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Potentiality of dry matter production and overwintering ability in dwarf napiergrass introduced from Thailand

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Abstract

The present research was aimed to investigate the growth characteristics in relation with dry matter production and overwintering ability in the field-grown dwarf napiergrasses, as compared with the normal ones for assessing the potentiality of growing dwarf napiergrass in Miyazaki, southern Kyushu, Japan. Two normal varieties of Wruk wona (Abbreviated as Wr) and Merkeron (Me), and two dwarf ones of early heading (D-E) and late heading (D-L) were transplanted at the density of 4 plants/m² by one tiller per plant. Growth characteristics and dry matter production were investigated every month through to late October, 1997 and overwintering ability was inspected in March and April, 1998. At the end of the growth season, plant length, top dry weight and mean tiller weight were the highest in normal napier; Wr, followed by Me, D-E and D-L, but the difference in leaf area index was small among the varieties and thus the dry weight percentage of leaf blade to the whole top was higher in the dwarf varieties than the normal ones. Particularly, tiller number was higher in D-L than other three varieties. Dwarf varieties tended to have the comparative leaf development with the lower net assimilation rate, which resulted in the lower crop growth rate than the normal varieties. At the end of the growth season, dwarf varieties tended to have leaf blades with shorter length, slightly smaller width, smaller area and dry weight, and larger specific leaf area than the normal. As for the internode, dwarf varieties had shorter internode length especially at the lower nodal positions before its stem-elongation. The sum of internode dry weight among the elongated nodal positions was linearly related with the sum of its volume, which suggested that the stem dry weight, the major part of plant dry weight, was primarily determined by the internode volume. In the dwarf varieties, the dry matter production, associated with the enlargement in internode volume was suggested to be suppressed severely by its dwarfism. Dwarf varieties had the similar overwintering ability with the normal, reaching above 80% of the overwintered plants, irrespective of cutting at either pre- or post-wintering. Thus, dwarf napiergrass was assessed to have some productive

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potentiality as the perennial plant in Miyazaki, if it should be planted at the higher planting density than the ordinary one for compensating the lower individual plant growth.

Key word : Dwarf napiergrass, Dry matter production, Growth characteristic, Overwintering ability.

Introduction

Since Thai dairy farm is mainly operated under the cut and carry system in the small holder farmers, it is essential to consider the best cutting method for optimizing forage productivity[12). Therefore, in Thailand, dry matter productivity of dwarf napiergrass (*Pennisetum purpureum* Schumach) bred recently was compared with the normal napiergrass varieties under the several cutting height from 0cm to 30cm and it was found out that dwarf napiergrasses exhibited the comparative dry matter productivity with normal ones if the cutting height was set to 10cm or 20 cm[6)]. There are obviously different climatic conditions between rainy and dry seasons in Thailand, and the farmers used to prolong the herbage cutting after even the dry season has commenced. However, as this manner of grassland utilization reduces severely the subsequent regrowth ability in the next season, it has just been investigated for the possibility of extending to cut dwarf napiergrass after the dry season starts[12)].

In dwarf napiergrass bred in Georgia, USA, several observations were already done for its growth characteristics in Florida and Georgia, and it was shown that *in vitro* dry matter digestibility and overwintering ability in the dwarf napiergrass was comparative with the normal napier varieties and the percentage of leaf blade to total dry matter weight and forage quality such as crude protein were superior to the normals, while dry matter productivity in the dwarf was inferior to the normals[1, 9, 14)]. Actually, the average daily gain of the grazed cattle was found to be higher in the dwarf napiergrass pasture in comparison with the bahiagrass pasture in Florida, USA[8)]. Recently, it was now a new trial to breed the hybrid between dwarf and normal napiergrasses for the aims at improving the dry matter production of the dwarf varieties and of investigating the dry matter productivity and forage quality in the semi-dwarf varieties[13)]. However, in these researches for comparing the dry matter productivity between dwarf and normal ones, it remains to be assessed precisely for the relations of dry matter productivity with some characteristics of each leaf and internode position. Thus, the present research was aimed to investigate the growth characteristics in relation to dry matter production from the view point of each leaf and internode position and the overwintering ability of field-grown dwarf napiergrass, as compared with the normal ones for assessing the potentiality in growing dwarf napiergrass in Miyazaki, southern Kyushu, Japan.

Materials and Methods

Napiergrass varieties tested were two normal varieties, *i. e.* Wruk wona (Abbreviated as Wr) of the tiller weight type and the promising high yielding variety and Merkeron (Me) of the intermediate type in its tiller weight and the most popular in the southern Kyushu of Japan, and the two dwarf varieties, *i. e.* Dwarf-early (D-E) of the early heading variety and Dwarf-late (D-L) of the late heading one. Planting of the rooted tillers from the overwintered stubbles was carried out on 31 May, 1997 for the normal ones and on 3 July, 1997 for the dwarf ones at the density of 4 plants/m² by one tiller per plant. Every month after planting, chemical fertilizer at the element rate of 300kg/ha/year for each of

N, P_2O_5 and K_2O was supplied at the three split-applications. At the end of the growth season on 26 October, just before the first frost date, plant characteristics related with dry matter productivity and several characteristics of leaf blade on each leaf position and of internode on each nodal position were compared among varieties of the dwarf and the normal. The dry matter productivity analyzed by the growth analytic research was investigated every month as a preliminary trial and the characteristics for the canopy structure, *i. e.* relative light intensity (RLI) at the ground surface and mean transparent angles (MTA) of the canopy, were investigated by the apparatus of Plant Canopy Analyzer (Licor Co. Ltd., LAI-2000) in the late growth season on 6 September and 26 October.

Results and Discussion

Changes in the climatic conditions

Figure 1 shows the change in the climatic conditions of ten day's averages of mean air temperature, solar radiation and precipitation. This experimental year had a relatively uniform rainfall except for late August when the solar radiation was consistently higher among the season, which may be the impediment to growth by water stress. The growth was completely suppressed by the first and heavy frost on 1 November, 1997 when it frosted so earlier by 20 days than in the normal year.

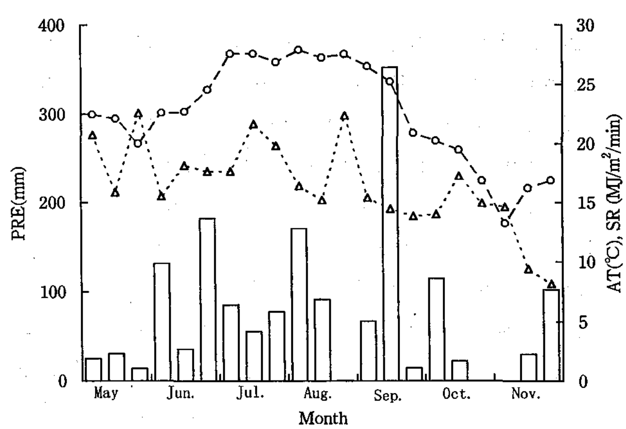

Fig. 1. Changes in ten day's average of mean air temperature (AT, ○), total solar radiation (SR, △) and ten day's total of precipitation (PRE, □) in 1997.

Growth characteristics at the end of growth season

The growth characteristics related with plant productivity were observed at the end of growth season on 26 October, just before the first frost date (Table 1). Plant length (PL) was higher in normal varieties of Wr and Me, than in dwarf ones of D-E and D-L. Tiller number (TN) was higher in D-L than the other three varieties, and it suggests that the variety of D-L was less affected by the mutual shading through to the end of its growth[5] at the present planting density. The top dry weight (TDW) was larger in the normal varieties than in the dwarf ones, which was principally due to the distinct difference in mean tiller weight (MTW). There was no significant difference in leaf area index (LAI) among varieties and thus, the consistent tendency was seen in the higher percentage of leaf blade weight to TDW (PLB) in the dwarf ones than the normal. Non-significant differences in TDW and LAI among normal Wr and Me were consistent with the other research[10], which showed the superior dry matter productivity in Wr to that in Me only under the higher N input above 600 kg/ha/year than the present input level.

Potentiality of growth functions in the dwarf napiergrass as compared with the normal ones

As a preliminary trial, the growth functions were compared among varieties only for the aboveground parts by the relations of LAI with crop growth rate (CGR, Fig. 2 A) and with net assimilation rate (NAR, Fig. 2 B). The CGRs were linearly correlated with LAI (A) and the NARs were negatively and logarithmically related with LAI (B) both in the normal and in the dwarf varieties. However, the regression coefficient in the relation between CGR and LAI was distinctly higher (Fig. 2 A) and the NAR was regressed to be always higher (Fig. 2 B) in

Table 1. Plant characteristics of the plant length (PL), tiller number (TN), top dry weight (TDW), leat area index (LAI), mean tiller dry weight (MTW) and dry weight percentage of leaf blade to the top (PLB) on 26 Oct., 1997

Plant characteristics	Variety			
	Wruk wana	Merkeron	Dwarf-early	Dwarf-late
PL (cm)	344[a1)]	332[a]	182[b]	120[c]
TN (No/m²)	21[a]	24[a]	24[a]	67[b]
TDW (g/m²)	3126[a]	2777[a]	1314[b]	1059[b]
LAI	6.84[a]	6.49[a]	6.22[a]	6.32[a]
MTW (gDW/tiller)	148.1[a]	108.1[b]	53.7[c]	15.8[d]
PLB (%)	16.0[a]	19.5[a]	25.5[b]	39.9[c]

1) Values with different letter were significantly different among varieties at 5 % level.

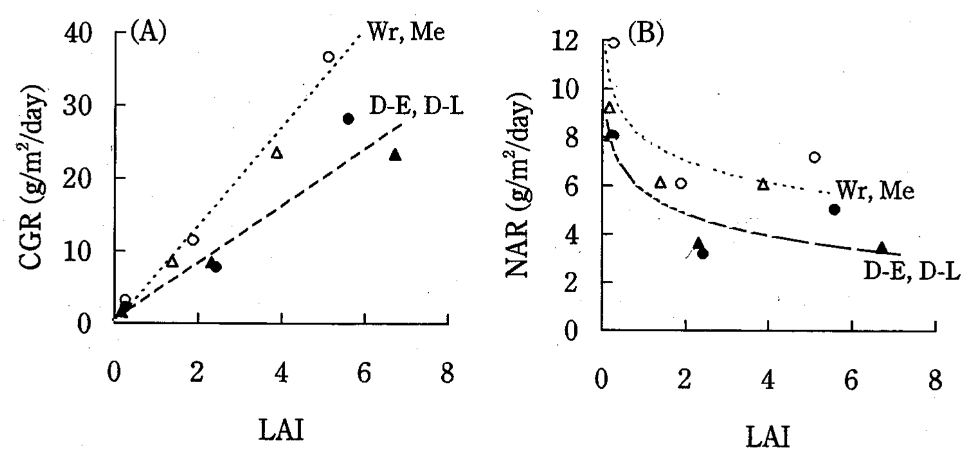

Fig. 2. Relations of leaf area index (LAI) with crop growth rate (CGR) of the aboveground parts (A) and of net assimilation rate (NAR, B) in the normal and dwarf varieties.
(A) Wruk wona (Wr, ○), Merkeron (Me, △) : y=-0.0763+6.739*x, r=0.991 ($P<0.001$),
Dwarf-early(D-E, ●), Dwarf-late (D-L, ▲) : y=0.324+3.969*x, r=0.958 ($P<0.01$).
(B) Wr, Me : y=7.967−1.307*ln(x), r=-0.780 ($P<0.10$),
D-E, D-L : y=5.761−1.307*ln(x), r=-0.881 ($P<0.05$).

the normal than in the dwarf varieties, if compared at the same LAI.

Thus, the leaf development, assessed by LAI, was comparative between the normal and the dwarf, while the NAR was distinctly lower in the dwarf than in the normal, which resulted in the lower CGR in the dwarf as much as 60% of the normal.

Characteristics of leaf blade

Several characteristics of leaf blade on some leaf positions on 26 October were shown in Fig. 3. Leaf blade length (LL), single leaf area (LA) and leaf dry weight (LDW) were larger in the normal than in the dwarf ones on every leaf position, whereas the difference between the dwarf and normal ones in leaf width (LW) turned to be small and the specific leaf area (SLA) was larger in the dwarf ones on every leaf position, which showed the tendency of thinner and spreading characteristics of leaf blade in the dwarf ones. The difference among leaf positions in the potential leaf area (PLA), calculated by the product of LL and LW, showed the similar pattern to the actual and measured LA. Comparing the difference in these characteristics

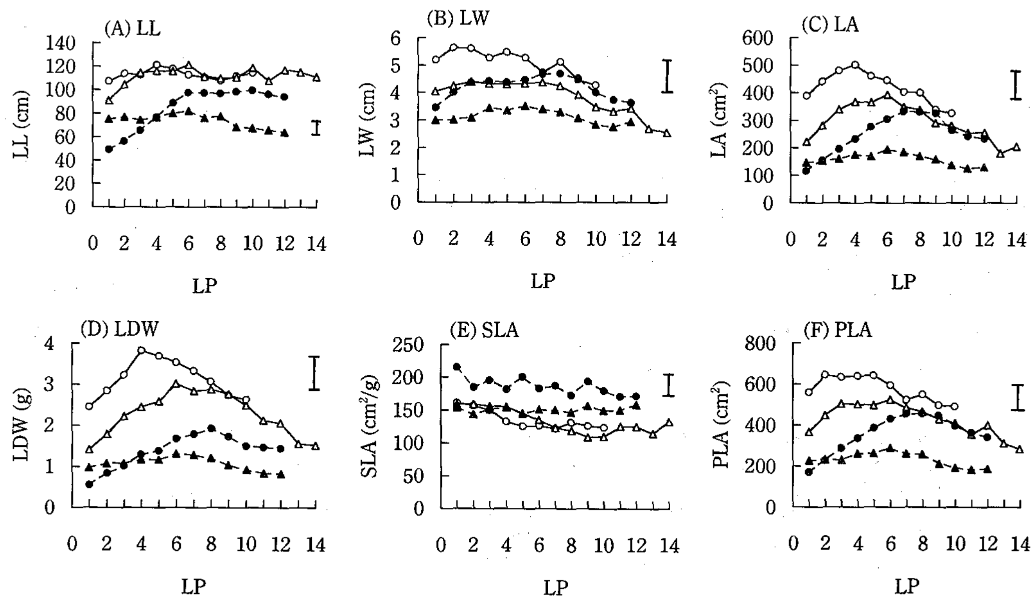

Fig. 3. Changes in the leaf length (LL, A), leaf width (LW, B), leaf area (LA, C), leaf dry weight (LDW, D), specific leaf area (SLA, E) and potential leaf area (PLA, F) on each leaf position (LP) on 26 Oct., 1997.
The PLA was calculated as the product of LL with LW and the LP was counted from the top to the base of the shoot.
Symbols are the same as in Fig. 2.
The bar (I) in the figure shows LSD at 5 % level.

among leaf positions, the dwarf varieties tended to have the higher LA and LDW on the lower leaf positions than the upper ones, and the variability in each leaf characteristic among leaf positions was shown to be quite small in D-L.

Therefore, actual LA was linearly related with PLA both in the normal and dwarf varieties (Fig. 4). However, regression coefficient in these regressions tended to be smaller in the dwarf varieties than in the normal, which reflected the bending characteristics of leaf blade in the dwarf ones, and was consistent with the relatively larger LW compared with LL in the dwarf ones than in the normal.

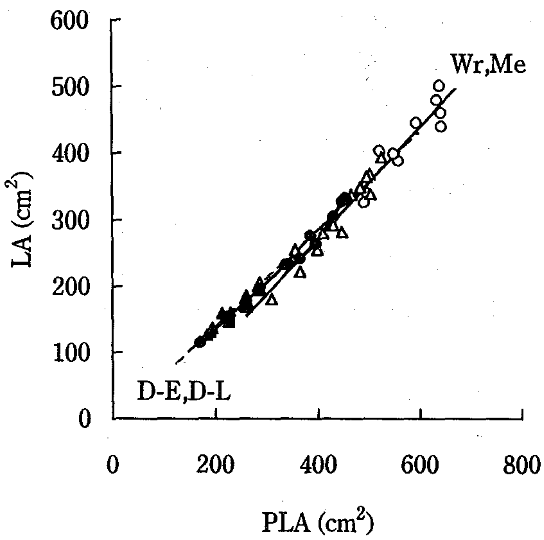

Fig. 4. Relation between potential leaf area (PLA) and measured leaf area (LA) on 26 Oct., 1997
Symbols and abbreviations are the same as in Fig. 2.
Wr, Me: $y=-64.24+0.8384x$, $r=0.976$ ($P<0.001$).
D-E, D-L : $y=-13.02+0.7368x$, $r=0.993$ ($P<0.001$).

Characteristics of internode

Several characteristics of internode were shown only for the aboveground and elongated ones among nodal positions in Fig. 5. The difference in the internode length (IL) between the normal and dwarf varieties was variable depending on the nodal position, *i. e.* IL in the dwarf varieties was smaller and showed the typical characteristics of the dwarf on the lower nodes, whereas it was almost similar to the normal on the upper nodal positions up to the 4 th (Fig. 5 A). This suggested that the difference in IL between the dwarf and normal ones disappeared once stem elongation commenced. These nodal positions

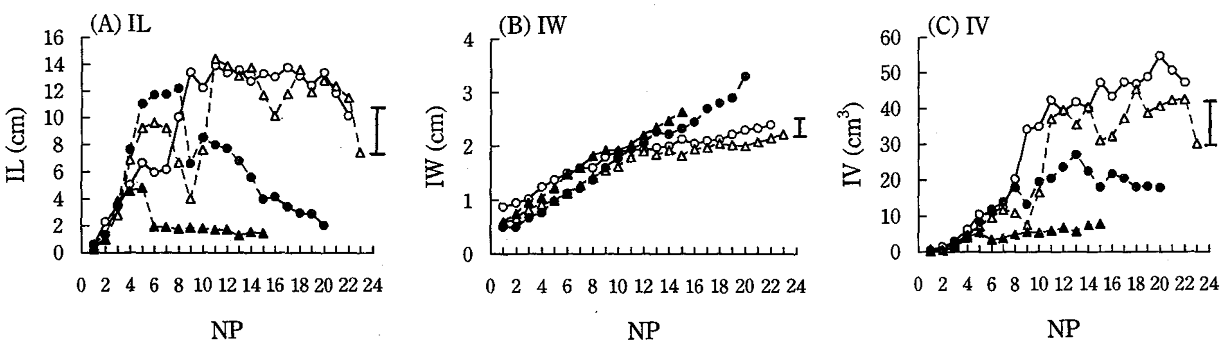

Fig. 5. Changes in the internode length (IL, A), internode width (IW, B), and internode volume (IV, C) on each nodal position (NP) on 26 Oct., 1997.
$IV=\pi*(IW/2)^2*IL$
The NP was counted from the top to the base of the shoot.
The symbols are the same as in Fig. 2.
The bar (I) in the figure shows LSD at 5 % level.

which showed no exhibited difference in IL between the dwarf and normal ones were from the top up to the 8th in the dwarf-early (D-E) and up to the 4 th in the dwarf-late (D-L). In addition, the sudden drop in IL around the 9 th to the 10th positions from the top in Wr, Me and D-E was inferred to be affected adversely by the short period of drought in late August.

As shown in Fig. 5 B, internode width (IW) appeared to be similar between normal and dwarf varieties on the upper and middle nodal positions, though it tended to be larger in the dwarf ones on the lower nodal positions, where the elongation in IL was severely restricted as shown in Fig. 5 A.

From this measurement, internode volume (IV) was calculated by the following equation, such as,

$$IV=\pi*(IW/2)^2*IL$$

and the difference in IV among nodal positions showed almost similar tendency to the case in IL (Fig. 5 C).

For considering the sink capacity in relation to the dry matter productivity, the relation between shoot internode dry weight (SIDW) and shoot internode volume (SIV) as shown in Fig. 6, was calculated to obtain sole linear regression nearly passing through the origin. Thus, there was almost constant density of 0.176g/cm³ if summed up the whole internode, irrespective of

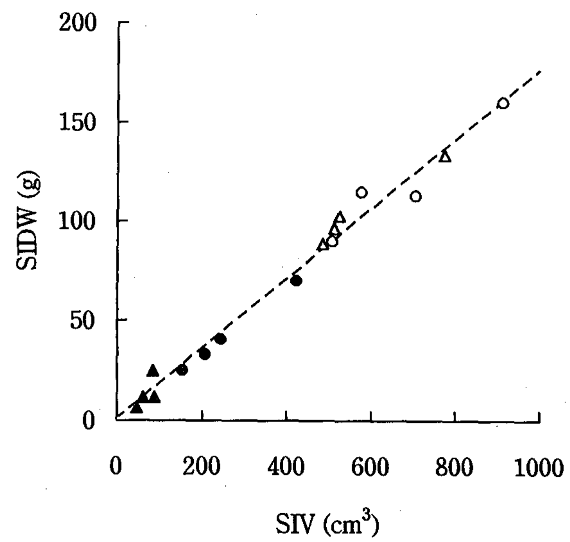

Fig. 6. Relation between the shoot internode volume (SIV) and shoot internode dry weight (SIDW) on 26 Oct., 1997.
Symbols are the same as in Fig. 2.
$y=0.913+0.1760x$, $r=0.991$ ($P<0.001$).

variety and shoot, and this relation suggested that the stem dry weight, which was the major part of plant dry weight both in the normal and the dwarf, was primarily determined by the internode volume.

Canopy structure

The relations of the characteristics in the canopy structure with dry matter productivity were assessed in Figs. 7 and 8. The relation of the mean transparent angle (MTA) with the canopy extinction coefficient (k), measured by

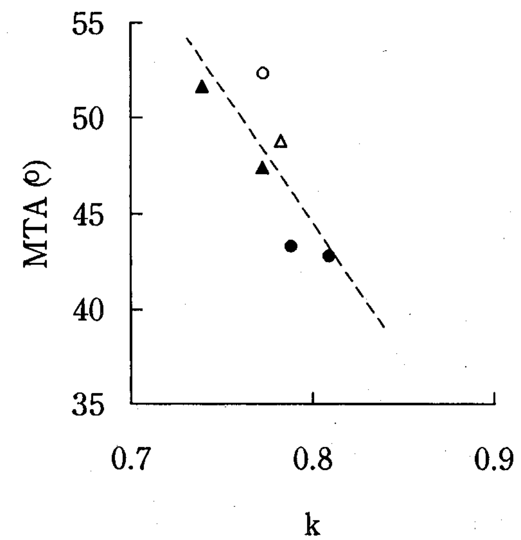

Fig. 7. Relation between mean leaf transparent angle (MTA) and canopy extinction coefficinet(k). The MTA was measured by the plant canopy analyzer (LAI-2000).
Symbols are the same as in Fig. 2.
$y=155.4-138.52*x$, $r=-0.790$ ($P<0.10$).

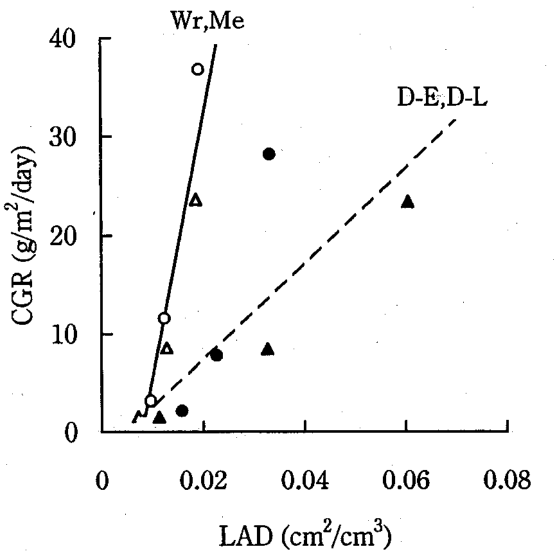

Fig. 8. Relation between leaf area density (LAD) and crop growth rate (CGR) of the aboveground parts.
Wr, Me : $y=-21.14+2655.4*x$, $r=0.944$ ($P<0.01$).
D-E, D-L : $y=-2.44+488.8*x$, $r=0.767$ ($P<0.10$).

the plant canopy analyzer, was shown to be significantly negative (Fig. 7). This relation suggested that the canopy of more erect leaf blade was accompanied with the lower k, which was the consistent tendency carried out only in the normal napiergrass of Me[3]. Especially, the dwarf variety of D-L showed the higher MTA with lower k, and these characterisitcs in the canopy structure suggested the erect habit of leaf blade during the whole growth stage.

In Fig. 8, the relation was assessed between CGR of the aboveground parts and leaf area density (LAD) which was the ratio of plant leaf area to the plant volume, expressed as the product of plant height with land area occupied by a plant (50cm by 50cm). The LAD increased with time in accordance with the increase in CGR, while the increasing rate in LAD was apparently larger in the dwarf varieties than in the normal ones. Thus, the significantly positive relation of CGR with LAD was strictly different between the normal and the dwarf varieties. The lower LAD in the normal varieties was maintained throughout the whole growth season, even they had the high LAI above 6, which was assumed to be effective for its superior dry matter productivity in the sense of carbon dioxide diffusive capacity and the reflecting sunlight absorption[4,11].

Assessment for potentiality of dry matter production

From these results, as stem elongation was reduced severely in the dwarf varieties during the early growth stage, the increase in top dry weight through the enlargement in internode volume associating with its dry matter accumulation, was suggested to be suppressed severely during the early growth stage. However, the dwarf varieties had higher percentage of leaf blade (PLB) than the normal and had the erect foliage with the smaller canopy extinction coefficient of k. These characteristics suggested that the dwarf varieties may have the production structure adapted to the planting condition under the higher density.

Overwintering ability

Overwintering ability was evaluated by the numeral percentage of overwintered plants with one or more regrown tillers to total plants (POP) and by mean regrown tiller number (RTN) in the overwintered plants (Fig. 9). The POP increased with time after March, reaching above 80 % in middle April in all of varieties,

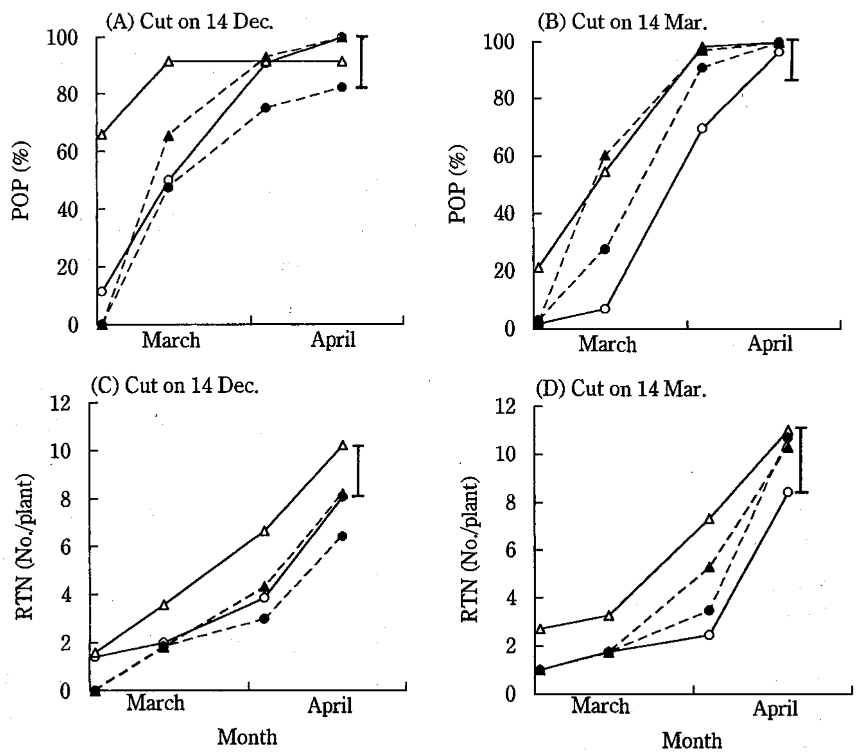

Fig. 9. Changes with time in the percentage of overwintered plants (POP, A, B) and mean regrown tiller number (RTN, C, D), cut on either 14 Dec., 1997 (A,C) or 14 Mar., 1998 (B, D).
Symbols are the same as in Fig. 2.
The bar (I) in the figure shows LSD at 5 % level.

irrespective of cutting before wintering on 14 December or not, although cutting at pre-wintering tended to promote the spring regrowth earlier than that at post-wintering.

The RTN was the highest in Mr, followed by D-L, Wr and the lowest in D-E, when they were cut at pre-wintering, while if cut at post-wintering, Wr had only lower RTN than the other three varieties in middle April.

Therefore, the dwarf varieties had the comparative overwintering ability with the normal ones enough to be assessed as the perennial even in Miyazaki, frost-prone area, which was the consistent result with the research in Florida, USA[13].

Concluding remark

In the further study, it is needed to consider the more suitable cultivating method in these dwarf napiergrass varieties by clarifying the relation of characteristics in dry matter production with plant density and cutting method, as already observed for the normal napiergrass[2,5,6,7,14]. Since planting density was fixed to be 4 plants/m^2 in this study, there was no decreasing tendency of TN in D-L as the reflection of the mutual shading[5], and it is furthermore stressed that the optimum planting density in D-L should be higher than the present study. Cutting height and interval were primarily the most principal components in cultivating and harvesting napiergrass in the sense of dry matter yield, digestibility and quality[2,6,7,14]. These components will be quantified to assess these dwarf napiergrasses as a promising forage grass, especially for the beef-cattle breeding farmers in Miyazaki. Considering for extending utilization of these dwarf napiergrasses, it should become an important application of the dwarf one into the grazed pasture, because of its higher nutritive value associating with the higher daily gain of the cattle, comparing with the tropical pasture of bahiagrass[8].

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タイから導入した矮性ネピアグラスの乾物生産性と越冬性

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摘　要

タイから導入した矮性ネピアグラス（*Pennisetum purpureum* Schumach）を，圃場試験により普通種と比較し，乾物生産に関する生育特性と越冬性を明らかにすることにより，南九州における同草種導入の可能性を検討した．供試品種は，普通種としてルクアナ（Wr）とメルケロン（Me）を，矮性種として早生種（D−E）および晩生種（D−L）を用い，株分け苗を普通種は5月31日に，矮性種は7月3日に，畦間，株間ともに50cm（4株/m²）とする栽植密度で，1株1本植えで植え付けた．植え付け後約1ヶ月ごとに，乾物生産に関する調査を初霜日（11月1日）の直前の10月26日まで行い，翌年の3，4月に越冬性を調査した．

生育季節の終期では，草丈，地上部乾物重，平均1茎重は，普通種のWr＞Me＞矮性種のD−E＞D−Lの順であったが，葉面積指数は品種間に大差なく，葉身重比率は矮性種が普通種に比べ高かった．また，茎数は，他の3草種に比べ，D−Lで最も多くなった．矮性種は普通種に比べ，葉面展開には大差ないものの，純同化率が低いため，個体群生長速度が低くなる結果であった．

生育末期における葉身の諸形質をみると，矮性種は普通種に比べ，葉身長，葉面積，葉身重が小さく，葉幅の品種間差は小さく，一方比葉面積は大きくなった．節間の諸形質をみると，矮性種は節間伸長の程度が大きくなる以前の下位節で，節間長が小さかった．茎の総節間体積と総節間重との間には，全ての草種をこみにして正の直線的関係が成り立ち，植物体乾物蓄積の主要部である茎の乾物重は，節間の体積により決定され，矮性種は節間の体積の拡大を通じた乾物生産の促進が妨げられていることが推察された．

越冬率は，越冬前の刈取りの有無に関わらず，矮性種でも80％以上であり，普通種と大差なかった．以上のことから，矮性ネピアグラスは個体当りの生産量が劣る点を補償できるよう，さらに高密度の栽植密度で栽培するならば，宮崎においても多年生草種としての潜在的生産能力を発揮できると推察された．

キーワード：矮性ネピアグラス，生長形質，越冬性，群落構造．

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