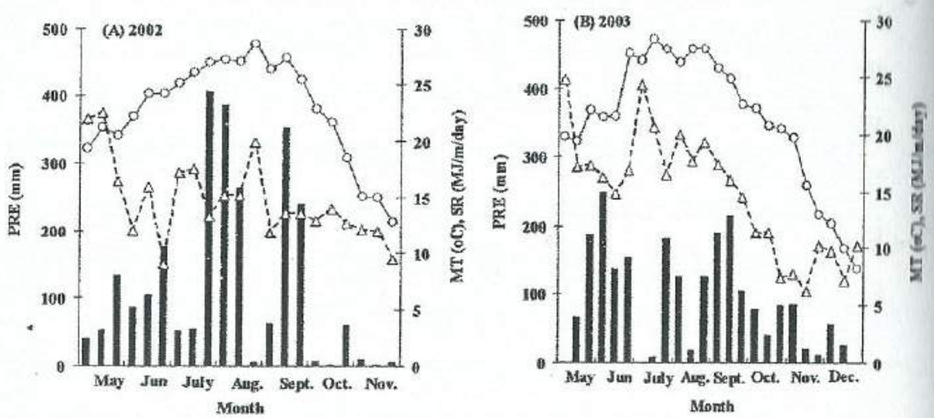


Fig. 1. The mean air temperature (MT, O), solar radiation (SR, Δ) and precipitation (PRE, ■) during the experimental period.

b. Growth Characters and Dry Matter Weight

The changes in growth characters and dry matter weight with time were compared among normal (Wr and Me) and dwarf (DE and DL) varieties cut three times in 2002 (Fig. 2) and two times in 2003 (Fig. 3).

Plant height was generally larger in normal varieties, Wr and Me, than in dwarf varieties, DE and DL in both years, except in November 2003 when DE and Wr had a similar PLH. Both the normal and dwarf varieties reached a maximum PLH in September and November in 2002 and 2003. Since the regrowth period from the first to the second cutting was longer in 2003 than in 2002, PLH in November 2003 reached almost 3 m in all varieties except for DL. This indicated that normal varieties and DE elongated stems after reproductive organ initiated. The PLH in Wr tended to be higher in the low-density plots than in higher density plot. On the contrary, PLH in DL was less than 2 m, irrespective of planting density, which matched with the previous study for the uncut vegetative height in dwarf varieties (SOLLENBERG and JONES, 1989; BURTON, 1989).

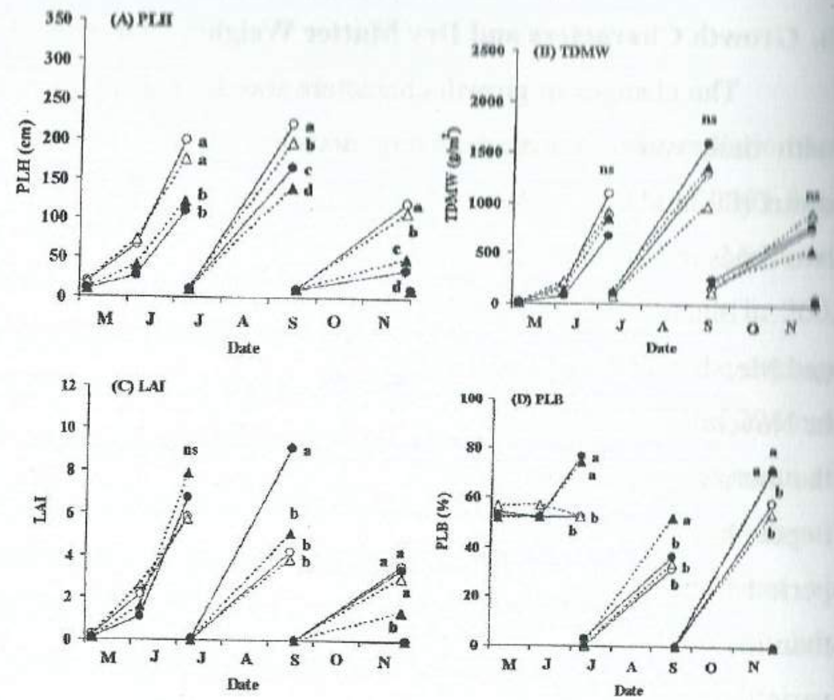


Fig. 2. Plant height (PLH, A), total dry matter weight (TDMW, B), leaf area index (LAI, C) and dry weight percentage of leaf blade (PLB, D) in 2002.

Wruk wona (Wr, ○), Merkeron (Me, Δ), Dwarf-early (DE, ●) and Dwarf-late (DL, ▲).

Arrows indicate the dates of cutting. Figures with different letters denote significant difference among varieties at 5 % level. ns: not significant.

In all varieties, total DM at the second cutting was larger than that at the first cutting in both years, but that at the third cutting in 2002 was lighter. Total DM among varieties tended to vary with the cutting times in both years. It tended to be larger in normal varieties than in dwarf ones at the first cutting in both years, but at the second cutting dwarf varieties produced larger total DM than normal varieties in 2002, and the difference in total DM among varieties was small at the last cutting in both years.

Arrows indicate the dates of cutting. Figures with different letters denote significant difference among varieties at the same cutting date at 5 % level. ns: not significant.

Leaf area index (LAI) was generally larger in the dwarf varieties than in normal ones, except at the third cutting in 2002 and at the first cutting in 2003. In 2002, LAI tended to decrease by repeated cuttings except in DE, while LAI at the first cutting was similar to that at the second cutting in 2003. The LAI was larger at both cuttings in 2003 than at all cuttings in 2002 due to longer regrowth period.

The dry weight percentage of leaf blade (PLB) was also larger in the dwarf varieties than in the normal ones in both years, except for DE at the second cutting in both years. The PLB at the second cutting was lower than that at the first cutting in all varieties in both years, but that at the third cutting in 2002 was similar to that at the first cutting.

Herbage yield

The annual herbage dry matter yield at each cutting, and PLB in the herbage part at each cutting in 2002 and 2003 are shown in Fig. 4.

The yield was higher in 2003 (cut twice) than in 2002 (cut three times) in all varieties. HDMYs were the highest in the second cutting, followed by the first cutting in both years and were the lowest in the third cutting in 2002 in all varieties. The present study indicated that the increase in cutting frequency (from two to three times) reduced the annual herbage dry matter yield. The annual herbage dry matter yield increased as planting density increased in all varieties in both years. The annual herbage dry matter yield was the highest in Wr, followed by Me, DE and DL in both years, while the difference in annual herbage dry matter yield among varieties was the least at a high density under twice cutting in 2003.

PLB was slightly affected by planting density, except for DE at the first cutting in both years when PLB tended to increase with the increase in planting density. It was higher in dwarf varieties than in normal varieties at all cuttings in 2002 and tended to be higher in both cuttings in 2003, except for DE at the second cutting.

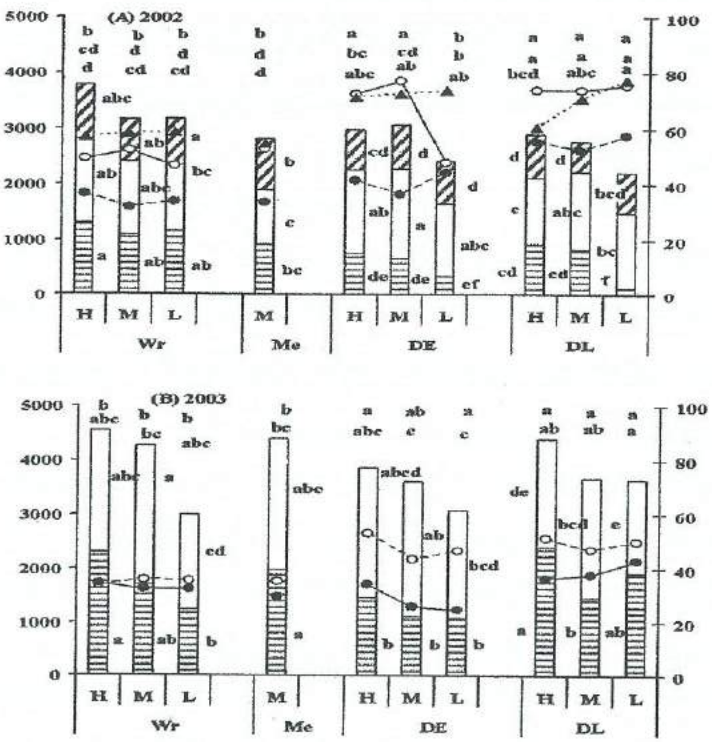


Fig. 4. Annual total of dry matter yield and dry matter weight of leaf blade (PLB) in 2002 (A) and 2003 (B).

Bar chart (HDMY) : First-cut (⊟), second-cut (□), and third-cut (□).

Dot chart (PLB) : First((1^{st})-cut (○), second (2^{nd})-cut (●), and third (3^{rd})-cut (▲).

Density : H (16 plants/m^2), M (8 plants/m^2), and L (4 plants/m^2).

Figures with different letters on the bar and besides the bar denote significant differences in PLB and HDMY, respectively, among different densities and varieties at 5 % level.

D. Discussion

Herbage dry matter yield increased with the increase in planting density from 4 to 16 plants/m^2. It was reported in elephantgrass that HDMY increased as planting density increased from 1.6 to 4 plants/m^2 by MIYAGI (1980), and from 4 to 8.2 plants/m^2 by ITO *et al.* (1989). Tiller number increased as planting density increased as reported by MIYAGI (1980) and ITO *et al.* (1989), while MTW tended to decrease as planting density increased in all cuttings, except for the first cutting in 2003 (when MTW was not influenced by planting density).

In 2003, HDMY showed the saturated response to planting density at medium to high densities in Wr and DE, while it tended to be saturated only at high density in DL. The difference in the response of HMDY to planting density between DE and DL in 2003 may be derived from the difference in leaf angel. Since DL had a more vertical leaves than DE in our observation, it is suggested that DL is more fitted to higher LAI for increasing the efficiency of solar radiation interception as observed in forage crops such as maize (GARDNER *et al.*, 1985) and in normal elephantgrass (ITO *et al.*, 1989).

HDMY decreased as cutting frequency increased from twice (2002) to three times (2003), although MTW also decreased severely as cutting frequency increased. Since the effect of cutting frequency was estimated by comparing the results obtained in the different years (2002 and 2003) in this study, it is necessary to consider the climatic conditions in the two years. Plants hardly suffered from the drought stress in both summers, though there was less precipitation in 2003. In normal elephantgrass, HDMY decreases with the increase in cutting frequency (MIYAGI 1985; WOODARD and PRINE 1991; SUNUSI et al., 1997). WOODARD and PRINE (1991) reported that the dwarf variety of Mott was less sensitive to the increased cutting frequency than normal varieties, although the two dwarf varieties in the present study were sensitive to cutting frequeny. This characteristic, insensitive to the cutting frequency may be due to the earlier recovery of ground cover by the leafage after harvest (GARDNER *et al.* 1985) because of larger TN in dwarf varieties than in normal varieties. It is necessary to compare the change in relative light intensity at the ground surface after cutting among varieties to support the above idea.

The dry matter productivity in normal elephantgrass is sensitive to the decrease in air temperature (MIYAGI 1980; ISHII *et al.*, 1996b). From the experiment in 2002, DL is assessed to be more sensitive to the decrease in air temperature than normal ones. A great decline of HDMY at the third cutting in DL may be attributed to the non-heading characteristics of DL. Since elongated stem functions as a storage organ, DL may lack in the sink capacity under a low air temperature at the third cutting in 2002.

LAI positively correlated with HDMY and negatively with PLB in both years. These correlations suggest that as planting density increases, LAI increases with the concomitant increase in PLB, and that as cutting frequency increases, LAI decreases with the concomitant decrease in HDMY and increase in PLB. These correlations should be considered in aspect to herbage quality (CUOMO *et al.*, 1996; ISHII *et al.*, 1996b; SUNUSI *et al.*, 1997).

E. Conclusions

Dwarf variety of dwarf-late shows a stable productivity at any planting density irrespective of cutting frequency. This characteristic may be derived from high capacity of tiller emergence at the cutting and high dry weight percentage of leaf blade in DL, compared with the normal varieties.

GRAZING TOLERANCE OF NORMAL AND DWARF ELEPHANTGRASSES PASTURE AT THE FIRST AND SECOND YEARS AFTER ESTABLISHMENT 2

A. Introduction

It is well known that both normal and dwarf elephantgrasses can produce greatly high herbage mass among tropical grasses under a cut and carry system (Ito et al., 1988; Woodard and Prine, 1991; Cuomo et al., 1996; Ishii et al., 1998; Tudsri et al., 2005), and they can be also utilized under a grazing system (Bose et al., 1970; Sollenberger and Jones, 1989). As for minimizing problems associated wsith rapid growth and early stem-hardening potentials of elephantgrasses (Ishii et al., 1995; Muia et al., 1999), an intensive grazing management to maintain the tolerance plant height for grazing use must be applied to a elephantgrass pasture. Such a grazing system has generally proved to fit to the management skill and/or desires of most cattle producers in Florida, USA (Williams and Hanna, 1995).

Use and management of elephantgrass varieties need to reflect their plant type and growth habit (Ito and Inanaga, 1988). Normal elephantgrasses with a tall plant type and rapid growth habit should be more tolerance for a cut and carry system, while dwarf elephantgrasses with a short plant type for a grazing system. However, since dwarf elephantgrasses were bred in 1980's in Florida, USA (Hanna and Monson, 1988; Hanna et al., 1993), information on the adaptability of normal and dwarf elephantgrasses to the grazing system has not been accumulated yet. It is necessary to determine the growth potential in spring and regrowth potential after defoliation of these elephantgrass pastures under the grazing system.

In addition, a perennial use of elephantgrass pasture should be verified in a couple of years after establishment in southern part of Japan, which is prone to frosting (Ishii et al., 2000). As bahiagrass is one of the most tolerant species to the frosting, it has been utilized under a grazing system for more than 30 years in southern part of Japan (Hirata and Fukuyama, 1997; Hirata, 1998, 2000; Pakiding and Hirata, 1999) as well as in Florida, USA (Adjei et al. 1980). As for comparing the grazing suitability between elephantgrass varieties transplanted on a bahiagrass pasture, production and utilization of any varieties or species should be compared in a monoculture (Adjei et al., 1980), while they can be affected by each other under the mixed cultivation of 3 elephantgrass varieties and bahiagrass in the present study. However, if production and utilization can increase by transplanting elephantgrass on a bahiagrass pasture, this innovation is necessary to be examined in this frost-prone area.

Therefore, this study was conducted to determine the growth and utilization potentials in normal and dwarf

elephantgrasses transplanted on a bahiagrass pasture and to evaluate the grazing habit of dairy cattle on a elephantgrass pasture in Miyazaki, Japan.

B. Materials and Methods

a. Experimental Design and Management

The research was carried out in a paddock of Sumiyoshi Field, Miyazaki University during the growing seasons in 2005 and 2006. The examined elephantgrass (*Pennisetum purpureum* Schumach) varieties were normal variety of Wrukwona (Wr) and dwarf varieties of early-heading type (DE) and late-heading type (DL), introduced from Department of Livestock Development (DLD) and Dairy Promotion Organization (DPO), Thailand, respectively in 1996.

The paddock (9 m × 36 m) was established on a bahiagrass (*Paspalum notatum* Flügge cv. Pensacola) pasture by transplanting rooted tillers of elephantgrass varieties from the overwintered stubbles in mid-September 2004. The paddock was connected with a resting area (20 m × 62 m) with shelter trees and a watering place via a gate on a 9-m side, and was divided into 6 plots (9 m × 6 m each) in 2 replication blocks (9 m × 18 m each). Within each block, the 3 elephantgrass varieties were systematically (not randomly) allocated to the 3 plots in the order of Wr, DE and DL from the gate side, to minimize the possible adverse effect that the tall Wr had on animals' exploration of the whole paddock area. Plant density was 4 plants/m^2 with a spacing of 1 m × 0.25 m (6 rows per plot).

After overwintering, stubbles were cut near to the ground level in late March in 2005 and 2006. The paddock field received chemical compound fertilizer at the start of the growing season in May and after each grazing period both years at rates of 5 g/m^2 of N, P_2O_5 and K_2O per application.

Table 1. Meteorological conditions during grazing periods in 2005 and 2006.

Year	Grazing period	Date	Weather	Sunshine hour (hr/day)	Maximum temp. (°C)
2005	1	June 30	Fine and hot	8.0	34.5
	2	July 31	Fine and cloudy	4.9	32.7
	3	August 31	Fine and hot	3.4	28.7
	4	November 17	Cold	8.3	18.7
2006	1	June 1	Fine and hot	10.9	29.5
	2	July 11	Fine and hot	6.9	29.8
	3	August 17	Fine and hot	11.7	32.7
	4	September 28	Cloudy	4.0	28.2
	5	November 20	Cold	6.3	15.6

From June to November in 2005, the paddock was grazed 4 times by 15 Holstein cows and 3 Japanese Black cows for periods of 7.5 hr in daytime at intervals of 30 or 77 days (Table 1). In 2006, the paddock was grazed 5 times by 16 Holstein cows and 2 Japanese Black cows for periods of 5 hr in daytime at intervals of 36-52 days. Weather was fine and hot in

all grazing days, except for July 31, 2005 and the last grazing days both years. When animals were not used for the experiment, they grazed bahiagrass pasture in daytime and were indoor-fed by concentrates at the milking.

b. Measurements of Plant and Grazing Behavior by Animals

Sampling of elephantgrass was conducted at both pre- and post-grazings by selecting 3 plants from 3 rows (rows 2, 4 and 6) per replication, and totally 6 plants per variety. Plants were divided into the herbage parts, cut at 10 cm above the ground surface both before and after grazing. Measured characters were tiller number (TN), plant height (PH), and dry matter weight (DMW) of leaf blade (LB), stem inclusive of leaf sheath (ST) and dead parts (D) of the herbage parts. Herbage consumption (HC) was estimated as the difference between pre- and post-grazing herbage dry matter yields (HDMYs), which were calculated by herbage DMW × plant density in May of each year and by herbage DMW × $1/(0.25)^2$ for elephantgrass and bahiagrass, respectively. Percentage overwintered plants (POP) and regrown tiller number (RTN) were measured for all elephantgrass plants in the paddock in late May 2005 and 2006.

Grazing behavior by 6-8 focal animals was recorded using a direct, continuous monitoring method for 7.5 hr (9:30–17:00) and 5 hr (9:30–14:30) in 2005 and 2006, respectively.

The shortened duration of observation in 2006 was due to the initiation of rumination in the afternoon, when all cattle never grazed on grasses. Grazing behavior was classified into grazing on grass species or varieties, standing without grazing, lying without grazing and drinking water, but not into ruminating.

c. Statistical Analysis

Statistical differences in the mean value of plant characters among elephantgrass varieties and percentage time spent by cattle were tested by analysis of variance (ANOVA) and least significant difference (LSD) method at 1% and 5% levels.

C. Results

a. Overwintering Ability and Plant Persistence

Percentage overwintered plants (POP) and regrown tiller number (RTN) in late May are shown in Fig. 1. Both POP and RTN were highest in DL, followed by Wr and DE both years, while the varietical differences in POP and RTN were smaller in 2006 than in 2005. Plant density remained almost constant during the growing season in each year.

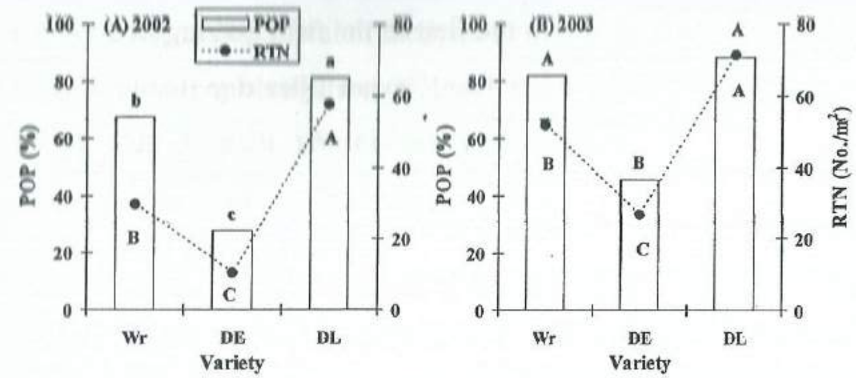


Fig. 1. Percentage of overwintered plants (POP) and regrown tiller number (RTN) in the overwintered plants on May 26, 2005 (A) and May 23, 2006 (B).
Variety : Wrukwona (Wr), dwarf-early (DE) and dwarf-late (DL).
Values with different capital and small letters denote significant difference at 1% and 5% levels, respectively.

b. Plant Characteristics

Temporal changes in plant characters are shown in Figs. 2 and 3. Plant height (PH) was always greater in Wr than in DE and DL. Both pre- and post-grazing PHs in Wr increased over the growing season, while those in DL remained stable. The large PH increase in DE between the third and fourth grazings in 2005 was due to stem elongation accompanied with the heading, while the fourth grazing in September 2006 suppressed heading of DE severely to limit the increase in PH after the fourth grazing in 2006. Tiller number (TN) was highest in DL followed by DE and Wr, and increased from the first to the third or fourth grazing in 2005 and from the first to the fifth grazing in 2006 for all varieties. On the other hand, mean tiller dry matter weight (MTW) was significantly greater in Wr than in two dwarf varieties both years. The increase in MTWs of DE and DL over the growing season was restricted to less than 10 g DMW at all grazings both years. Herbage dry matter weight (HDMW), as TN × MTW, was larger in Wr than in two dwarf varieties both before and after grazing. Pre-grazing HDMW increased from the first to the fourth grazing for all varieties in 2005 and from the first to the third grazing for all varieties in 2006. The increase in HDMW was markedly larger at the fourth grazing than at previous grazings in 2005, because of extended rest period of more than two months, while the increase in HDMW was limited at the fifth grazing in 2006, due to the declining air temperature in this rest period. Leaf area index (LAI) was generally highest in DL, and lowest in DE both years. Percentage leaf blade (PLB) was higher in DE and DL than in Wr, except for the fourth grazing in 2005 when PLB in DE dropped to the same level as in Wr. DL showed stable PLB values above 60 % until the fourth grazing both years.

The temporal changes in DMW ratio of leaf blade to stem inclusive of leaf sheath (LB/ST) among four and five grazings are shown in Fig. 4. Pre-grazing LB/ST was larger in two dwarf varieties than in Wr both years, except for DE at the

fourth grazing in 2005, which dropped its ratio to the same value as Wr due to stem elongation. Higher PLB was consistent with larger LB/ST in DL throughout the whole growing seasons. Gradual decline in LB/ST suggested that stem capacity increased from the first to the fourth or fifth grazing in all varieties. Post-grazing LB/ST decreased below 0.5 in all varieties, except at the first grazing in 2005 and at the second grazing in 2006 when a considerable number of leaves attached in the lower positions of stem node escaped defoliation by cattle.

e. Herbage Cconsumption and Grazing Behavior

Changes in herbage consumption and its LB/ST ratio (HC and LB/STc, respectively) are shown in Table 2.

In 2005, HC increased from the first through the fourth grazing in all varieties, while LB/STc had a higher ratio of above 10 at the first and second grazings than at the latter grazings for dwarf varieties and tended to decrease toward the fourth grazing in all varieties. Contrarily in 2006, HC increased from the first to the third or fourth grazing and then decreased through the fifth grazing in all varieties except for Wr which had highest HC at the last grazing, while LB/STc consistently decreased from the first through the fifth grazing in all varieties, and dwarf varieties had higher LB/STc than Wr from the second to the fifth grazing. Percentage utilization (PU) of herbage was highest in DL, followed by DE and lowest in Wr and bahiagrass both years. Animals grazed more than half of herbage in dwarf elephantgrasses, while they left more than half of herbage uneaten in Wr, especially at the final two grazings both years.

Grazing time spent by animals during each grazing period is shown in Fig. 5. In 2001, grazing time on bahiagrass was highest among 4 grazing times, while the difference between time on napiergrass varieties and that on bahiagrass tended to be reduced as the grazing season progressed. In 2005, grazing time on bahiagrass was reduced faster than in 2001, while that on DL was highest from the second to the fifth grazing, followed by Wr and DE. Compared with HC, grazing on Wr and DL was generally more efficient in grazing herbage than that on DE and bahiagrass, based on HC per percentage grazing time. Grazing time was shorter on the sunny and hot days in June and August 2001, and in June, July and August 2005 than that on the cloudy days in July 2001 and in September 2005 and that on the cold days in November both years (Table 1).

(A) 2005

Grazing period		Species or variety[1] Wr	DE	DL
1	HC[2]	41.4	10.8	44.1
	LB/STc[3]	4.0	99.5	12.4
	PU (%)	46.5	57.9	64.1
2	HC	119.8	51.7	73.5
	LB/STc	22.9	25.1	106.8
	PU (%)	41.1	67.7	52.3
3	HC	140.5	82.8	199.0
	LB/STc	1.0	124.4	4.3
	PU (%)	32.4	64.8	78.0
4	HC	333.7	214.0	372.4
	LB/STc	1.5	1.8	6.2
	PU (%)	33.8	41.7	69.1
Annual mean	HC	158.9	89.8	172.3
	LB/STc	7.3	62.7	32.4
	PU (%)	38.5[B4)]	58.0[A]	65.9[A]

(B) 2006

Grazing period		Species or variety[1] Wr	DE	DL
1	HC[2]	68.9	10.6	118.6
	LB/STc[3]	32.2	34.1	7.2
	PU (%)	37.1	77.5	89.0
2	HC	191.8	21.7	168.7
	LB/STc	0.9	62.4	9.8
	PU (%)	27.2	48.0	71.1
3	HC	110.3	54.2	307.3
	LB/STc	0.7	6.5	3.7
	PU (%)	9.4	51.8	70.8
4	HC	164.5	143.2	186.4
	LB/STc	0.7	1.5	7.9
	PU (%)	14.8	78.5	59.7
5	HC	284.3	6.3	140.8
	LB/STc	0.8	0.8	4.6
	PU (%)	18.1	5.2	45.1
Annual mean	HC	164[A4]	47.2[B]	184.4
	LB/STc	7.1	21.1	6.6
	PU (%)	21.3[B]	52.2[AB]	67.1[A]

1) Species or variety : Wrukwona (Wr), dwarf-early (DE), dwarf-late (DL) and bahiagrass (Bahia).
2) HC = Pre-grazing herbage dry matter yield (HDMY) – post-grazing HDMY

3) LB/STc = (Pre-grazing leaf blade dry matter yield (LBDMY) – post-grazing LBDMY/
4) (Pre-grazing stem with leaf sheath dry matter yield (STDMY) – post-grazing STDMY).
5) Values with different letters denote significant difference varieties at 1% level.

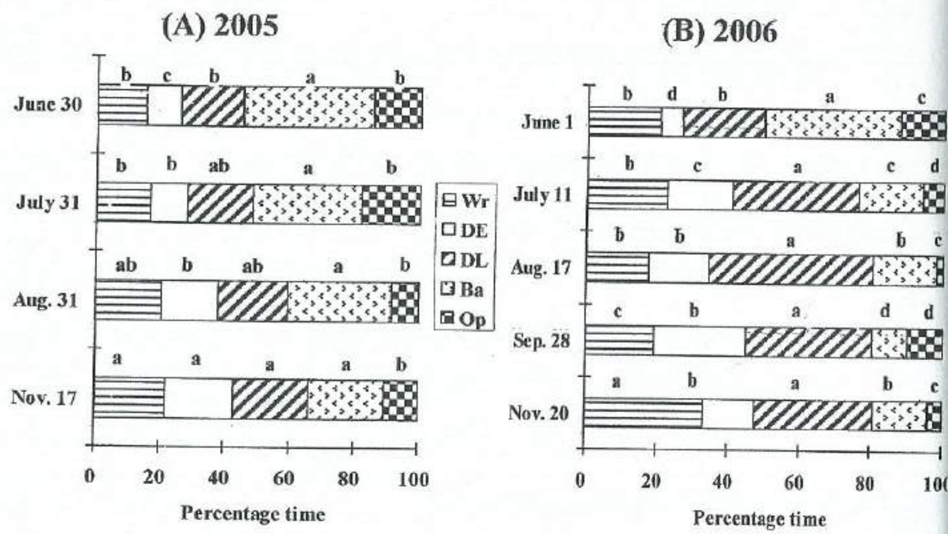


Fig. 5. Percentage grazing time spent by animal during each grazing period in 2005 (A) and 2006 (B).

Wr : Wrukwona, DE : dwarf-early, DL : dwarf-late, Ba : Bahiagrass, Op : Other plants. Values with different letter denote significant difference among varieties at 5% level.

D. Discussion

a. Overwintering Ability and Plant Persistence of Elephantgrass Varieties

The overwintering ability assessed by POP differed among elephantgrass varieties, although this variation in POP among varieties reduced greatly at the second overwintered season, mainly due to large stubbles accumulated against frosting at the end of growing season in 2005. The lowest POP for DE in May 2005 can be primarily explained by 2 facts. The first is the strong sensitivity to low temperature for DE (Ishii et al., 1998) and the second is to transplant larger tiller at about 50 cm of length in September 2000, which suppressed tillering severely due to the apical dominance of mother tillers and reduced the sites for regrowth (tiller buds) in the next year.

The variation in POP among varieties was larger under the cut and carry system than under the present grazing system where the stubbles remained above 30 cm, if compared at the same year after establishment. Therefore, as for plant persistence, all elephantgrass varieties can be tolerant to the rotational grazing use.

b. Plant Characteristics in The Second and Third Years After Establishment Under the Grazing

Grazing was conducted in this experiment at four and five times in the second and third year after establishment, respectively, since about one-month rest periods in the hot summer season with the prolonged rest period at the last cooler season were necessary to recover leafage in dwarf varieties both years. The start of grazing can be advanced by one month in the third year than in the second year after establishment, which made the difference in annual total grazing times between the second and third year after establishment. Climatic conditions in May were more favorable for the growth of elephantgrass in 2006 than in 2005, when mean air temperatures were 20.6 °C and 21.3 °C and total solar radiations were 6.75 MJ/m^2/day and 10.42 MJ/m^2/day in 2005 and 2006, respectively. In addition, number and DMW of stubbles were extremely larger at the last grazing of the previous year in 2005 than in 2001. These conditions seemed to stimulate the regrowth of elephantgrass after overwintering at the third year in 2006. However, since the grazing time was based on the regrowth of dwarf varieties in the present rotational grazing system, the rest period seemed to be longer than the optimum for grazing in Wr. Therefore, it can be assumed that high DMW tended to accumulate in the stubbles with the time of grazing in Wr due to the longer rest period than the optimum.

The last grazing was conducted in mid-November both years, since this season belongs to late autumn just before the first frost, when the averaged first frosting date is November 23

from the data of Miyazaki Meteorological Observatory. As suggested in LAI and PLB at the last grazing, slight frost that occurred just before these grazings both years had a negligible effect on the life of leaf blade and grazing suitability. Thus, a elephantgrass pasture, especially with a dwarf variety, can function as autumn-saved pasture (ASP) and the dwarf variety has a tendency to fit a broad range of rest period, compared with the strictly frequent grazing necessary for protecting deterioration of grazing suitability and herbage quality in normal variety of elephantgrass (Muia et al., 1999).

After grazing, dwarf varieties maintained average plant height over 30 cm, which is assessed as enough stubbles for the regrowth as remaining sources of leaf area, carbohydrate and nitrogen (Tudsri et al., 2005). Thus, plant persistence during the growing season in elephantgrass pasture could not become a matter for consideration, even though normal and dwarf elephantgrass varieties are classified into bunch grass without stolon (Hanna and Monson, 1988; Hanna et al., 1993).

Extremely high ratio of LB/ST or PLB in consumed herbage, due to the defoliation by cattle mostly at the leaf junction of elephantgrass tillers, suggests the high digestibility and diet selectivity in the tropical grasses (Chacon et al., 1978). These situations seemed to be accelerated with the grazing from the increase in TN, since a number of tiller buds attached on the elongated stem nodes were initiated to emerge once the mother tiller was defoliated by the grazing cattle and these smaller tillers used to have higher ratio of LB/ST than their mother tiller (Fukuyama and Ito, 1997). In addition, this regrowth system from the tillers attached on the elongated stem nodes was favorable for the immediate land cover of leafage, compared with that only from the underground stem nodes. However, regrowing tillers on the elongated stem nodes tended to be larger at the nodes near to the ground in dwarf varieties, due to the restriction of stem elongation (Hanna and Monson, 1988), than at the higher positioned nodes far from the ground level in normal variety. This seemed to be one of the mechanisms for promoting tillering ability in the dwarf varieties. If mother tiller in the normal variety was hardly defoliated by cattle, then, the growth of normal variety continued to elongate its PH, which resulted in the hardness for cattle to roll herbage by their tongue easily, just in the case of Wr at the third grazing and thereafter both years.

Thus, even though normal Wr produced higher HDMY before each grazing than dwarf varieties, low PLB and high PH with live leaves attached on the higher nodal positions in Wr hindered cattle from grazing severely. Based on these conditions, both dwarf varieties were more tolerance for the grazing system than Wr, and especially DL was the most

tolerance because it produced stable PLB and had higher POP with RTN than DE.

c. Time Spent by Grazing Animal on Elephantgrass Varieties, Compare with Bahiagrass

From the first to the third or fourth grazing, grazing time on dwarf napiergrass varieties extended in accordance with the increase in HC and temporal change in tiller anatomy or architecture to increase total (sward) and leaf bulk densities (Sollenberger and Burns, 2001), which were more favorable for cattle to ingest herbage as a herbivore. Contrarily, in the case of normal napiergrass variety, leaf blades attached almost horizontally on the elongated nodes were so easy to be vibrated by the grazing action. The percentage grazing time on Wr increased to the limited extent with the increase in PH, compared with the consistent increase in percentage grazing time on DE and DL from the first to the third or fourth grazing. In addition, grazing on dwarf napiergrasses tended to be earlier on each of the grazing day, which denoted the high palatability in dwarf napiergrass temporally from the first to the fourth or fifth grazing both years. In bahiagrass, reduction in grazing time from the first to the fourth grazing both years seems to be caused by the increase of HC in napiergrass and seasonal decline in dry matter digestibility and N concentration of bahiagrass (Hirata et al., 2006).

Since PU of herbage was lowest and dry matter productivity was highest in Wr (Mukhtar et al., 2006) among napiergrass varieties, HDMY increased to retain more than half of herbage after each grazing, and finally, HDMY in Wr was the highest markedly among the examined varieties.

As total grazing time was influenced primarily by weather conditions in the summer season (Sollenberger and Burns, 2001), hot and sunny days suppressed grazing of cattle more than cloudy or cold days as shown in Table 5.1. However, as suggested in temporal change in post-grazing PH and LAI, grazing on DL was almost completed in each grazing day.

E. Conclusions

As the percentage utilization was higher in two dwarf elephantgrasses than in normal Wr, dwarf elephantgrasses were tolerance for the rotational grazing system. Since DL showed highest overwintering ability and stable percentage leaf blade over four or five grazings in a couple of following years after establishment, DL was the most tolerance for an intensive grazing system in the examined elephantgrass varieties.

ROTATIONAL GRAZING SYSTEM FOR BEEF COWS ON DWARF ELEPHANT GRASS PASTURE FOR TWO YEARS AFTER ESTABLISHMENT 3

A. Introduction

Rotational grazing is a method of intensive grazing management that allows livestock continuous opportunities to consume fresh forage at an active growth stage. The grazing system and associated management practices can substantially influence grazing patterns and use of a pasture (Chacon *et al.*, 1978). The selection of defoliated herbage is probably the most important effects of grazing animals on pasture, with consequences such as leaf area reduction in combination with a reduction in carbohydrate storage, tiller development, leaf and stem growth (Chaparro *et* al., 1996, Sollenberger and Burns, 2001).

Beef calf breeders are eager to obtain a stable sources of self-supplying feed that protects against cattle disease, which will probably come from imported herbage. From our previous research, we know that dwarf elephantgrass (*Pennisetum purpureum Schumach)* of the late-heading type (DL) has a higher percentage of leaf blade than other normal and dwarf varieties (Mukhtar, 2006). DL elephantgrass is also the most suitable for grazing use among examined elephantgrass varieties because it is shorter, with a higher percentage of leaf blade than other varieties (Mukhtar and Ishii, 2007).

In a preliminary study, we found that 0,05 ha of DL elephantgrass pasture had the capacity to graze three beef cows for a week, with approximately a one-month rest period, without concentrated feeding in the hot summer season, in the 2 years following establishment (Mukhtar, 2007). However, to enhance our understanding of rotational grazing on DL elephantgrass pasture, it is important to identify such variables as herbage consumption, carrying capacity and sward management techniques to increase the live weight (LW) of beef cows, and to maintain the live weight (LW) of breeding beef cows. There have been several study reporting the high forage quality of dwarf elephantgrass in Florida USA (Woodard and Prine, 1991; Sollenberger *et al.*, 1993; Williams and Hanna, 1995), Georgia, USA (Hanna and Monson, 1988; Hanna *et al.*, 1993), Taiwan (Hsu and Hong, 1993) and Thailand (Tudsri *et al.*, 2002a, 2002b).

In this study, a rotational grazing system for DL elephantgrass pasture was examined without feeding cattle with concentrate or supplied roughage to determine herbage consumption, carrying capacity and daily gain of breeding and raising beef cows on DL elephantgrass pasture for the 2 years following establishment.

B. Research Methods

a. Pasture Management

The research was carried out in the Experimental Field, Miyazaki University, during rainy season from May 2003 to November 2004. The dwarf and late heading variety of elephantgrass (*Pennisetum purpureum* Schumach) was obtained from the Dairy Promotion Organization (DPO), Thailand. The area of each paddock was 0.05 ha, and four paddocks were established for rotational grazing by transplanting rooted tillers of elephantgrass at about 20 cm in length. The elephantgrass plants were sown at a density of two plants per m^2, and space in a 1 m × 0.5 m pattern. Each paddock was fertilized with 20 g N/m^2/year of chemical compound fertilizer ($N:P_2O_5:K_2O$ = 13%:13%;13%) applied in four split applications every year. Fertilization was conducted at pre-grazing and post-grazing. Each paddock was connected to the watering facility and trees for shelter via a road.

b. Grazing Design and Animal Measurements

Three breeding beef cows (not pregnant) were used for the rotational grazing and the grazing schedule was totally 3 cycles in 2003 and 6 cycles in 2004. The average liveweight (LW) during rotational grazing was 446.9 kg/head and 378.6 kg/head in 2003 and 2004, respectively. LW was measured at 11.00 hours when cows moved to a different paddock. Each paddock were grazed 1-week from the first to third cycles in 2003 and from the first to sixth cycles in 2004. The rest period and the length of the last grazing cycle was determined depending on the herbage mass in each paddock in both years , because the pre-grazing regrowth for the last cycle was variable among paddocks due to the air temperature becoming colder overtime. No concentrates were given to the beef cows, but they did have *ad libitum* access to mineral supplements during the rotational grazing. Paddocks were not moved throughout the experimental period.

c. Plant Measurements

Six DL elephantgrass plants were sampled by using the line transect method both before and after grazing in each paddock. Herbage mass before and after grazing was determined by cutting plants at 10 and 30 cm above the ground level, respectively. The measured characters were tiller number, plant height, leaf area index and dry matter (DM) mass of leaf blades, stem with leaf sheath and dead parts. Plant heights before and after grazing, and tiller number before grazing were determined in four set rows (200 and 40 plants in 2003 and 2004, respectively) per paddock.

d. Calculation of Herbage Production, Herbage Consumption, Herbage Allowance, DM Intake and Carrying Capacity

Herbage production (g DM/m^2) during the grazing period was estimated by the by the sum of the crop growth rate (CGR) whitin a certain grazing period, which was the difference between herbage mass before and after grazing in the following grazing periods divided by the rest period. Herbage consumption by beef cows (g DM/m^2) was estimated by the sum of the difference between herbage mass before and after grazing, and herbage production during the grazing period. Herbage allowance (kg DM herbage mass per 100 kg LW) was calculated by the herbage mass before grazing, divided by the total LW of the grazing cows. DM intake (g/kg LW/day) was calculated by the herbage consumption during the grazing period divided by stocking density, cow LW and grazing period (days). Carrying capacity (cow-days, CD) was calculated by the product of stocking density (No. per ha) and grazing period (days), corrected for cow LW at 500 kg.

e. Statistical Analysis

Statistical significance with respect to the differences in the mean value of plant characters in DL elephantgrass was assessed by using the analysis of variance (ANOVA) and least significant difference (LSD) method at the 5% and 10% levels.

C. Results

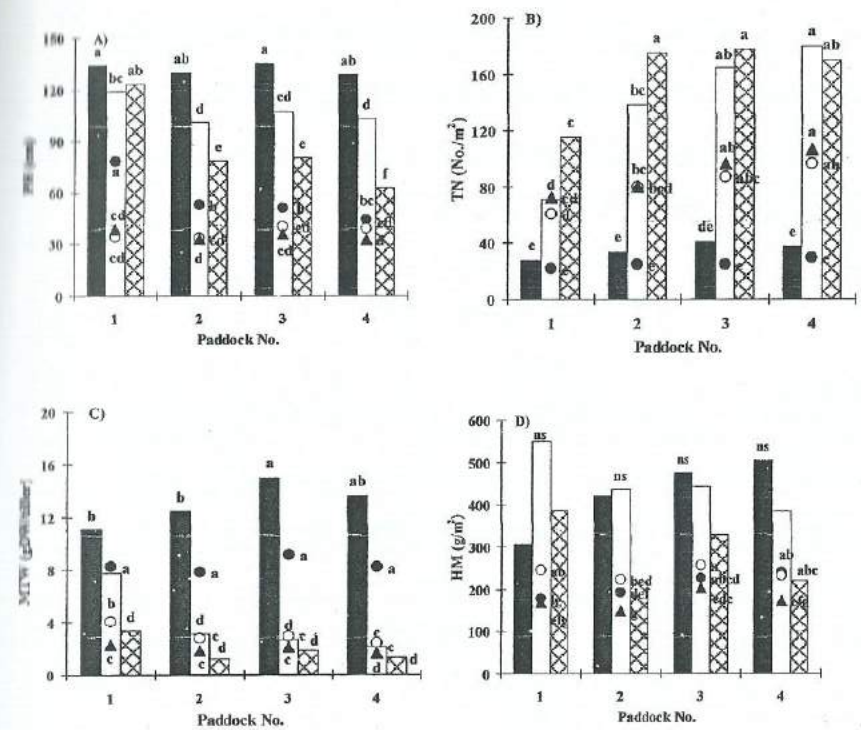
a. Changes in Plant Characteristics

Changes in plant height, tiller number, mean tiller weight, herbage mass, leaf area index (LAI) and ratio of leaf blade to stem with leaf sheath (LB/ST) both before and after grazing in DL elephantgrass with a grazing cycle in 2003 are shown in Figure 1.

Before grazing, plant height, mean tiller weight, herbage mass, LAI and LB/ST tended to be lower, whereas tiller number was higher for all paddocks from cycle 1 to cycle 3. Herbage mass and mean tiller weight tended to be higher, with a concurrent decrease in LB/ST for paddock 1-4 at the first cycle, and this was mainly due to the extension of the growing period before the start of grazing for paddocks 1-4, while tiller number in this cycle was relatively stable among paddocks. As the contrasting seasonal pattern, plant height, mean tiller weight, herbage mass and LAI tended to be higher for paddocks 1-4 at the third cycle, mainly due to the rapid decrease in air temperature after the second grazing. During rotational grazing, plant characters before-grazing varied greatly among paddocks, while plant characters after grazing were more stable.

Changes in several plant characters in DL elephantgrass both before and after grazing during the grazing cycle in 2004 are shown in figure 2. Before grazing, plant height, LAI, LB/ST

were highest, while tiller number tended to increase with a similar increasing tendency in herbage mass as the grazing progressed, except for the first grazing and paddock 4. Plant height, mean tiller weight and herbage mass tended to be lower in 2004 than in 2003, especially in the early grazing period, because of the earlier grazing use in 2004 than in 2003.



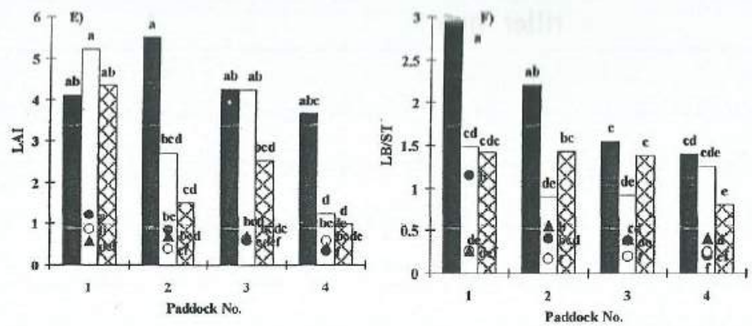


Fig. 1. Change in (a) plant height (PH), (b) tiller number (TN), (c) mean tiller dry matter weight (MTW), (d) herbage mass (HM), (e) leaf area index (LAI) and (f) ratio of leaf blade to stem with leaf sheath (LB/ST) before and after grazing in 2003.

Before grazing (bar chart) : (■) first, (□) second, (⊠) third cycle.

After grazing (dot chart) : (●) first, (○) second, and (▲) third cycle.

Different letters denote a significant difference at the 5% level.

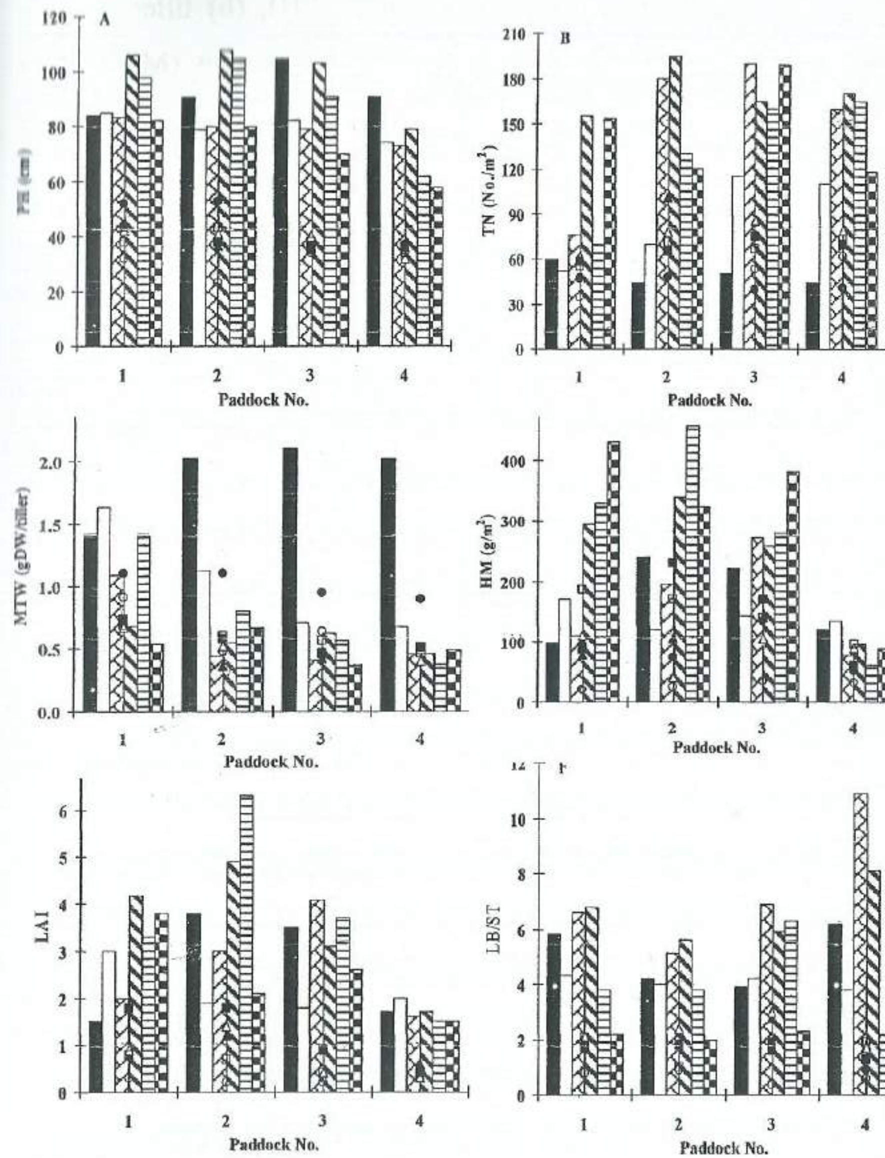


Fig. 2. Change in (a) plant height (PH), (b) tiller number (TN), (c) mean tiller dry matter weight (MTW), (d) herbage mass (HM), (e) leaf area index (LAI) and (f) ratio of leaf blade to stem with leaf sheath (LB/ST) before and after grazing in 2004.

Before grazing (bar chart) : (■) first, (□) second, ( ) third, ( ) fourth, ( ) Fifth and ( ) sixth cycle.

After grazing (dot chart) : (●) first, (○) second, (▲) third, (Δ) fourth, (■) fifth, and (□) sixth cycle.

b. Herbage Consumption

Changes in herbage consumption (HC) and rate of herbage consumption (Rate of HC) in 2003 and 2004 are shown in Figure 3.

In 2003, herbage consumption and rate of herbage consumption tended to decrease from cycle 1-3 in all paddocks, except for paddock 1, where they increased from cycle 1 and 2. In 2004, seasonal change in herbage consumption were different among paddocks, and herbage consumption tended to increase and decrease as grazing preceded in paddocks 1 and 4, respectively. The rate of herbage consumption had similar seasonal change as herbage consumption, and generally tended to decrease with grazing, except at cycle 1 in paddock 1. Both herbage consumption and rate of herbage consumption were highest in year grazing of 2004 than in grazing of 2003.

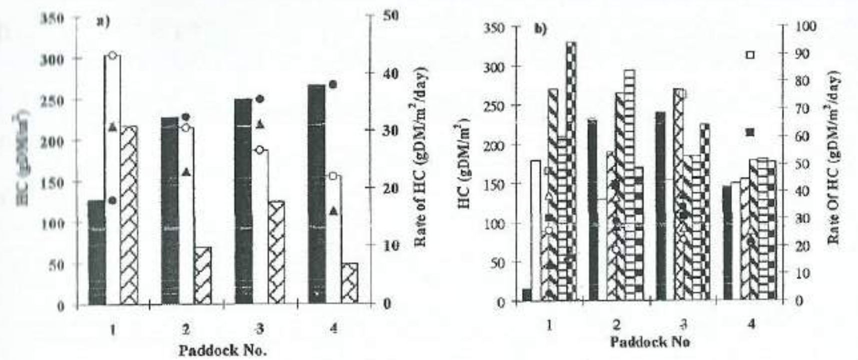


Figure 3. Change in herbage consumption and rate of herbage consumption in in 2003 (a) and 2004 (b).

Herbage consumption (bar chart) : (■) first, (□) second, ( ) third, ( ) fourth, ( ) Fifth and ( ) sixth cycle.

Rate of herbage consumption (dot chart) : (●) first, (○) second, (▲) third, (Δ) fourth, (■) fifth, and (□) sixth cycle.

c. Changes in live weight of breeding and raising beef cows

The average daily (ADG) beef cows grazed in 2003 and 2004 is shown in Table 1. In 2003, ADG was highest at 0.45 kg/day during cycle 1, whereas ADG was negative during cycle 2 and 3. In 2004, ADG was positive during cycle 2 – 5, and the total seasonal ADG was higher in 2004 than in 2003. Thus, the LW of the breeding beef cows was at least maintained under this rotational grazing system without any concentrate or supplied roughage in either year. Although the grazing period was reduced by approximately 60 % during the final cycle, compared with the previous cycles in both years, the carrying capacities during the first two cycle and during the third cycle in 2003 were 768 CD per ha

and 248 CD per ha, respectively, and those during the first five cycles and during the sixth cycle in 2004 were 1233 CD per ha and 122 CD per ha, respectively.

Table 1. Average daily gain (ADG) and carrying capacity of breeding beef cows in 2003 and 2004.

Cycle no.	Period (days)	Grazing length (days) in each paddock				Stocking rate	Mean LW	ADG (kg/day)	Carriying capacity
		1	2	3	4	(cattle/ha)	(kg/head)		(cow/day/ha)
2003									
1	28	7	7	7	7	15	455.9	0.54	383.0
2	28	7	7	7	7	15	457.7	-0.18	384.5
3	17	7	3	4	3	15	487.1	-0.22	248.4
2004									
1	28	6	8	7	7	15	355.0	-0.18	298.2
2	28	7	7	7	7	15	357.9	0.30	300.6
3	28	7	7	7	7	10	381.5	0.79	213.6
4	28	7	7	7	7	10	405.2	0.48	226.9
5	23	7	7	6	3	10	421.8	0.71	194.0
6	16	7	4	3	2	10	379	-.013	121.5

LW, liveweight

D. Discussion

a. Herbage production and plant characteristics

Before grazing herbage mass averaged 389.4 g/m2 and 221.3 g/m2 for the three and six grazing cycles in 2003 and 2004, respectively. The increased in herbage mass was correlated positive with that in plant height at the five level (r = 0.680 and 0.468 in 2003 and 2004, respectively) but it was not significantly correlated at the 5% level with the increase in tiller number in either year. The non significant correlation of tiller number with herbage mass was derived from the significantly negative correlation of tiller number with mean tiller weight at the 1% level (r = -0946 and -0.689 in 2003 and 2004, respectively) during grazing. However, the ratio of leaf blade to stem with leaf sheath decreased with the increase in herbage mass in 2004 ($r = -0.437$, $P<0.05$). The decrease in the ratio of leaf blade to stem with leaf sheath with the grazing cycle was associated with an increase in stem for DM accumulation.

The tendency for herbage mass to increase with grazing, especially in the second year suggest that DL elephantgrass pasture expands the capacity to graze, and supplies enough herbage for beef cows for 1 week in every 4 weeks during the rainy season, with five cycles in the second year, in addition to 2 – 7 days of grazing during the last cycle. The number of tillers before grazing increased uniformly up to the third and fourth grazing in 2003 and 2004, respectively, and suggest a high tillering ability after defoliation of the mother tillers. An increase in tiller number with a concomitant decrease in mean tiller weight with the grazing cycle is a desirable tendency for plants to be consumed by grazing beef cows, because DL elephantgrass had such a high mean tiller weight during the first grazing cycle that the consumption of a whole tiller tended not to be easy for grazing beef cows.

Plant height after grazing was confined to 30-50 cm in both years, except for paddock 1 at the first grazing in the first year and this height was mainly determined by the position of the leaf junction, because grazing beef cows are usually reluctant to graze stem parts. Relatively constant plant height after grazing may be caused by the high palatability of elephantgrass for grazing cows.

b. Daily gain and carrying capacity for grazing beef cows (comparison of DL elephantgrass with overseas tropical grass pastures)

Based on herbage consumption in the DL elephantgrass pasture and the live weight of grazing beef cows, DM intake ranged from 10,2 to 14,5 and from 15.4 to 23.2 g DM kg $LW^{-1}day^{-1}$ among the four paddock in 2003 and 2004, respectively, except for the lowest DM intake in paddock 4 in 2004. The organic matter (OM) intake of grazing steers on banagrass

(*Pennesetum purpureum* x *P. americanum*) over five grazing seasons was 8.37 kg/day (13.7 g OM kg/LW/day) in South Africa (Koster *et.al.*, 1992), which was equivalent to 14,7 g DM kg/LW/day), the same as the present study, if mineral content was 6%. The increase in DM intake during corresponding period in the second year relative to the first year was correlated with the increase in herbage allowance in the second year. Judging from breeding beef cow performance, 0.05 ha of DL elephantgrass pasture can supply enough herbage (without concentrate) for a week to maintain the LW of three breeding beef cows and to keep ADG at 0.35 kg day^{-1} for two raising beef cows in the first and second years following establishment, respectively. However, under a more lenient stocking rate at 1510 kg $ha^{-1}day^{-1}$ on Mott dwarf elephantgrass pasture in Florida, USA, compared with the high rate of 3786 LW/ha/day we used in 2004, ADG over 3 years was 0.97 kg for 15 to 18-month-old raising beef cows (Sollenberger and Jones, 1989). The inferior ADG in the present study is probably mainly due to the higher stocking rate with the shorter regrowth period in the present study for dwarf elephantgrass, whereas a 35-day rest period was used in Florida, USA (Sollenberger and Jones, 1989).

The carrying capacities of DL elephantgrass pasture was 1016 CD/ha in the first year and 1355 CD/ha in the second year. Because daily gains was negatively during the final cycle for both years, these carrying capacities were not underestimates (Sakanoue, 2001). In the tropical grasses, ADG over time on three varieties of stargrass swards in Florida, USA, ranged from 0.18 to 0.56 kg/day, and was inversely related to stocking rate when stocked with 7.5, 10 and 15 head/ha (average LW 230-250 kg; Adjei *et al.*, 1980) and that on bahiagrass pasture was 0.38 kg/day for 15- to 18-month-old raising beef cows under the lenient stocking rate of 1680 kg/LW/day in Florida, USA (Sollenberger and Jones, 1989).

E. Conclusions

A four-paddock system of DL elephantgrass pasture with an area of 0.05 ha per paddock can be grazed rotationally by 3 head of breeding and raising beef cows in a rainy season period with a regime of 1 week grazing, then a 3 week rest period in the first and second years following establishment. The LW of beef cows were at least maintain for breeding cows and steadily increased for raising cows under this rotational system in a rainy season. Thus, the DL elephantgrass pasture can be used under a rotational grazing system at 3.4 – 4.3 animal units/ha over the whole year in the low-altitude site of Miyazaki, Southern Kyushu. To increase the daily weight gains in grazing beef cows under rotational grazing system on DL pasture, it is necessary to reduce the stocking rate or to increase the rest period for restoring the regrowth of DL elephantgrass.

4 ROTATIONAL GRAZING SYSTEM OF DWARF ELEPHANTGRASS PASTURE BY BREEDING BEEF COWS AT THE FIRST YEAR AFTER ESTABLISHMENT

A. Introduction

Rotational grazing is a method to enable an intensive grazing management which allows livestock to get a continuous opportunity to consume fresh matter forage at an active growth (Chacon *et al.*, 1990). Grazing system and associate management practices can substantially influence grazing patterns and utilization of a pasture. Pattern of selection and defoliation of herbage are probably the most important effects of the grazing animal on the pasture such as leaf area reduction in the combination with carbohydrate storage, tiller development, leaf and stem growth and herbage consumed (Sollenberger and Burns, 2001).

It is eagerly required by beef calf breeding farmers to obtain the self-supplying feed stably against the cattle disease probably caused by the imported herbages. From the previous study, dwarf elephantgrass of late-heading type (dwarf-late, DL), introduced from Dairy Promotion Organization (DPO), Thailand, was able to overwinter in the lowland areas of Kyushu and had a higher percentage leaf blade (PLB) than other normal and dwarf varieties. DL was also the most suitable for the grazing use among elephantgrass varieties, because of the lower plant height with higher PLB than other varieties (Ishii *et al.*, 1998).

In a preliminary study, we found that 0,05 ha of DL elephantgrass pasture had the capacity to graze three beef cows for a week, with approximately a one-month rest period, without concentrated feeding in the hot summer season, in the 2 years following establishment (Mukhtar *et al.*, 2004). However, to enhance our understanding of rotational grazing on DL elephantgrass pasture, it is important to identify such variables as herbage consumption, carrying capacity and sward management techniques to increase the live weight (LW) of beef cows, and to maintain the live weight (LW) of breeding beef cows. There have been several study reporting the high forage quality of dwarf elephantgrass in Florida USA (Woodard and Prine, 1991; Sollenberger *et al.*, 1993; Williams and Hanna, 1995), Georgia, USA (Hanna and Monson, 1988; Hanna *et al.*, 1993), Taiwan (Hsu and Hong, 1993) and Thailand (Tudsri *et al.*, 2002a, 2002b).

In this study, a rotational grazing system for DL elephantgrass pasture was examined (without feeding cattle with concentrate or supplied roughage) to determine plant characters, herbage mass, herbage consumption and daily gain of breeding and raising beef cows on DL elephantgrass pasture.

B. Materials and Methods

a. Pasture Management

The research was carried out in the Experimental Field, Miyazaki University, Japan during rainy season from May to November 2003. The examined variety of elephantgrass (*Pennisetum purpureum* Schumach) was the dwarf-late (dwarf variety of late-heading type, DL) from Dairy Promotion Organization (DPO), Thailand. The area of each paddock was 0.05 ha, and four paddocks were established rotational grazing by transplanting rooted tillers of elephantgrass at about 20 cm in length. The elephantgrass plants were sown at a density of two plants per m^2, and space in a 1 m × 0.5 m pattern. Each paddock was fertilized with 20 g N/m^2/year of chemical compound fertilizer ($N:P_2O_5:K_2O$ = 13%:13%;13%) applied in four split applications every year. Fertilization was conducted at pre-grazing and post-grazing. Each paddock was connected to the watering facility and trees for shelter via a road.

b. Grazing Design and Animal Measurements

Three breeding beef cows (not pregnant) were used for the rotational grazing and the grazing schedule was totally 3 cycles. The first 2 cycles were conducted 1-week of grazing and 3-weeks of rest period for each paddock, and the third cycle was determined depending on the herbage mass, because the regrowth after the second cycle was variable among paddocks due to the change in herbage mass. Live weight (LW) was measured at 10.00 a.m. when cows moved to a different paddock. No concentrates were given to the beef cows, but they did have *ad libitum* access to mineral supplements during the rotational grazing. Average of pre-grazing live weight was 451 kg/head.

c. Plant Measurements

Six DL elephantgrass plants were sampled by using the line transect method both at pre- and post-grazing in each paddock. Herbage mass at pre- and post-grazing was determined by cutting plants at 10 and 30 cm above the ground level, respectively. The measured characters were tiller number (TN), plant height (PH), leaf area index (LAI) and dry matter (DM) mass of leaf blade (LB), stem with leaf sheath (ST) and dead parts (D). plant heights at pre- and post-grazing, and tiller number at post-grazing were determined in four set rows (200 plants) per paddock.

d. Calculation of Herbage Production, Herbage Consumption, Dry Matter Intake and Carrying Capacity

Herbage production during the grazing period was calculated by the estimated crop growth rate (CGR) which was the difference between pre- and post-grazing herbage dry matter yield (HDMY) in the next grazing divided by the rest period.

Herbage consumption (HC) by beef cows was estimated by the sum of the difference between pre- and post-grazing HDMY. Dry matter intake (DMI) to beef cows was calculated by the sum of HC and herbage production during the grazing period, multiplied with planting area, divided by grazing cows number, cow LW and grazing duration (day). Carrying capacity was calculated by the product of cow density (No./ha) and grazing duration (day).

e. Statistical Analysis

Statistical significance with respect to the differences in the mean value of plant characters in DL elephantgrass was assessed by using the analysis of variance (ANOVA) and least significant difference (LSD) method at the 5% level.

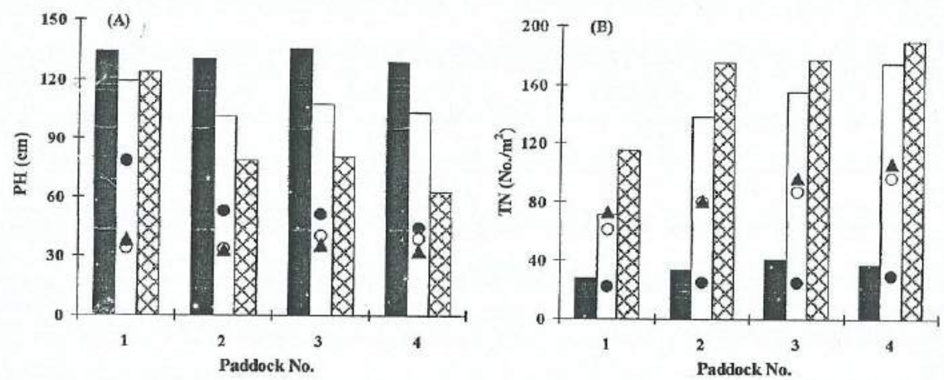
C. Results

a. Changes in plant characteristics

Changes in plant height, tiller number, mean tiller weight, herbage mass, leaf area index (LAI) and ratio of leaf blade to stem with leaf sheath (LB/ST) at both pre- and post-grazing with the grazing cycle are shown in Fig.1.

In the pre-grazing plant characters, there were decreasing tendencies in plant height, mean tiller weight, herbage mass, LAI and LB/ST, whereas tiller number was higher for all paddocks from cycle 1 to cycle 3.

Herbage mass and tiller weight tended to be higher, with a concurrent decrease in LB/ST for paddock 1-4 at the first cycle, and this was mainly due to the extension of the growing period before the start of grazing for paddocks 1-4, while tiller number in this cycle was relatively stable among paddocks. As the contrasting seasonal pattern, plant height, mean tiller weight, herbage mass and LAI tended to be higher for paddocks 1-4 at the third cycle, mainly due to the rapid decrease in herbage mass. During rotational grazing, plant characters at pre-grazing varied greatly among paddocks, while plant characters after grazing were more stable.



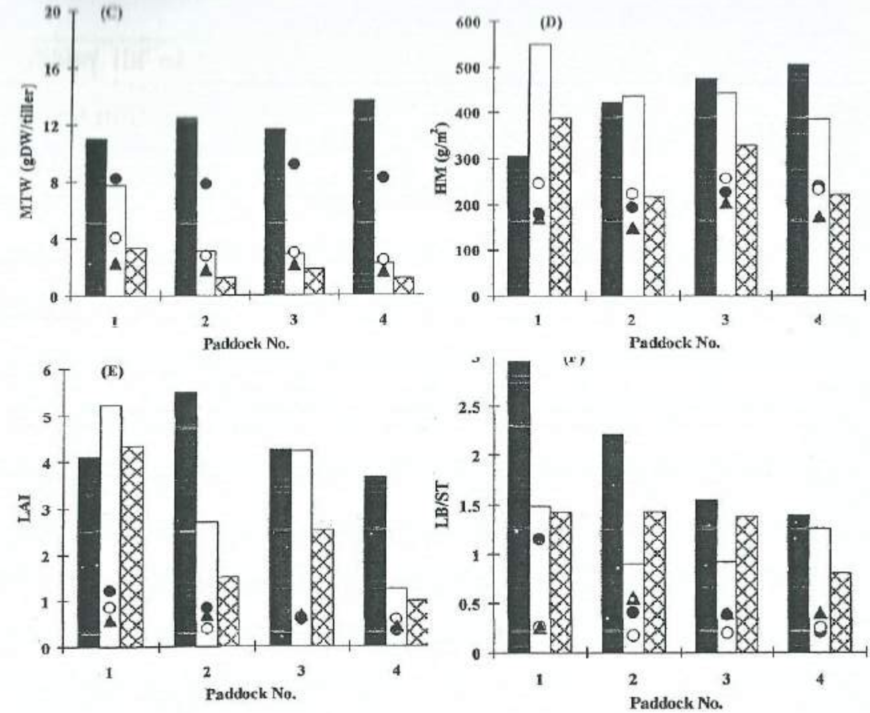


Fig. 1. Change in (a) plant height (PH), (b) tiller number (TN), (c) mean tiller dry matter weight (MTW), (d) herbage mass (HM), (e) leaf area index (LAI) and (f) ratio of leaf blade to stem with leaf sheath (LB/ST) at pre- and after-grazing on dwarf late-heading elephantgrass pasture.
Pre-grazing (bar chart) : (■) first, (□) second, (□) third cycle.
Post-grazing (dot chart) : (●) first, (○) second, and (▲) third cycle.
Different letters denote a significant difference at the 5% level.

b. Herbage consumption

Changes in herbage consumption (HC), percentage utilization (PU), herbage production in the grazing period and dry matter intake (DMI) are shown in Table 1.

Due to the diffence herbage production in all paddocks, herbage consumption and rate of herbage consumption tended to decrease from cycle 1-3 in all paddocks, except for paddock 1, where they increase increased from cycle 1 and 2. Percentage utilization and dry matter intake decreased from cycle 1-3 in all paddocks, except for paddock 1 where they increased from cycle 1 to 2. The dry matter intake averaged 10.2 – 14.5 g/kg LW/day among 4 paddocks. Therefore as in analysis, there were positive relationship between rate of the herbage consumption and dry matter intake.

Table 1. Herbage consumption (HC) and percentage utilization (PU) by beef cows, herbage production in the grazing period and dry matter intake (DMI) during rotational grazing.

Grazing cycle	Character	Paddock			
		1	2	3	4
1	HC (g/m^2)	127,08	228,04	249,32	265,96
	PU (%)	41,60	54,20	52,50	52,60
	Production (g/m^2)	101,09	71,27	62,18	51,24
	DMI (g/kg LW/day)	12,10	15,63	15,95	16,38
2	HC (g/m^2)	303,26	213,82	186,54	153,72
	PU (%)	55,20	49,10	42,10	39,90
	Production (g/m^2)	72,30	22,97	41,77	15,80
	DMI (g/kg LW/day)	19,70	12,45	11,89	8,46
3	HC (g/m^2)	216,90	68,90	125,30	47,40
	PU (%)	56,20	31,60	38,10	21,50
	Production (g/m^2)	21,09	2,87	7,37	2,19
	DMI (g/kg LW/day)	11,68	8,24	11,33	5,65
Annual Total	HC (g/m^2)	647,24	510,76	561,16	467,08
Annual mean	PU (%)	51,00	44,97	44,23	38,00
	Production (g/m^2)	64,83	32,37	37,11	23,08
	DMI (g/kg LW/day)	14,49	12,11	13,06	10,16

c. Changes in live weight of breeding beef cows

Live weight (LW) changes in breeding beef cows and the relationship between DMI and average daily gain (ADG) are shown in Fig. 2 and Fig 3, respectively.

There were increasing tendencies in live weight with the grazing at the first and second cycles, and cow live weight almost maintained at the third cycle in for three head beef cows. Thus, cow live weight at least maintained under this rotational grazing system without any concentrate.

ADG was highest at 0.54 kg per day during cycle 1, whereas ADG was negative during cycle 2 and 3 and there were no significant correlations between DMI and ADG. Thus, the LW of the breeding beef cows was at least maintained under this rotational grazing system without any concentrate or supplied roughage. Although the grazing period was reduced by approximately 60 % during the final cycle, compare with the previous cycle. The carrying capacities during the first two cycle and during the third cycle were 768 CD per ha and 248 CD per ha, respectively.

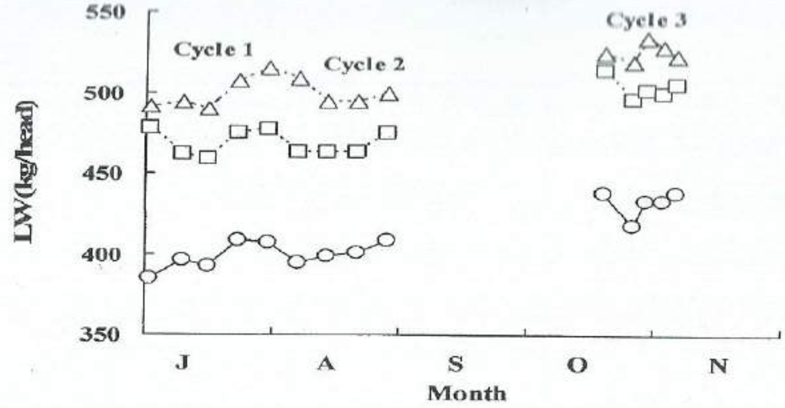


Fig. 2. Live weight (LW) change in breeding beef cows without any concentrate feeding in the field. All cows produced 6 calves from their birth and were graze under no pregnancy.

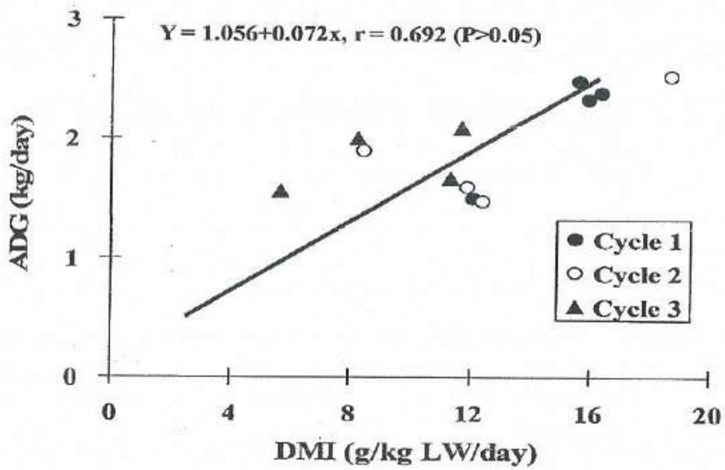


Fig. 3. Relationship between dry matter intake (DMI) and average daily gain in the dwarf-late elephantgrass during rotational grazing.

D. Discussion

a. Herbage production and plant characteristics

The tendency for herbage mass to increase with grazing suggest that DL elephantgrass pasture expands the capacity to graze, and supplies enough herbage for beef cows for 1 week in every 4 weeks during the rainy season. The number of tillers at pre-grazing increase uniformly up to the third grazing and suggest a high tillering ability after defoliation of the mother tillers. An increase in tiller number with a concomitant decrease in mean tiller weight with the grazing cycle is a desirable tendency for plants to be consumed by grazing beef cows, because DL elephantgrass had such a high mean tiller weight during the first grazing cycle that the consumption of a whole tiller tended not to be easy for grazing beef cows.

Plant height at post-grazing was confined to 30-50 cm, except for paddock 1 at the first grazing, and this height was mainly determined by the position of the leaf junction, because grazing beef cows are usually reluctant to graze stem parts. Relatively constant plant height at post-grazing may be caused by the high palatability of elephantgrass for grazing cows.

b. Daily gain and carrying capacity for grazing beef cows (comparison of DL elephantgrass with overseas tropical grass pastures)

Based on herbage consumption in the DL napiergrass pasture and the live weight of grazing beef cows, DM in ranged from 10,2 to 14,5 DM kg $LW^{-1}day^{-1}$ among the paddock. The organic matter (OM) intake of grazing steers Banana (OM) intake of grazing steers on banagrass (*Penne purpureum* x *P. americanum*) over five grazing season was kg day^{-1} (13.7 g OM kg $LW^{-1}day^{-1}$) in South Africa (Koster et 1992), which was equivalent to 14,7 g DM kg $LW^{-1}day^{-1}$), same as the present study, if mineral content was 6%. Jud from breeding beef cow performance, 0.05 ha of elephantgrass pasture can supply enough herbage (with concentrate) for a week to maintain the LW of three breed beef cows and to keep ADG at 0.35 kg day^{-1} for two tra beef cows in the first and second years following establishm respectively. However, under a more lenient stocking rat 1510 kg $ha^{-1}day^{-1}$ on Mott dwarf elephantgrass pastur Florida, USA, compare with the high rate of 4669 $LW^{-1}day^{-1}$ used in 2004, ADG over 3 years was 0.97 kg for 15 to month-old raising beef cows (Sollenberger and Jones, 1989).

The carrying capacities of DL elephantgrass pasture 1016 CD ha-1, because daily gains on DL elephantgrass w negatively during the final cycle. These carrying capaties w not under estimates. In the tropical grasses, ADG over tim three varieties of stargrass sward in Florida, USA, ranged fr 0.18 to 0.56 kg day^{-1}, and wasinversely related to stocking

when stocked with 7.5, 10 and 15 head ha^{-1} (average LW 230-250 kg; Adjei *et al.*, 1980) and that on bahia grass pasture was 0.38 kg day^{-1} for 15- to 18-month-old raising beef cows under the lenient stocking rate of 1680 kg $LW^{-1}day^{-1}$ in Florida, USA (Sollenberger and Jones, 1989).

E. Conclusions

The dwarf-late (DL) elephantgrass pasture with four paddocks and an area of 5 a per paddock can be grazed by 3 head of breeding beef cows in a rainy season period under the rotational grazing at 1-week grazing with 3-week rest period at the first year after establishment. Dry matter intake averaged 10.2-14.5 g DM/kg LW/day in DL elephantgrass pasture. Live weights of beef cows tended to increase under the rotational grazing use of DL elephantgrass in a rainy season period and they were almost maintained during the grazing period. To increase the daily weight gains in grazing beef cows under this rotational grazing system on DL elephantgrass pasture, it is necessary to reduce the stocking rate or to increase the rest period for restoring the regrowth of DL elephantgrass.

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Dry Matter Productivity & Grazing Characteristics in Dwarf & Normal Elephant Grass

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