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Production and Quality in Dwarf Napier Grass Pasture Fertilized by Digested Effluent of Manure under Two-Years of Dairy Cow-Grazing in Warm Regions of Japan

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Abstract: Dwarf Napier grass (*Pennisetum purpureum*) pasture is suitable for beef cow grazing in warm regions of Japan, while it is not assessed for the suitability by a herd of dairy cows in the region. This study was conducted to determine the effects of Digested Effluent (DE) application on herbage yield and quality, Herbage Consumption (HC) and Dry Matter Intake (DMI) under a paddock scale of rotational grazing by a herd of dairy cows on dwarf Napier grass pasture in southern Kyushu, Japan for two years in 2007 and 2008. Plant growth attributes, such as plant height, tiller number and herbage mass and HC increased consistently from the first to the second or third grazing cycle in the two years. Pre-grazing herbage mass was averaged at 176 and 193 g m^{-2} in Chemical Fertilizer (CF) and DE treatments, respectively and HC and DMI did not differ between the two treatments. Overwintering ability was almost perfect in Miyazaki, judged by 97.1% of regrown plants in May 2008. Thus, dwarf Napier grass pasture fertilized with liquid DE can be utilized by dairy cow grazing as the same with CF fertilization, where DMI was averaged at 4.4 kg dry matter $head^{-1}$ day^{-1} for 3 summer months in the two years.

Keywords: Digested Effluent of Manure, Dwarf Napier Grass, Quality, Rotational Grazing, Yield

Introduction

The impact of grazing animals on community structure and ecosystem functioning in the grass pasture is a key issue for rotational grazing management in order to maximize livestock production, sustainability and longevity of the pasture (Krysl and Hess, 1993). Grazing system is a management tool, which allows pasture managers to control the frequency and duration of grazing and rest periods to optimize livestock and plant performance (Savory and Parsons, 1980). One of the major factors, limiting milk production especially from a tropical pasture is a low Dry Matter Intake (DMI) by dairy cows (Distel *et al*., 1995), which is more intolerant to heat stress in a hot summer season in the warm region of Japan. It is important that Herbage Mass (HM) should be maintained throughout the grazing periods in order to achieve a high DMI, but changes in herbage quantity and quality associated with the huge consumption by grazing animals may have a serious damage on herbage DMI (McGilloway *et al*., 1999).

Dwarf variety of Late-heading type (DL) Napier grass (*Pennisetum purpureum*) bred in Florida, USA (Sollenberger *et al*., 1988), has already examined for the local adaptability in many tropics and subtropics of the world (Hanna *et al*., 1993; Williams and Hanna, 1995; Tudsri *et al*., 2002), as well as in the warm regions of Japan (Mukhtar *et al*., 2004; Utamy *et al*., 2011). Since southern Kyushu in the region has one of the largest beef cow densities in Japan, it is essential to treat livestock wastes promptly. One of the solution for processing livestock wastes is through the biogas-plant (Thy and Buntha, 2005), in which the end-product is the Digested Effluent of manure (DE) that could be applied to tropical grass pasture (Hasyim *et al*., 2014) at the same rate with annual fodder cropland. The DL Napier grass can adapt for the intensive rotational grazing by beef cows (Ishii *et al.*, 2005) and is getting to expand cultivation areas in southern Kyushu (Utamy *et al.*, 2011; Ishii *et al.*, 2013). Grazed perennial DL Napier grass produces a high herbage mass and quality and hence provides herbages cheaper than imported hay feeding. The objectives of this study were to examine the effects of applying DE solution on herbage quantity, quality, consumption (HC) and DMI on DL Napier grass pasture by the rotational grazing of a herd of dairy cows in Miyazaki, southern Kyushu for 2 years in 2007 and 2008.

Materials and Methods

Site and Fertilizer Treatment

The grazing study was carried out in Sumiyoshi Livestock Experimental Station (Sumiyoshi), University of Miyazaki, Japan (131.46°E, 31.99°N) from 23 July 2007 to 31 October 2008. One-ha of DL Napier grass pasture, established by rooted tillers on 18-20 May 2005, was equally divided into 5 paddocks (40×50 m, 0.2 ha each). Spacing and density of DL Napier grass were 1 m grid and 1 plant m^{-2}, respectively. Each paddock was connected to the watering facility under shelter woods. For treatments, paddocks 1-3 were equally subdivided into 0.1-ha areas with DE and Chemical Fertilizer (CF) plots and the other paddocks 4 and 5 were subjected to CF plot. DE plots were applied by liquid DE at 46 KL ha^{-1} $year^{-1}$ (112 kg of NH_4^+-N) by 4 times of split application in 2007 and at 58 KL ha^{-1} $year^{-1}$ (141 kg of NH_4^+-N) by 5 times of split applications with additionally fertilized with chemical compound fertilizer at 93 kg N ha^{-1} in 2008. CF plots were fertilized with 112 kg N and 234 kg N ha^{-1} $year^{-1}$ of chemical compound fertilizer by 4 times and 5 times of split applications in 2007 and 2008, respectively. Overwintering ability was almost perfect in Miyazaki, judged by percentage of regrown plants at 97.1% in May 2008.

Cut-and Carry Management

Cut-and-carry study was conducted in Kibana Agricultural Experimental Station (Kibana), University of Miyazaki (131.41°E, 31.83°N) in the same two years as reported in Heitschmidt *et al*. (1983). DL Napier grass was cultivated by transplanting rooted tillers at a rate of 2 plants m^{-2} (0.5×1.0 m of spacing) in 2007 and 2008. Lime (200 g m^{-2}) and fermented cattle manure (600 g m^{-2}) were applied on 8 May 2007, as a basal dressing. Three DE treatments with a control fertilized with a CF as top dressing were employed with a randomized block design of three replications (blocks). DE treatments were supplied with 4-times of split application per year under three levels of application (2.4, 1.2 and 0.6 L m^{-2} per application equivalent to 5.04, 2.52 and 1.26 g m^{-2} nitrogen (N) per application, respectively), which constituted high, medium and low application rates, respectively. The control involved application of a CF at 36 g m^{-2} per application (5.04 g N m^{-2} per application), equivalent to the high rate of N application in DE treatment on the same days. At Kibana, the cutting height of DL Napier grass was simulated with the grazing trial in Sumiyoshi, where the defoliated stubble height was risen with grazing proceeded.

Grazing Management

A herd of lactating dairy cows (Holstein, 23 head and initial body weight averaged at 552 kg), which was almost half of the average daily farms (41.7 head) in Miyazaki (MAFF, 2011), were used for the rotational grazing on one-ha DL Napier grass pasture. Grazing schedule was totally 4 cycles both in 2007 and 2008, where the first 3 cycles were from 23 July to 30 October and from 14 July to 22 October in 2007 and 2008, respectively with 5 days of grazing and almost 4 weeks of rest period for each paddock. The fourth cycle was from 5 to 22 November and from 27 to 31 October in 2007 and 2008, respectively, since the grazing period in the last fourth cycle was according to the pre-grazing herbage mass due to the decline in air temperature in the rest period after the third grazing was terminated. Three-six days of rest period folded at the switching grazing cycle.

Plant Measurements for Herbage Yield, Consumption and Dry Matter Intake by Dairy Cows

Ten DL Napier grass plants per paddocks were sampled by line transecting method at both pre- and post-grazing in each paddock. Both pre- and post-grazing Dry Matter Weights (DMWs) of herbages were determined by cutting plants at 10 cm above the ground level. Measured plant characters were tiller number, plant height and DMWs of Leaf Blade (LB), stem inclusive of with leaf Sheath (ST) and Dead parts (D). Both pre- and post-grazing plant height and pre-grazing tiller number were determined at four fixed rows (40 plants) per paddock.

Amount of herbage production in the grazing period was calculated by estimated Crop Growth Rate (CGR), multiplied by the grazing days. The HC by dairy cows was determined by the sum of the difference between pre- and post-grazing herbage mass and herbage production in the grazing days. The DMI by dairy cows was calculated by HC, multiplied by plant area, divided by number of grazing cows and grazing day.

Chemical Analysis for Forage Quality and Liquid DE

In vitro Dry Matter Digestibility (IVDMD) of herbage was determined by pepsin-cellulase digestion assay using *in vitro* incubator (Model: DAISY II-200/220, ANKOM Technology Co. Ltd., Macedon, NY, USA) regulated at 39.0°C. Neutral detergent fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) contents of herbages were determined by detergent assay method using fiber analyzer (Model: ANKOM 200/220, ANKOM Technology Co. Ltd., Macedon, NY, USA). The major mineral ion content of liquid DE was determined by Ion-analyzer (Model: IA-300, Toa-DKK Co. Ltd., Tokyo, Japan).

Statistical Analysis

For plant attributes, consumption and intake of herbages of DL Napier grass, one-way Analysis of Variance (ANOVA) for a completely randomized design was performed using SPSS software (version 15.0, Madison, USA). Mean separations were tested using the Least Significance Difference (LSD) method at the 1% and 5% level.

Results

Plant Growth Attributes in the Grazing Period

Changes in both pre- and post-grazing plant height of DL Napier grass pasture over time are shown across paddocks for 2007 (A) and 2008 (B) in Fig. 1. Pre-grazing plant height increased up to cycle 2 or 3 and decreased through to cycle 4 and tended to be higher in paddock 5 than in the other paddocks across cycles for both years and tended to be higher in 2008 than in 2007. However, post-grazing plant height remained similarly across paddocks around 40-50 cm above the ground, where lamina junction was positioned. No significant effects on pre- or post-grazing plant height were obtained by DE application, compared with CF treatment (Fig. 1).

Pre- and post-grazing tiller densities of DL Napier grass pasture increased consistently from the first to the last cycle and tended to be larger by DE application than CF treatment over grazing cycles in the two years and tended to be larger in 2008 (B) than in 2007 (A) in Fig. 2. No significant effects on pre- or post-grazing tiller density were obtained by DE application, compared with CF treatment over the two years. Increase in tiller density with grazing cycles suggested for high tillering ability of mother tillers after defoliation by the grazing of dairy cows.

Pre- and post-grazing herbage mass of DL Napier grass pasture increased consistently from the first cycle to the third cycle in the two years (Fig. 3). Pre-grazing herbage masses averaged across 4 cycles for CF and DE treatment, respectively, were 165 and 161 g m^{-2} in 2007 and 187 and 224 g m^{-2} in 2008, while no significant difference was obtained between the two treatments. The variation in pre-grazing herbage mass was almost correlated with that in tiller density within cycles 1 to 3 in 2007 ($r = 0.517$, $p<0.01$) and in 2008 ($r = 0.643$, $p<0.01$). The increase in herbage mass was concurrent with that in tiller density up to cycle 3, while regrowth in herbage mass suppressed severely in the rest period after the third cycle in the two years. Rotational grazing showed that pre-grazing plant characters in plant height, tiller density and herbage mass showed large variations among paddocks, while the post-grazing characters were more stable than the pre-grazing ones over the two years.

Pre- and post-grazing percentage of leaf blade (PLB) in DL Napier grass decreased consistently from the first cycle to the last cycle in the two years and tended to be higher in 2008 than in 2007. Pre-grazing PLB was extremely high, while the post-grazing percentage decreased significantly due to the consumption of dairy cows grazed mostly at the lamina junction of shoots. New tillers emerging from the elongated stem nodes were favorable for the quick coverage of land by leafage, compared with those only from the underground stem nodes. The post-grazing PLB tended to be higher in DE treatment than in CF treatment and decreased constantly to around 20% in the third cycle of the two years (Fig. 4).

Herbage Consumption and Dry Matter Intake

Herbage consumption increased from the first cycle to the third cycle and turned to drop severely at the last paddock 1 or 4 in CF treatment in the two years. The DMI by dairy cows increased from the first to the third cycle and was closely correlated with HC, from the first to the third cycle. The DMIs in CF and DE treatment averaged across 4 cycles were 4.1 and 7.0 kg Dry Matter (DM) $head^{-1}$ day^{-1}, respectively, in 2007 and 2.8 and 3.6 kg DM $head^{-1}$ day^{-1}, respectively, in 2008 (Table 2). The rise of DMI in paddocks 1-3 at the last cycle in 2007 was brought about by the only one-day of grazing practice due to poor regrowth and shortage in herbage (Fig. 5).

Herbage Quality

Changes in pre-grazing IVDMD of DL Napier grass pasture showed in Fig. 6 that IVDMD was the highest in cycle 1 and 2 in 2007 and 2008, respectively and decreased constantly over time in the two years, while IVDMD even at the fourth cycle maintained above 55 and 60% in 2007 and 2008, respectively. In the first cycle of the two years, IVDMD tended to be higher in ST than in LB, although no significant differences were obtained between the two fractions across cycles (Fig. 6).

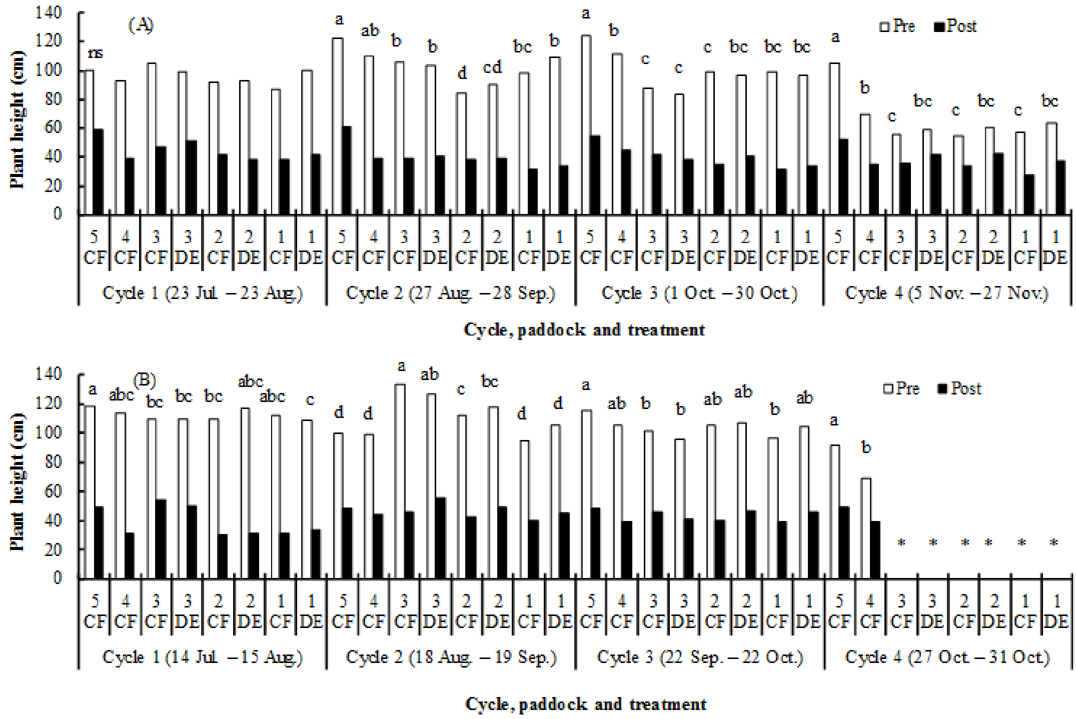

Fig. 1. Changes in pre- and post-grazing plant height in the dwarf Napier grass pasture in 2007 (A) and 2008 (B). * Not conducted. Treatment: Chemical Compound Fertilizer (CF), Digested Effluent of manure (DE). Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05.

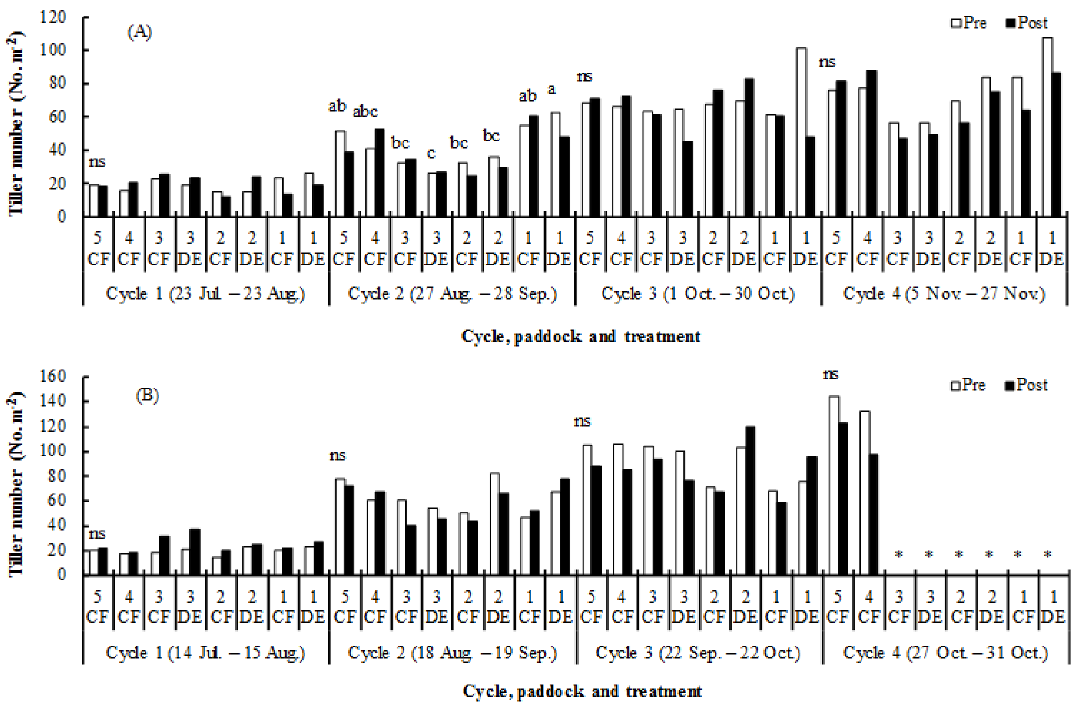

Fig. 2. Changes in pre- and post-grazing tiller number over time in the dwarf Napier grass pasture in 2007 (A) and 2008 (B). * Not conducted. Treatment: Chemical Compound Fertilizer (CF), Digested Effluent of manure (DE). Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05

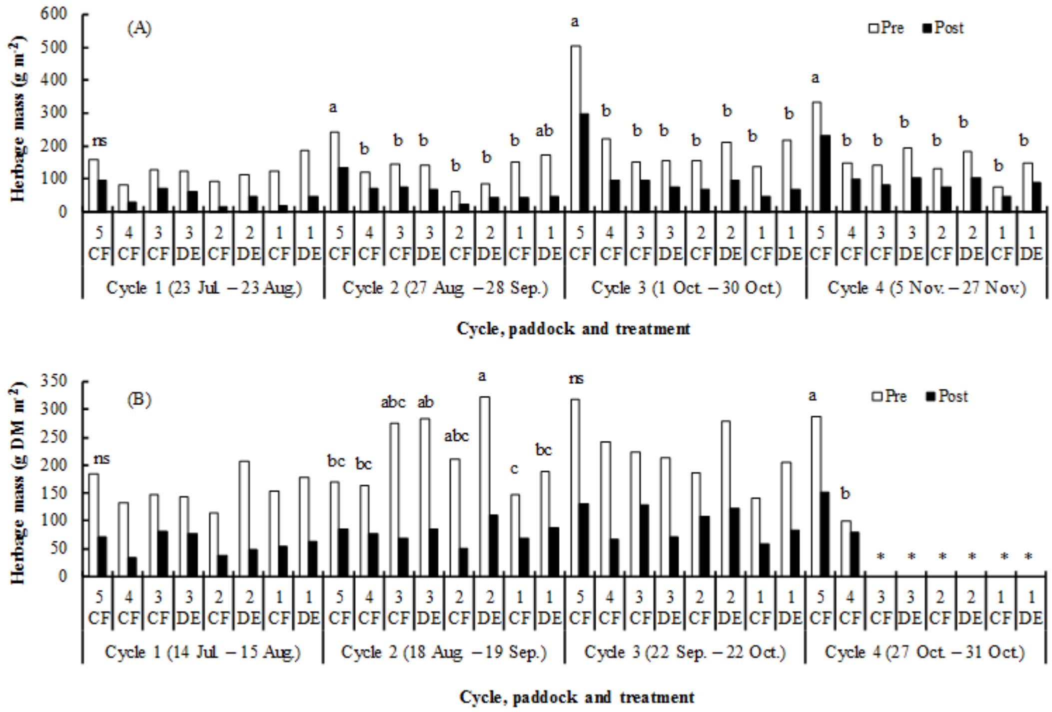

Fig. 3. Changes in pre- and post-grazing herbage mass over time in the dwarf Napier grass pasture in 2007 (A) and 2008 (B). * Not conducted. Treatment: Chemical compound Fertilizer (CF), Digested Effluent of manure (DE). Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05

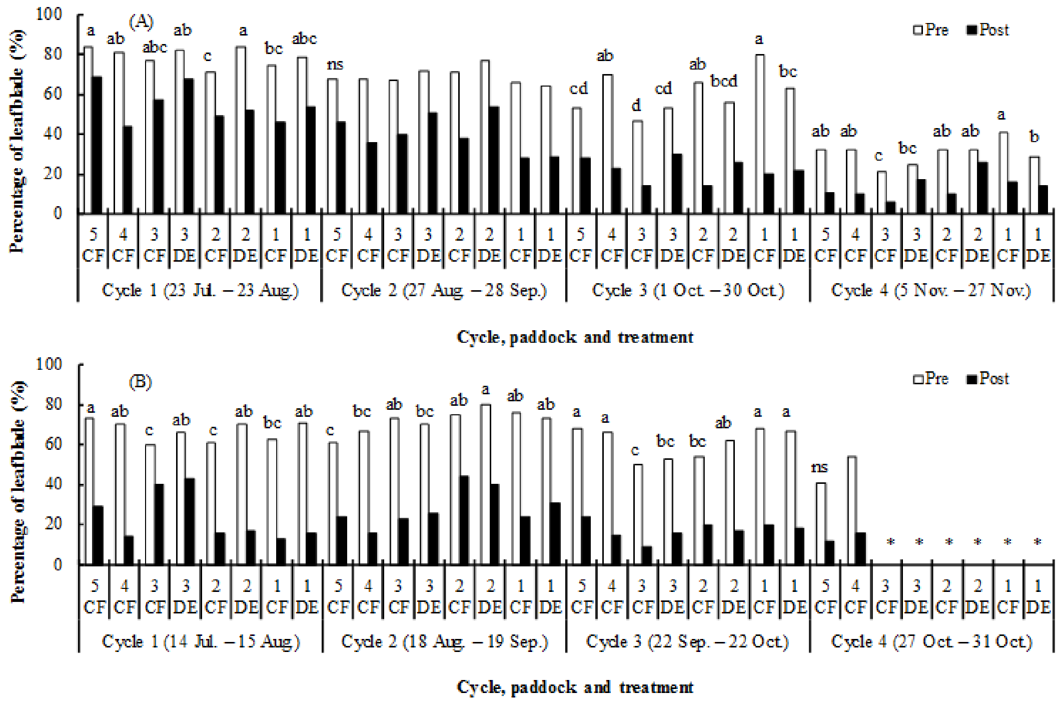

Fig. 4. Changes in pre- and post-grazing percentage of leaf blade over time in the dwarf Napier grass pasture in 2007 (A) and 2008 (B). * Not conducted. Treatment: Chemical compound Fertilizer (CF), Digested Effluent of manure (DE). Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05

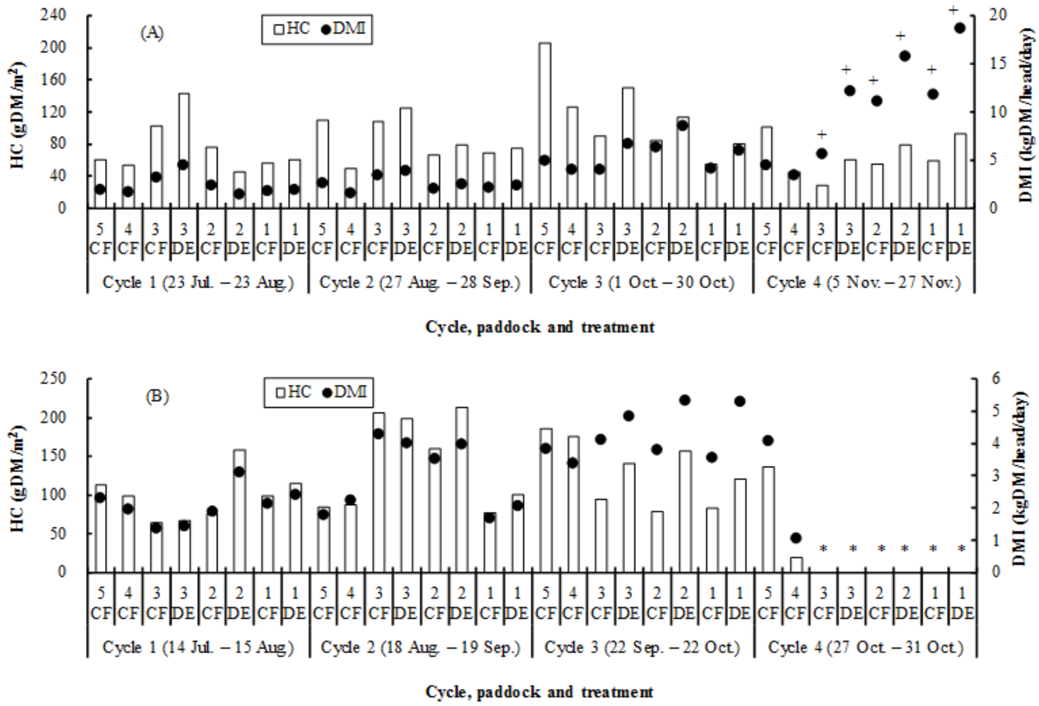

Fig. 5. Changes in the Herbage Consumption (HC) and Dry Matter Intake (DMI) over time in the dwarf Napier grass pasture in 2007 (A) and 2008 (B). *Not conducted. Treatment: Chemical compound Fertilizer (CF), Digested Effluent of manure (DE). Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05

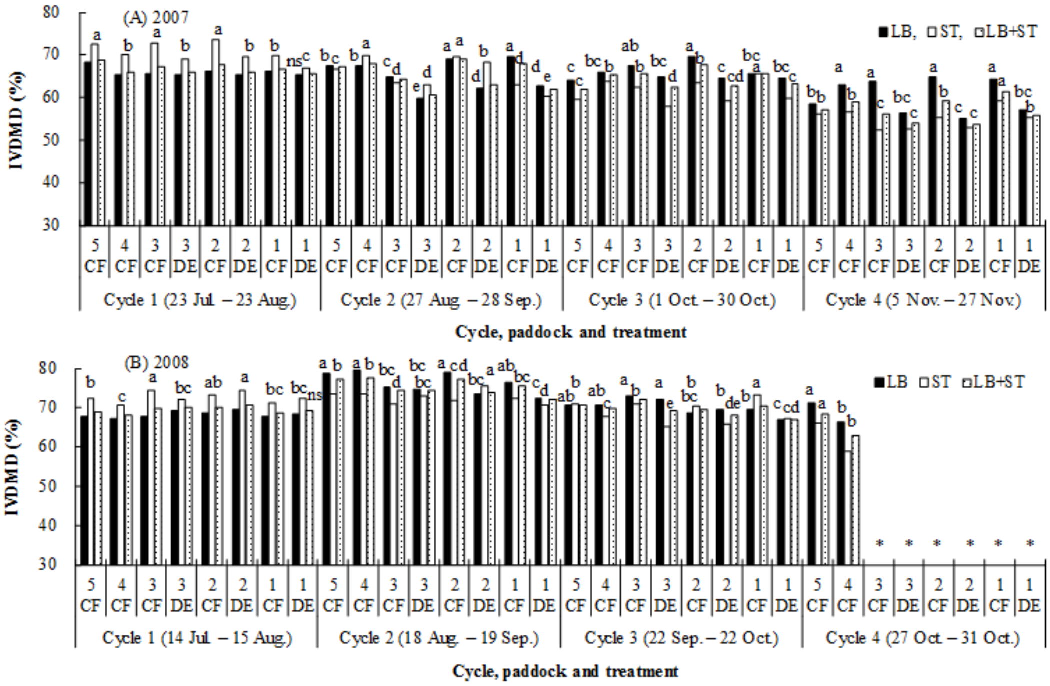

Fig. 6. Changes in the pre-grazing *In Vitro* Dry Matter Digestibility (IVDMD) of dwarf Napier grass over time in 2007 (A) and 2008 (B). *Not conducted. Treatment: Chemical compound Fertilizer (CF), Digested Effluent of manure (DE). LB: Leaf blade, ST: stem inclusive of leaf sheath. * Not conducted. Symbols with different letters denote significant difference among pre-grazing paddocks and treatments in the same cycle at the 5% level. ns: p>0.05

Table 1. Changes in Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) contents in Leaf Blade (LB) and stem inclusive of leaf sheath (ST) over time in 2007 and 2008

			NDF (%DM)		ADF (%DM)		ADL (%DM)	
Year	Cycle and period	Organ[†]	CF[††]	DE[††]	CF	DE	CF	DE
2007	I (23 Jul.-23 Aug.)	LB	63.8ns[†††]	64.4	35.0[b]	36.7[a]	5.4[b]	6.9[a]
		ST	60.1ns	61.0	35.0ns	35.9	5.4ns	5.9
	II (27 Aug.-28 Sep.)	LB	65.3ns	64.6	35.2[b]	38.4[a]	5.3[b]	7.1[a]
		ST	63.9[b]	66.0[a]	37.3ns	38.3	5.2[b]	6.9[a]
	III (1 Oct.-30 Oct.)	LB	65.5ns	65.7	35.7[b]	38.1[a]	5.1[b]	7.2[a]
		ST	62.8[b]	64.9[a]	37.5[b]	39.3[a]	5.9[b]	6.9[a]
	IV (5 Nov.-27 Nov.)	LB	63.3[a]	60.9[b]	37.2[b]	38.6[a]	7.0[b]	7.8[a]
		ST	63.4[b]	64.7[a]	39.7ns	39.6	6.3[b]	7.7[a]
2008	I (14 Jul.-15 Aug.)	LB	64.9[a]	62.6[b]	37.1[b]	38.8[a]	6.0ns	6.5
		ST	58.9ns	58.9	34.9[b]	36.2[a]	5.2ns	5.7
	II (18 Aug.-19 Sep.)	LB	60.7ns	61.4	35.2[b]	37.3[a]	6.2ns	6.7
		ST	59.8ns	59.9	38.0ns	37.0	5.4[b]	6.3[a]
	III (22 Sep.-22 Oct.)	LB	60.1[b]	61.7[a]	35.1ns	35.9	5.8[b]	7.2[a]
		ST	58.4ns	58.7	36.6[b]	38.5[a]	5.2-	6.0[a]
	IV (27 Oct.-31 Oct.)	LB	63.5	–	34.5	–	7.7	–
		ST	63.1	–	37.9	–	7.3	–

[†] Organ: LB (Leaf Blade), ST (stem inclusive of leaf sheath); [††] Treatment: CF (Chemical Fertilizer), DE (Digested Effluent of manure); [†††] Symbols with different letters in a row denote significant difference for NDF, ADF and ADL among treatments on the same cycle at the 5% level. ns: Non-significant (p>0.05).

Table 2. Effect of fertilizing source on pre-grazing herbage mass, quality and consumption and dry matter intake in the 2 years of 2007 and 2008

		Treatment[†]		
Year	Character	CF	DE	Significance
2007	Herbage mass (g DM m^{-2})	164.90	161.10	p>0.05
	Herbage IVDMD (%)	64.60	61.20	p<0.05
	Herbage NDF content (%)	64.00	64.40	p>0.05
	Herbage ADF content (%)	36.50	38.20	p<0.01
	Herbage ADL content (%)	5.66	7.17	p<0.01
	Herbage consumption (g DM m^{-2})	80.30	92.00	p>0.05
	Dry matter intake (g DM $head^{-1}$ day^{-1})	4.10	7.00	p>0.05
2008	Herbage mass (g DM m^{-2})	188.00	224.10	p>0.05
	Herbage IVDMD (%)	71.20	70.50	p>0.05
	Herbage NDF content (%)	61.40	61.20	p>0.05
	Herbage ADF content (%)	36.00	37.40	p<0.01
	Herbage ADL content (%)	5.98	6.57	p<0.05
	Herbage consumption (g DM m^{-2})	108.40	141.10	p>0.05
	Dry matter intake (g DM $head^{-1}$ day^{-1})	2.80	3.60	p>0.05

[†]Treatment: Chemical Fertilizer (CF), Digested Effluent of manure (DE).

Changes in NDF, ADF and ADL contents in LB and ST of the same plant samples over time are shown in Table 1. NDF contents in CF and DE treatments averaged 63.5 and 64.0%, respectively in 2007 and 61.2 and 60.5%, respectively in 2008. ADF contents in CF and DE treatments averaged 36.6 and 38.1%, respectively in 2007 and 36.1 and 37.3%, respectively in 2008. ADL contents in CF and DE treatments averaged 5.7 and 7.1%, respectively in 2007 and 6.1 and 6.4%, respectively in 2008. NDF content did not differ consistently between CF and DE treatment across cycles, while ADF and ADL contents tended to be higher in DE treatment than in CF treatment, although the difference was not statistically significant.

In ST, correlations of IVDMD with NDF, ADF and ADL contents were r = -0.568 (p<0.05), -0.841 (p<0.01) and -0.913 (p<0.01), respectively under DE treatment in 2007, while the significantly positive correlation (r = 0.817, p<0.01) of IVDMD with NDF content was obtained in LB under DE treatment in 2007. CF treatment also caused negative correlations of IVDMD with the three fiber fractions in ST (r = -0.614, -0.904, -0.751), which were significant at the 1% level.

Discussion

Response of Plant Characters, Herbage Consumption and Intake by Grazing Animals to Different Source of Fertilizer Application

Effect of fertilizing sources, CF and DE on plant growth attributes, herbage consumption and intake by grazing animals are summarized in Table 2. No significant differences obtained in every attribute between the two fertilizing sources, except for the pre-grazing herbage IVDMD in 2007 and ADF and ADL content in 2007 and 2008. Higher IVDMD in CF treatment was concurrent with lower ADF and ADL contents than in DE treatment and these quality attributes were closely related with herbage mass (Minson, 1990). In our previous research on herbage yield and quality in DL Napier grass pasture supplied by the two fertilizing sources, positive correlation of herbage yield with fiber contents and negative correlation of that with IVDMD were obtained (Hasyim *et al*., 2010). Except for these minor variations between the two fertilizing sources, the effect of DE application on herbage mass and consumption was almost equivalent with that of CF application in DL Napier grass pasture for 2 years of grazing practice.

Variations in Plant Response to DE Application between Cut-and-Carry and Grazing Systems

The effect of DE application on herbage yield under the dairy-cow grazing was almost equivalent with that of CF application in the two years. Responses of herbage production to DE application can be compared with our previous results in the cut-and-carry system, where the cutting height was simulated with the defoliated height by the current grazing trials and DE was applied at 3 levels, combined with the highest N level of DE by CF application in the same two years (Hasyim *et al*., 2014). A sole positive correlation was obtained in each year between herbage mass and N input in the annual total across cutting and grazing systems under both DE and CF applications (Fig. 7). The regression coefficient was almost the same at around 19 g DM g N^{-1} between the two years, while y-intercept increased from 2007 to 2008 possibly due to several reasons. The first reason for increasing herbage yield could be doubling N input from 11.2 in 2007 to 23.4 g N m^{-2} yr^{-1} in 2008 at the present grazing study and the second reason might be due to the regrowth from the overwintered stubbles in 2008. It is a common feature for Napier grass that annual herbage yield increased in the following year after establishment (Wadi *et al*., 2004). Therefore, it is concluded that effect of DE application on stimulating herbage production was regulated by the rate of N input in the same regression with CF application.

Handling Difficulty of Spraying Liquid DE to the Grazing Pasture

In the present study, liquid DE was applied to DL Napier grass pasture twice before the grazing started on DL Napier grass pasture and at every cycle after the grazing terminated in each paddock. Therefore, almost 1,200 L (1.2 m^3) of liquid DE needed to be transported from the bio-gas plant to 0.2-ha of post-grazing pasture and be applied by vacuumed sprayer. However, this fertilization method has several merits that DL Napier grass pasture required high rate of liquid DE at more than 200 kg N ha^{-1} yr^{-1} in the growing season, which was a suitable situation for high density of livestock producers in southern Kyushu and pasture managers can replace purchase of chemical fertilizer with the application of liquid DE to reduce the fertilization cost. It is necessary to estimate the effect of supplying liquid DE on the quality in soil and percolated water (Hasyim *et al*., 2009).

Effect of Spraying Liquid DE to Leafage of DL Napier Grass on Herbage Consumption by Grazing Animals

It is a common feature that positions of cattle dung on the grazing pasture interfere with the grazing behaviors of animals (Marten and Donker, 1964; Marsh and Campling, 1970). Even if liquid DE had already fermented in an anaerobic process by bio-gas plant (Cu *et al*., 2015), there remained slight odor in the solution. In the present study, we maintained almost 30 days of rest period after foliar application of liquid DE was carried out at the post-grazing in each paddock and herbage consumption was not significantly different between DE and CF plot in either year. We had a preliminary trial where restart of grazing by dairy cows was conducted just after the foliar application of liquid DE was completed at the post-grazed DL Napier grass pasture as usual, to find that grazing behavior of dairy cows had no obvious difference between DE-applied and CF areas. Therefore, it is suggested that soil injection or percolation by fertilizing tube should not be necessary for supplying liquid DE instead of foliar application, which is much more convenient method of liquid fertilizer (Schröder *et al*., 2005). Liquid fertilizer in a foliar application seemed to be fast effective than the solid fertilizer, since the solved process of solid CF and uptake of inorganic elements (Markewich *et al*., 2012) by plant roots, which are easily affected by pattern of precipitation, could be skipped in foliar application (Dorahy *et al*., 2004).

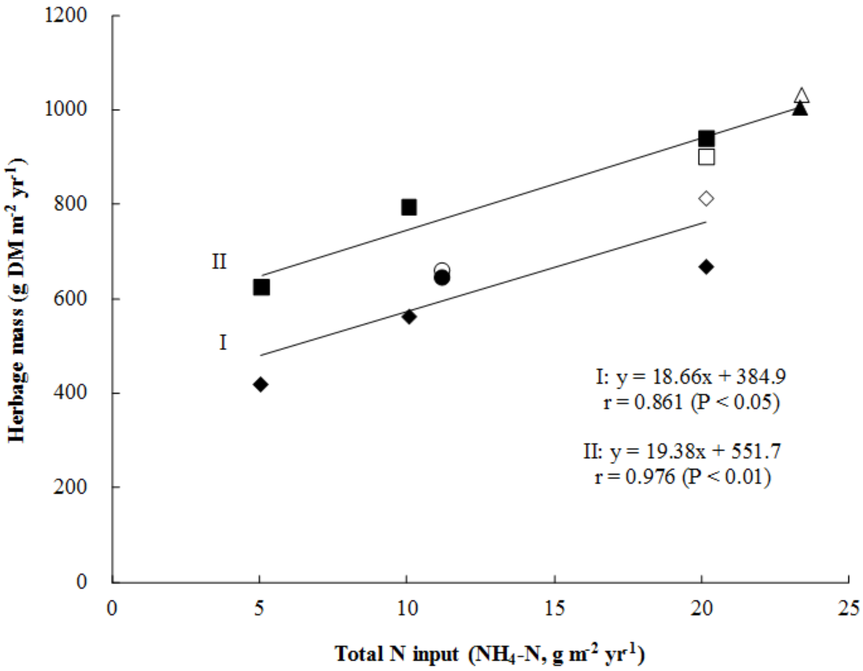

Fig. 7. Relationships between annual total of herbage mass and annul total of N input in Dwarf Napier grass in 2007 (I) and 2008 (II). (I) In 2007 under grazing management: CF (○), DE (●); under cut-and-carry management: CF (◇), Low, medium and high levels of DE (◆). (II) In 2008 under grazing management: CF (△), DE (▲); under cut-and-carry management: CF (□), Low, medium and high levels of DE (■); Under cut-and-carry management, from Hasyim *et al*. (2014).

Grazing Behavior of Dairy Cows on DL Napier Grass Pasture

Grazing management aims to provide herbage in sufficient quantity and quality so as to satisfy animal needs under the sustaining pasture. During a grazing sequence, animals frequently face a choice between patches differing in vegetation structure and/or quality and cattle are shown to select the feed that provided the highest food intake rate (Distel *et al*., 1995) as well as in sheep (Kenney and Black, 1984) and goats (Illius *et al*., 1999), resulting in higher intake rate with higher quality and energy intake rate. Mukhtar *et al*. (2004) reported that plant height of DL Napier grass pasture decreased continuously with the grazing proceeded, suggesting that herbage consumption by grazing beef cows was more frequent in leaf blade than in leaf sheath and stem.

In many cases, plant growth reduction is less than expected from the proportion of biomass removed, which means that the vegetation could show a compensatory response to defoliation (Ferraro and Oestersheld, 2002). Wadi *et al.* (2004) reported that compensatory response in Napier grass and *Pennisetum* relatives to defoliation may be linked with plant environment (the decrease of self-shading), plant physiology (an increase of photosynthetic rate, the reallocation of growth from other parts of the plants, reduction of leaf senescence and greater light use efficiency) and morphogenetic adaptation (an activation and proliferation of axillary meristems, tillering and clonal development). Reducing pollution and intensive management for environmental purposes can be achieved by rotational grazing system on DL Napier grass pasture by dairy cows due to high percentage of leaf blade, dry matter yield and nutritive value. The most attractive aspect of time-controlled grazing systems to livestock producers is the increase in stocking rates (Heitschmidt *et al*., 1987; Jacobo *et al*., 2000), because of more intensive management resulting from the subdivision of large pastures and the addition of water sources (Hart *et al*., 1993). Difficulty in maintaining high stocking rates under continuous grazing for any extended period of time (Heitschmidt *et al*., 1983) has led to initial experiments to evaluate rotational grazing systems at stocking rates higher than those used in continuous grazing. However, maximization of livestock production requires maintaining high stocking rates because this variable determines the potential magnitude of profits realized by a ranching enterprise (Conner, 1991). We assessed that it is possible to achieve a sustainable utilization and longevity of DL Napier grass with rotational grazing of dairy cows. A remarkable feature of this grazing system is its flexibility, based on the understanding of the biological processes involved and rest periods varied throughout the seasons depending on the regrowth rate of the DL Napier grass. Later on, the present study could be applied into individual farms in one of the organic farming (Yadav *et al*., 2013) because the paddock scale experiment has been carried out for 2 years.

Conclusion

In conclusions, plant growth attributes, herbage mass, consumption and dry matter intake were comparatively similar between DE and chemical fertilizer plots for 2 years of grazing trials by dairy cows. Thus, DE can be utilized as a rapidly effective fertilizer on DL Napier grass pasture by rotational grazing system of dairy cows whose dry matter intake averaged 4.4 kg DM head^{-1} day^{-1} across 4 grazing cycles both years in the hottest summer season from July to October in southern Kyushu, warm regions of Japan.

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Author's Contributions

Hadijah Hasyim: Participated in all experiments, coordinated the data analysis and contributed to the manuscript writing.

Ahmad Wadi: Participated in all experiments, coordinated the data analysis and contributed to the manuscript writing.

Yasuyuki Ishii: Designed the research plan, participated in the grazing experiment and contributed to the manuscript writing.

Sachiko Idota: Designed the research plan, participated in the chemical analysis and contributed to the manuscript writing.

Kiichi Fukuyama: Participated in the DE application and grazing experiment and organized the study.

Etics

It is declared that there are no ethical issues that may arise in the present study.

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