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A Simple Method to Estimate the Leaf Area in Napiergrass

Keo INTABON[1]*, Morio KATO[2], Takaaki SATAKE[1], Norio SUGIURA[1] and Takaaki MAEKAWA[1].

[1] Institute of Agricultural and Forest Engineering, University of Tsukuba, Tennodai 1-1-1, Tsukuba 305-8573, Japan.

[2] Institute of Agriculture and Forestry, University of Tsukuba, Tennodai 1-1-1, Tsukuba 305-8573, Japan.

Abstract

Napiergrass (*Pennisetum purpureum* Schumach.), a well known tropical forage crop for its high biomass production, can be a worldwide important source of biomass energy and non-wood source as pulp for paper fabrication and lignin for construction materials. In order to back up the research about the dry-matter production of this plant, a simple method to estimate its leaf area was examined using simple regression analysis basing on the measurement of leaf blade length and width. Leaf area measurement was done on leaves taken from plants grown in the experimental field, the Agricultural and Forestry Research Center, University of Tsukuba. It was found that the leaf area of this crop could be easily estimated by the following equation: $Y=0.74X-11.8$ (Y: leaf area, X: length×width).

Key words : Leaf area, Leaf blade length, Leaf blade width, Napiergrass, Simple regression analysis.

Introduction

Napiergrass or elephant grass (*Pennisetum purpureum* Schumach.), is a famous perennial forage crop having the highest productivity of biomass (Snaydon 1991). Originally it has grown in tropical Africa within the latitude range of 10° north to 20° south (Sasaki 1964). However, it is now widely cultivated as a forage crop in tropical regions in South America including Hawaii (Heath et al. 1973) and tropical Asia, mainly, Thailand (Ishii 1997). The introduction of the crop into Japan, Okinawa and Kagoshima Prefecture, was from 1959 (Sasaki 1964) and, nowadays, it is also grown as a forage crop for beef cattle in Miyazaki Prefecture (Ito and Inanaga 1988).

* Corresponding Author: keo@sakura.cc.tsukuba.ac.jp

Because of its high biomass productivity, this plant is focused as an important source of biomass energy (directly as fuel or methane fermentation), and as non-wood sources for paper pulp and lignin for construction materials. Therefore, the cultivation of this crop for mass consumption could be promoted so that it is possible to reduce the actual deforestation rate and the increasing CO_2 concentration in the world. From this point of view, a relative importance of this crop might be clearly emphasized as the world greenhouse effect is approaching critical situation. Toward this tremendous situation, it is very important to accumulate basic information in terms of physiology, morphology and cultivation of this crop.

The crop productivity is generally evaluated by the crop growth rate (CGR) which is divided into net assimilation rate (NAR) and leaf area index (LAI). NAR is limited by the photosynthetic rate of each leaf. Napiergrass is known as C_4 plant with high photosynthetic ability. Therefore, to spread the cultivation of this crop, it is important to evaluate the leaf area in plant community. Leaf area can be measured by several types of automatic area meters or by image analysis using a scanner. Because of their costs and applicability, these apparatus are not always available in a field experiment or in economically less-developed tropical countries. As a height of Napiergrass is as high as 4m, it is necessary to develop a simple method to estimate leaf area with time-saving and without expensive machine for the productivity research. The study reported here describes that the leaf area of this plant could be estimated accurately from the regression equation based on its leaf blade length × width.

Materials and Methods

Sprouted seedlings of Napiergrass (*Pennisetum purpureum* Schumach. cv. Wrukwona) were obtained from the Faculty of Agriculture, the University of Miyazaki. They were planted at 1 m × 1 m spacing in the experimental field of the Agricultural and Forestry Research Center, University of Tsukuba on May, 29th, 2000. Nitrogen, phosphorus (P_2O_5) and potassium (K_2O) were fertilized at rate of 15kg/10a as a compound fertilizer. During cultivation, weeds were removed by hand and watered properly. From the establishment of plants until harvest time at Oct. 16th, 6 hills with 29 tillers were sampled randomly and divided into tillers. Plant height, leaf blade length, width at the half point of the blade were measured for all leaves attached to a tiller. The actual leaf area was measured by an automatic area meter (Hayashi Denko, AAM-9). The relationship between the products of leaf blade lengths × leaf widths, and the actual leaf areas, and a derived regression equation were examined. At last, 370 leaves were sampled for this investigation. On the other hand, in order to describe the leaf blade shape, leaf blades having length of about 95 cm to 105 cm were cut into sections at 10 cm long from the base, and the distribution of leaf area and width along leaf length were measured.

Results and Discussion

The averages of length, width and area of leaf blades in Napiergrass were 128.7 cm ± 20.3 (standard deviation), 4.6 cm ± 1.1, and 443.7 cm^2 ± 138.1, respectively (Table 1). Plant height of tillers ranged from 95 cm at plant establishment to 455 cm at final harvest.

Leaf area distribution along the leaf length in leaves with about 100 cm blade length is shown in Fig. 1. As the leaf changes its width from the base toward the tip, the area increases and reaches a maximum level at the position of 50–60 cm (Fig. 1). The leaf width distribution along the leaf length of the same leaves is shown in Fig. 2. The maximum leaf width fell on the portion of 50–60 cm from the blade base. This position was about the

Table 1 Size, areas and number of leaves used in the investigation

Size ranges (cm)	Numbers	Length (cm)	Width (cm)	Area (cm^2)
60– 70	11	63.1(± 2.8)	0.44 (±0.05)	34.6(± 9.5)
70– 80	10	76.4(± 2.1)	2.33 (±0.79)	145.9(± 33.8)
80– 90	9	88.0(± 2.4)	3.31 (±1.05)	191.3(± 65.1)
90–100	10	93.4(± 1.4)	4.19 (±0.89)	236.4(± 42.1)
100–110	14	104.8(± 2.4)	3.76 (±0.74)	267.6(± 39.2)
110–120	14	114.6(± 1.6)	4.96 (±0.50)	379.6(± 37.8)
120–130	37	124.1(± 3.0)	4.74 (±0.51)	425.5(± 62.0)
130–140	133	135.7(± 2.8)	5.01 (±0.55)	494.8(± 76.0)
140–	132	143.3(± 2.7)	5.01 (±0.46)	523.5(± 62.4)
Averages		128.7(±20.3)	4.60 (±1.10)	443.7(±138.1)

Notes: Total leaf number used was 370. Figure in ( ) is standard deviation.

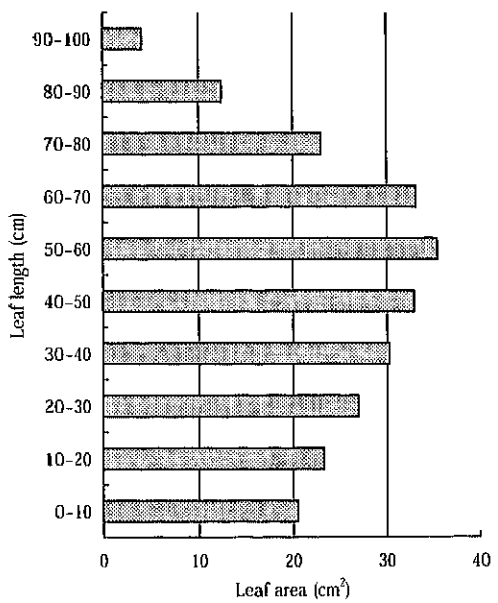

Fig. 1 Leaf area destribution in each leaf length section in a leaf

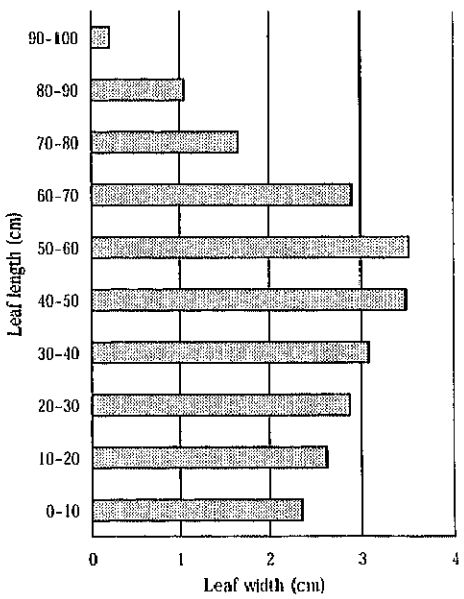

Fig. 2 Leaf width destribution along the leaf length

middle of the leaf blade (Fig. 3). The estimation of leaf area using simple regression analysis in this study was based on the width at this point of the leaf blade.

Fig. 4 shows a relationship between the actual leaf area (Y axis) and the product of the length of leaf blades times width at the middle of leaf blades (X axis). It shows that the actual leaf area was highly correlated with the value of length multiplied by width with r=0.9766**. A regression equation of Y=0.74X−11.85 (Y: area, cm^2; X: leaf length × width, cm^2) was derived from 370 observations.

Fig. 5 shows a relationship between actual leaf area and estimated leaf area derived from the regression equation. The regression coefficient of this relationship was 0.74. Leaf area could be estimated from this equation accurately (R^2=0.954).

Regression equations of Y=0.802X, and Y=0.72X+1.20 for rice were observed by Bhan and Pande (1966) and Kawashima and Hirano (1982), respectively, even though their leaves are much shorter than Napiergrass. Using a similar method, Kato et al. (1989) calculated out a regression equation to simulate the leaf areas of edible canna (*Canna edulis* Ker.). The equation reported by Kato et al. was Y= 0.704X (Y: area, cm^2; X: length × width, cm^2). The leaf shape of Napiergrass is quite different from that of edible canna. The average rectangular dimensions of Napiergrass in this study were 128.7 cm (±20.3) length by 4.6 cm (±1.1) width, while the shape of edible canna leaf was circular. Since the Napiergrass

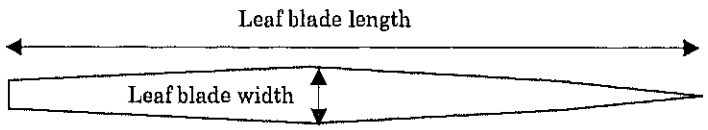

Fig. 3 Leaf length and leaf blade width of Napiergrass

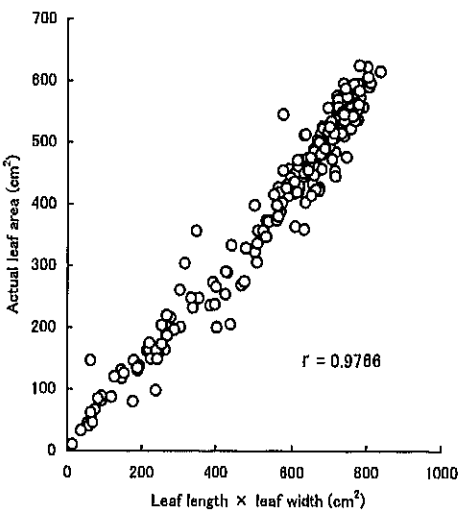

Fig. 4 Relationship between the actual leaf area and leaf length × leaf width

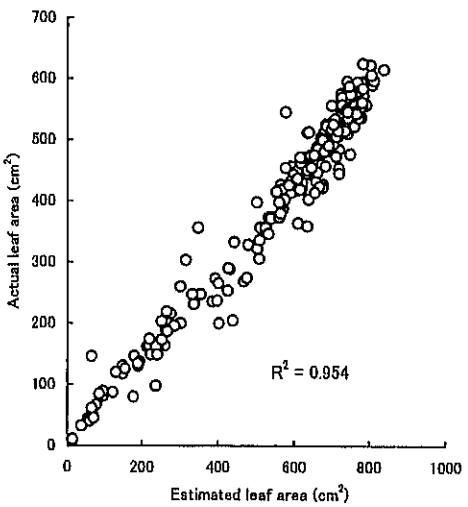

Fig. 5 Relationship between the actual leaf area and estimated leaf area

leaf shape was not perfectly rectangular, some difference between the actual area and the calculated one was inevitable. In this study, the calculated area should equal approximately to 417.3 cm^2 which was about 26.3 cm^2 or 5.93 % smaller than the actual value. In the case of edible canna, this kind of difference was from 1 to 3 %.

Notwithstanding the above facts, leaf area of Napiergrass could be estimated easily by the equation similar to other plants such as rice and edible canna, irrespective of the difference in shape and size. This method could be used in the field experiment in which a large area had to be measured, or in tropical or subtropical countries where the use of area meter is difficult because of its cost. As Napiergrass has several tillers which have 2-3 leaves, leaf area per tiller and that of plant should be estimated by accumulating each leaf area. Leaf area index (LAI) could be also revealed when the planting density was employed.

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ネピアグラスにおける葉面積の簡単推定法

院多本華夫[1]・加藤盛夫[2]・佐竹隆明[1]・杉浦則夫[1]・前川孝昭[1]

[1] 筑波大学農林工学系，305-8572　茨城県つくば市天王台1-1-1
[2] 筑波大学農林学系，305-8572　茨城県つくば市天王台1-1-1

要　約

ネピアグラス（*Pennisetum purpureum* Schumach.）は，熱帯原産植物で，乾物生産の最高能力を有し，メタン発酵，非木材性のパルプや木質などの原料として使用できることから，将来，広く世界規模で重視される可能性がある。本作物の物質生産に関する研究を推進するためには，その高生産性の基礎となる葉面積の把握が重要であり，葉面積の簡単な測定法を検討した。2000年度に筑波大学農林技術センター実験栽培圃場にて定植した個体の各個葉について実葉面積，葉身長を測定し，実葉面積（Y）と葉身長×葉身幅（X）との間の単回帰分析を行った。その結果，本作物の実葉面積は回帰関数，Y=0.74X−11.8により精度よく推定可能であった。

キーワード：単回帰分析，ネピアグラス，葉身長，葉身幅，葉面積

* Corresponding Author: keo@sakura.cc.tsukuba.ac.jp