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Effect of Level of Manure Application on Leaf and Tiller Growth in Pot-cultured Napiergrass (*Pennisetum purpureum* Schumach)

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Summary : To determine growth rates of napiergrass (*Pennisetum purpureum* Schumach) as affected by mineralized nutrients from applied manure, leaf and tiller growth and growth parameters of a plant were determined under several levels of manure application in a pot-cultured condition from June to September. With the increase in manure application, leaf growth was promoted primarily by the increase in tiller number and total expanded leaf number per shoot, but not by the increase in percentage of live leaf. With the increase in manure application, tiller growth increased by the increase in tiller number and mean tiller weight, up to the medium level (4 kg/m^2) of manure application. For dry matter partitioning in a plant, ratio of leaf blade to stem inclusive of leaf sheath and that of top to root (T/R) decreased with time, except for the T/R in early June, and were not affected significantly by the level of manure application. The increases in leaf and tiller growth with the increase in manure application lead to the increase in leaf area index (LAI), with which crop growth rate (CGR) was linearly related across a whole range of LAI. Highest CGR in the warm summer season in manure application was mediated with the stable net assimilation rate in a range of LAI, suggesting the higher rate of mineralization from manure.

Key words : Growth parameters, Leaf, Manure application, Napiergrass, Tiller.

Introduction

A comprehensive manure management on herbages is essential for forage production by understanding the amount of manure input, absorption of manure nutrients by herbages and reasonable balance between the input and the absorption of forage crops (Idota *et al.* 2005). As for supplying herbages to animals, the quantity and quality of herbages should be maintained by choosing the suitable species that can achieve high production with high quality (Mendoza & Schank 1987), be adapted to local environments and survive in high longevity (Humphreys 1991).

Absorption of manure nutrients by herbages is dependent on the growth of herbages, and careful management of fertilization is required to main-tain high quality of herbages (Humphreys 1991). Napiergrass (*Pennisetum purpureum* Schumach) can be adapted to the southwestern warm region of Japan (Ito *et al.* 1988) and survive in Miyazaki for many years. Napiergrass grows rapidly and requires heavy fertilization to achieve high production (Miyagi 1981 ; Mohammad *et al.* 1988 ; Sunusi *et al.* 1999 ; Wadi *et al.* 2003a). The growth characters as well as forage quality are variable depending on the growth stage of herbages (Hsu *et al.* 1989 ; Woodard *et al.* 1991 ; Sunusi *et al.* 1997 ; Ishii *et al.* 1999). High leaf expansion, vigorous tillering and rapid leaf production in tall canopy are characterized as fundamental factors to achieve high production of napiergrass (Ferraris *et al.* 1986 ; Matsuda *et al.* 1991 ; Wadi *et al.* 2003b). Thus, high level of manure input is expected to obtain high level of forage yield in napiergrass (Sunusi *et al.* 1997). The growth of napiergrass is expressed by a

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strong thermal response (Ferraris 1978). After transplanting at an established year and in early regrowth from the overwintered stubble at the following year, the growth rate of napiergrass increases with the increase in temperature (Ferraris *et al.* 1986). The mineralization of applied manure is also regulated by temperature condition *via* microbial activity in applied soil environments. Growth rate of napier-grass should be maintained in accordance with mineralized rate of manure nutrients, so as to mitigate the risk of mineral pollution in the productive for-age field (Sunusi *et al.* 2006).

In this paper, the growth of napiergrass is examined by leaf and tiller development, as affected by the level of manure application at the established year in 2002 and 2003.

Materials and Methods

Plot design

Napiergrass (cv. Wruk wona) was grown in sandy soil of 1/2000 a Wagner pot for 4 months in an experimental field of the Faculty of Agriculture, University of Miyazaki, in 2002 and 2003. The pots were arranged by a blocked design of manure application (4 levels and 3 levels in 2002 and 2003, respectively) as 3 replicates for 12 and 3 pots per replicate in 2002 and 2003, respectively. Pots were spaced at 50 cm×50 cm, and the sizes of each replicated plot were 2 m×1.5 m (3 m^2) and 1.5 m×0.5 m (0.75 m^2) in 2002 and 2003, respectively. Plot was surrounded by bordering plants grown in the soil. Same grass species and same plot arrangement were applied for chemical fertilizer application in 2000 (Wadi *et al.* 2003a).

Plant culture

A single rooted tiller was transplanted at one tiller per pot, on May 13, 2000, May 14, 2002 and May 14, 2003. Commercial fermented cattle manure (Sun-green, Miyazaki Taihi Co. Ltd.) was supplied to the soil surface in the pot at 0, 2, 4 and 6 ton/10 a (kg/m^2) for the control (C), low (L), medium (M) and high (H) levels, respectively in 2002 and the same application levels except for the M level were repeated in 2003. Total nitrogen (N) concentration of applied manure was 0.85 % (Idota *et al.* 2005) and mineralization percentage of N from manure in the growing season was 50 % (Idota *et al.* unpublished). Therefore, mineralized N rates from supplied manure in the growing season were estimated at 0, 8.5, 17.0 and 25.5 g/m^2 for C, L, M and H levels, respectively. In 2000, chemical compound fertilizer, consisting of N, P_2O_5 and K_2O = 13 : 13 : 13, was supplied as 2 split applications up to the late August and total N inputs were 3.33, 6.67 and 20 g/m^2 for L, M and H levels, respectively (Wadi *et al.* 2003a). Watering was done everyday with a plastic vase set at the outlet of Wagner pot for protecting the runoff of nutrients in water.

Plant measurements

Changes in dry matter weight (DMW) of every plant part (leaf blade, LB ; stem with leaf sheath, ST ; dead parts, D ; underground parts, UG ; and root, R) and some plant growth characters, such as plant height, PH ; tiller number, TN ; live leaf number, LLN ; and leaf area, LA, which are related to dry matter production, were investigated for 3 plants (1 plant from each replicate) at each fertilization level at intervals of about 30 days from June to September. After harvest, sampled pots were re-transplanted by the bordering plants to fill the empty space left by the sampling. Plant organs from harvested plants were separated and dried at 70°C to determine DMW. Plant LA was measured with an automatic area meter, AAM-8 (Hayashi Denkoh Co. Ltd.).

Statistical analysis

Statistical significance with respect to the difference in the mean value of plant characters at the sampling date were assessed by using the analysis of variance and least significant difference at the 5 % level.

Results and Discussion

Changes in leaf and tiller growth

For all levels of manure application, plant height increased along a sigmoid curve in both 2002 and 2003 (Fig. 1). With the increase in manure application, plant height increased up to the medium level and showed a saturated response at the highest 2 levels in 2002. Total expanded leaf number (TELN), which is the sum of live and dead leaf number, increased with the increase in manure application and reached a peak in July or August in every application level for both years. The TELN can be divided into TELN per shoot (TELN/S) and tiller number. The TELN/S increased with time through September in every application level for both years and tended to increase with the increase in manure application in 2002. Percentage of live leaf number to TELN (PLL) decreased with time for both years except for the lower PLL in June 2002 due to the death of lower leaves by the damage at the transplanting. The PLL was hardly affected by the

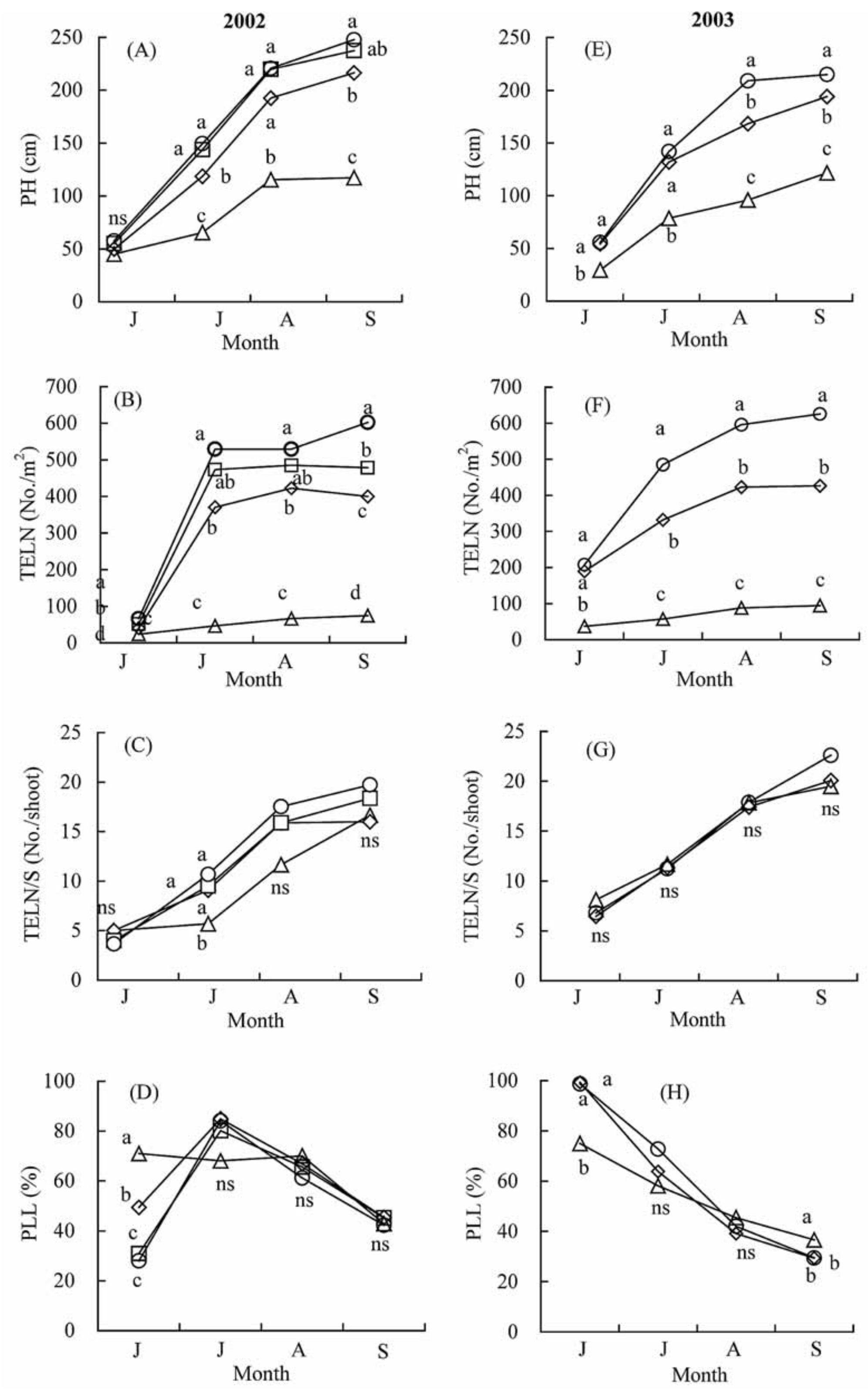

Fig. 1. Changes in plant height (PH ; A, E), total expanded leaf number (TELN ; B, F), total expanded leaf number per shoot (TELN/S ; C, G) and percentage of live leaf (PLL ; D, H) of napiergrass under different levels of manure application in 2002 (A-D) and 2003 (E-H).
Treatment : control (△), low (◇), medium (□) and high (○) manure level.
Manure level (ton/10a) : control (0), low (2), medium (4) and high (6).
The values followed by different letters on the same date were significantly different ($P < 0.05$). ns : not significant.

level of manure application for either year, as in the same effect by the level of chemical fertilizer application (Wadi *et al.* 2003b). Thus, with the increase in manure application, leaf growth was promoted by the increase in TELN, which was principally mediated with TELN/S and tiller number, as shown in Fig. 2.

Changes in tiller growth were determined by tiller number (TN) and mean tiller weight (MTW) in 2002 and by tiller number in 2003 (Fig. 2). Both TN and MTW increased with the increase in manure application up to the medium level and showed a saturated response at the highest 2 levels in 2002. The TN increased significantly with the increase in manure application through the whole growing season in 2003.

Changes in DMW of whole plant, dry matter partitioning in a plant and leaf area index (LAI) were

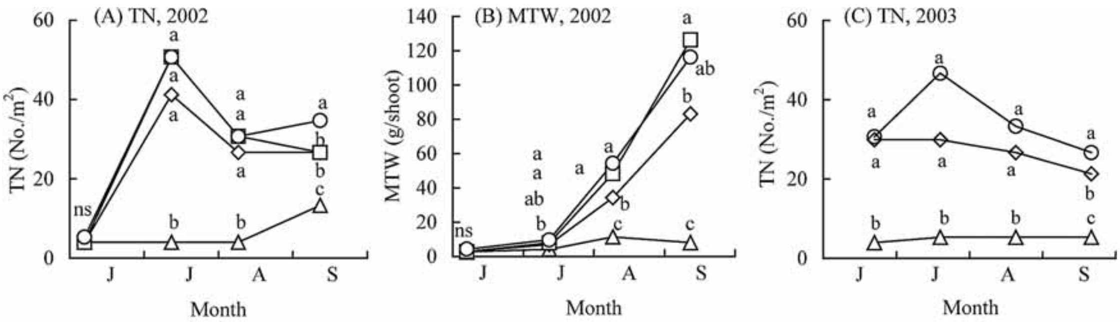

Fig. 2. Changes in tiller number (TN ; A, C) and mean tiller weight (MTW ; B) of napiergrass under different levels of manure application in 2002 and 2003.
Treatment : control (△), low (◇), medium (□) and high (○) manure level.
The values followed by different letters on the same date were significantly different ($P<0.05$). ns : not significant.

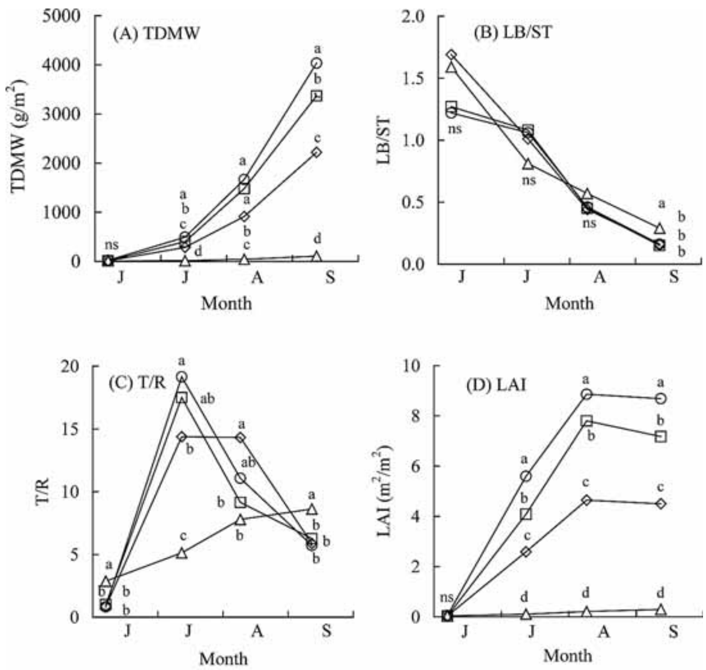

Fig. 3. Changes in dry matter weight of whole plant (TDMW ; A), ratio of leaf blade to stem with leaf sheath (LB/ST ; B), top to root ratio (T/R ; C) and leaf area index (LAI ; D) of napiergrass under different levels of manure application in 2002.
Treatment : control (△), low (◇), medium (□) and high (○) manure level.
The values followed by different letters on the same date were significantly different ($P<0.05$). ns : not significant.

compared for 4 levels of manure application in 2002 (Fig. 3). Dry matter weight of whole plant (TDMW) increased with time and increased significantly with the increase in manure application. To determine dry matter partitioning, the ratio of leaf blade to stem inclusive of leaf sheath (LB/ST) and that of top to root (T/R) were calculated. The LB/ST decreased with time through September and was hardly affected by the level of manure application, which was the same tendency with chemical fertilizer application (Wadi *et al.* 2003a). The T/R showed the lowest ratio at 3 weeks after transplanting in early June consistently under different levels of manure application, which was the similar tendency under chemical fertilizer application (Wadi *et al.* 2003a). The T/R reached a peak in early July and decreased significantly with time in every manure applications, except for the control where T/R increased steadily with time. Thus, the root growth followed the top growth under 3 levels of manure-applied plots. On the contrary, T/R increased with time after one month from transplanting under chemical fertilizer application (Wadi *et al.* 2003a). The LAI increased steadily from planting through early August and showed a saturated response through September under 3 levels of manure-applied plots. The LAI increased significantly with the increase in manure application.

Growth parameters and their relationship to dry matter yield

Relationships between crop growth rate (CGR) and mineralized N input were compared with time under 4 levels of manure application in 2002 and under 3 levels of chemical fertilizer application in 2000 (Fig. 4). The CGR increased with the increase in N input and the positive effect of manure application was strengthened with time until the final period for both years. In the final period for 2002, CGR tended to increase linearly with the increase in N input, suggesting that the mineralization rate of manure was promoted with the increase in growth temperature in the warm summer season.

Relationship between CGR and LAI was positively linear across 4 levels of manure application over the whole growing season ($r = 0.982$, $P < 0.01$), as shown in Fig. 5 (A). Under the chemical fertilizer application in 2000, linear regression coefficient of CGR with LAI tended to decrease with time (Wadi *et al.* 2003a), which was contrary to the same regression coefficient existed between CGR and LAI under manure application in 2002. Under the manure application, NAR was negatively regressed on LAI ($r = 0.882$, $P < 0.01$), as shown in Fig. 5 (B) and the drop in NAR with the increase in LAI was negligible between the medium and high levels of manure application. Highest CGR in the warm summer season under

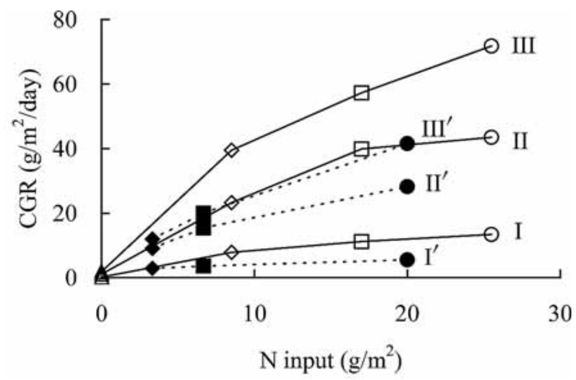

Fig. 4. Seasonal changes in the relationship between crop growth rate (CGR) and N input.
2002 : I (June 6 – July 12), II (July 12 – Aug. 8), III (Aug. 8 – Sep. 9).
2003 : I' (May 27 – June 27), II' (June 27 – July 25), III' (July 25 – Aug. 23).

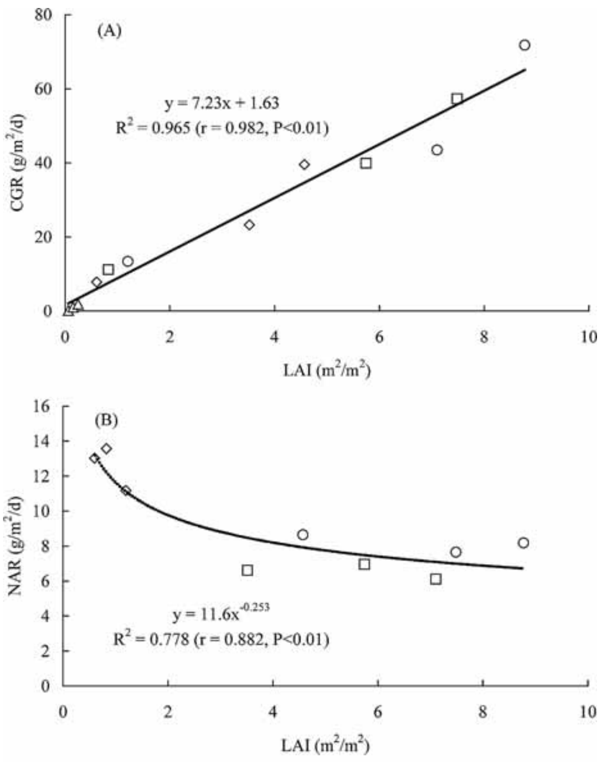

Fig. 5. Relations of crop growth rate (CGR ; A), and net assimilation rate (NAR ; B) with leaf area index (LAI) of napiergrass under different levels of manure application in 2002.
Treatment : control (△), low (◇), medium (□) and high (○) manure level.
The values followed by different letters were significantly different ($P < 0.05$).
ns : not significant.

manure application was mediated with the stable net assimilation rate in a range of LAI, suggesting the higher rate of mineralization from manure. Thus, CGR increased linearly with the increase in LAI, which resulted in the non-saturated increase in TDMW through the whole growing season under the examined levels of manure application.

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* : In Japanese with the English summary.

堆肥の施用量がポット栽培したネピアグラス（*Pennisetum purpureum* Schumach）の葉と分げつの成長に及ぼす影響

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要　約

ネピアグラスの成長に及ぼす堆肥から無機化した養分量の影響を検討するため，異なる堆肥施用量の下でポット栽培したネピアグラスの分げつと葉の成長および個体当りの成長形質を測定した．堆肥施用量の増加に伴い，葉の成長は主として茎当りの総展開葉数および分げつ数の増加により促進された．分げつ数および平均分げつ重は，堆肥施用量が中程度（4 kg/m^2）のレベルまで増加するにつれて増加した．植物体内の乾物分配については，茎（葉鞘を含む）に対する葉身の比率や地下部に対する地上部の比率は生育に伴い低下したが，堆肥施用量の影響はほとんど認められなかった．堆肥施用量の増加により葉と茎の成長が促進され，それが葉面積指数（LAI）の増加をもたらし，さらに個体群成長速度（CGR）の増加をもたらした．CGRはLAIとの間に，全LAIを通して正の直線関係が成り立った．堆肥施用により，高温の盛夏期間にCGRが最も高くなったのは，広範囲のLAIの下で純同化率がほぼ一定であったことによっており，盛夏期間に堆肥からの無機化速度が高まったことが示唆された．

キーワード： 成長形質，堆肥施用量，ネピアグラス，葉，分げつ.