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Branching Pattern and Effective Leaf Area of Spreading Herbs, The Crabgrass and The Korean Lawn

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포복형 초본(바랭이와 잔디)의 分枝型과 유효 엽면적

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摘 要

1992년 6월부터 1993년 9월 동안에 서울에서 이루어진 바랭이와 잔디의 分枝型(branching pattern)과 유효엽면적(effective leaf area)에 대한 정량적 연구 결과는 다음과 같다.

1. 分枝 끝 지점의 2차원적인 위치는 수학적 模式을 이용한 이론적 모델에 의해 分枝사이의 각과 分枝 길이들의 상대적인 비를 이용하여 계산할 수 있다.
2. 分枝각과 分枝길이의 상대적인 비는 바랭이나 잔디의 개체와 군락의 전체적인 구조를 효과적으로 분석하는데 있어 매우 적절하게 사용될 수 있다.
3. 시간에 따라 변화되는 分枝型을 명확히 분석하기 위해 positive feedback theory를 성장 분석 모델로 적용하였다.
4. 分枝의 마디 배열은 봄에서 여름에 이르는 생장 기간동안에 변화됨을 나타내었다. 主枝(mother branch)와 副枝(daughter branch)사이의 각은 적정치에 수렴하는 양상을 보였으며 그 평균값은 바랭이가 50°, 잔디가 59°임을 알 수 있었다.
5. 야외에서 관찰된 실험적 측정치와 모식적 구성을 통해서 최대 물질 생산과 연관된 햇빛 흡수와 수용의 극대화를 위한 分枝型과 최대 유효엽면적의 상관 관계를 분석하였다.
6. 따라서 수학적 모식을 이용한 分枝型 분석은 실험적 측정치와 잘 일치하며, 이런 樹冠型의 형성은 유전적 요소와 환경적 요소에 의해 영향을 받을 뿐만 아니라 식물의 적응적 중요성을 지니는 유효잎면적, 광수용 및 광합성과 물질생산의 극대화를 분석하는데도 유효하게 쓰일 수 있다.

INTRODUCTION

Architecture of a herb canopy plays an important role in sunlight interception for photosynthesis and hererin taken size, geomtry and external structure of a plant. The geometry of small treelike systems was first modeled by Honda(1971), and Honda & Fisher(1978). Increasing use of computers has enabled progressively more precise quantification and simulation of branch systems of trees. The branch angle and branch length are considered in a computer model of Honda(1971) describing the crown growth and crown shape.

In the case of herbs, the optimization of a canopy structure for interception of sunlight is a significant for the study of adaptive herb geometry. In a preliminary report, observed natural branching angles which establish branch geometry are very similar to theoretical angles which produce the maximum effective leaf area. We also show that branching geometry of real herbs influence the effective leaf surface through the theoretical study of terminal branching growth.

MATERIALS AND METHODS

1. Observation, measurement and photograph of crabgrass and Koren lawn

These experiments were performed at Seoul area, Korea from June, 1992 to September, 1993. We observed and measured natural branching angles of *Digitaria sanguinalis* and *Zoysia japonica*.

We also presented branching patterns of the spreading herbs by through top view of a photographic branch tier and computer simulated one.

2. Application of mathematical and simulation model, and interpretation of field data

We used mathematical and simulation model to study relationship between branching geometry and effective leaf area at different ages by plotting succesive growth stages.

Branching angles were measured directly, using a protractor. Those field data were compared to the positive feedback system model.

RESULTS AND DISCUSSION

1. Mathemetical model of canopy architecture

The studies on the canopy form and branching pattern of sapling and adult trees in forests were reported by Whitney(1976), Honda and Fisher(1978), Honda et al.(1981), Fisher and Hibbs(1982), and Honda and Tomlinson(1982).

However, any study on branch geomtry and effective leaf area of the herbaceous canopy is not found out.

The assumption and a terminal point P(x, y) of a daughter branch could be modified from the calculational equation proposed by Honda(1971). Each branch tier consists of 'm' lateral branch complexes with a divergence angle, 'θ', between sucessively produced complexes. Bifurcations are repeated at every discrete time interval and take place simultaneously every time. Rule 1 of Fisher and Honda(1977) says that branching increases in discrete units. When the mother axis is 'N', the daughter axis is 'N+1':Rule 3 says that the sign of the branch angles divergence at every branch order, so that a zigzag main axis of unit 1's with alternating direction is formed.

In case of herbs, it is simplified in two dimension, because that the spreading herbs is considered as two dimensional canopy shape. Hence, the geometrical model is dervied from

$$x=x_B+R\left(u\cos\theta-\frac{Lv\sin\theta}{\sqrt{u^2+v^2}}\right) \quad (1)$$

$$y=y_B+R\left(v\cos\theta-\frac{Lv\sin\theta}{\sqrt{u^2+v^2}}\right)$$

Here two terminal points, $P_A(x_A, y_A)$ and $P_B(x_B, y_B)$ of a mother branch(P_AP_B), $\theta=$ branching angle, $U=x_B-x_A$, $V=y_B-y_A$ and $L=\sqrt{u^2+v^2}$

As shown in Fig. 2. These assumptions compared with a crabgrass canopy. The shape or geometry of a herbs canopy gives insight into the adaptive mature of herb form which for sunlight interception and absorption, photosynthetic efficiency of the leaves and matter production.

When all the leaves of a mother branch and an individual crabgrass was removed, the development of the branch pattern of herbaceous architecture is presented in Fig. 3 and 4. It indicates their canopy characteristics from a young herb to a mature one fits well with the branching model.

The growth equation of the number of the terminal points was dervied by the positive feedback system.

$$N=\frac{N_{max}}{1-b\cdot e-\frac{t}{T}} \quad (2)$$

Here N, N_{max}, b, t, and T are the number of the branch, the asymptotic number of the branches, a constant of intergration time, feedback ratio, and a time constant for the

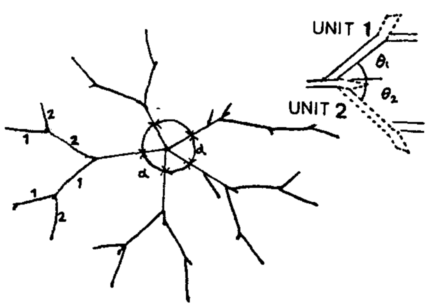

Fig. 1. Branch tier of young tree viewed from above. Successively produced lateral branch complexes form a divergence angle, θ, with each other. Branch units 1 and 2 indicated in one lateral branch complex. Insert: schematic explanation of the branch units 1 and 2 their branching angles, θ_1 and θ_2

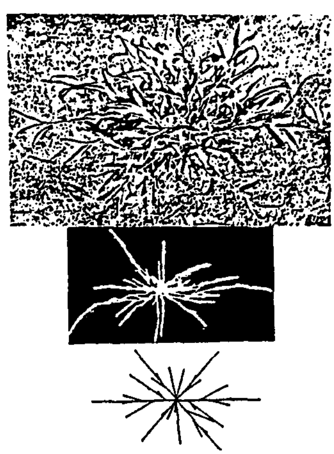

Fig. 2. Photographs, which were taken at Seoul area June, 1993, of canopy shape, branch tier and simulated branch *D. saguinalis*.

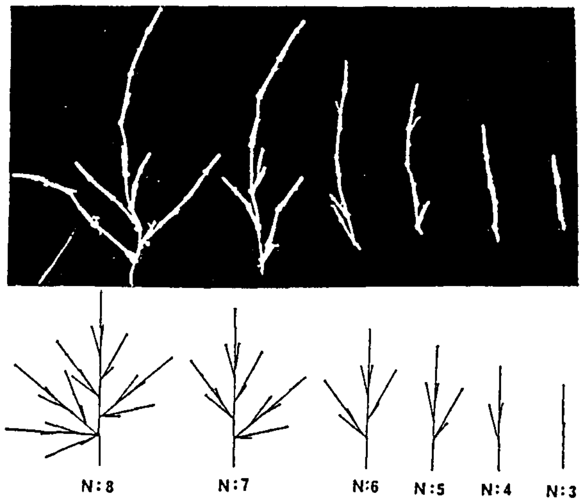

Fig. 3. Branch tiers and simulates ones from young branch of crabgrass to mature one viewed from above.

growing period of a herb. This mathematical model is especially useful for the increase of the dry matter production of the grassland.

2. Branching angles in real plant and relation between branching angle and effective leaf area

The growth of a branch angle of the crabgrass and the Korean lawn between another branch and a daughter one shown in Fig. 5. The branch angles of the crabgrass and the Korean lawn were increased from initial degree 0 to final degrees 50° and 59°, respectively. Those results mean that the branch angle of simulater tiers if a crabgrass is 50°.

We can interpret above results as following, optimal branching angle increasing with growth of plant result that maximize effective leaf area. Although simulated value is not identical to the observed one, we find that theoretical valules of with respect to maximum EA are very similar to the observed values in real crabgrass or Korean lawn.

We are assuming that there is selective pressure on a plant to fill the space it occupies with the most efficient leaf surface consistent with its ecophysiological limitations and its architectural model(branching pattern).

Optimal branching angles can be varied with tier symmetry of the plant, optimal of branch complexes in a tier(complexity of the daughter branch), relative size of leaf cluster, and the ratio of branch unit lengths in real plant. We need more information in order to find out precisely geometry of plants such as exposure sunlight, mechanical stability, heat exchange, water efficience, or their interactions.

In summary, two aspects of herbaceous architecture on morphological bases are dis-

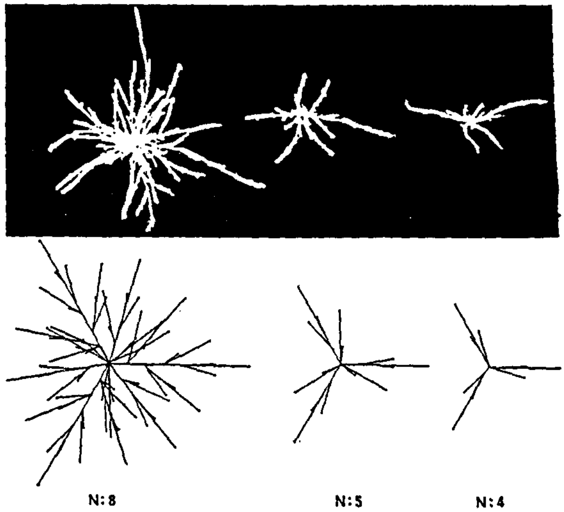

Fig. 4. Branch patterns of individidual tiers and simulated ones from a young individual crabgrass to a mature one viewed from above.

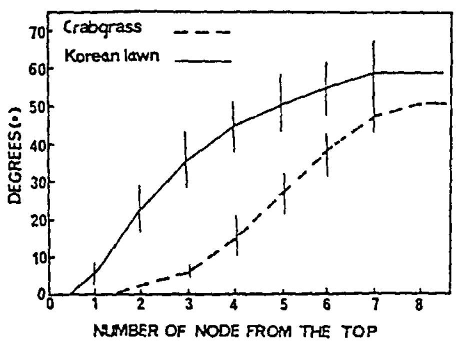

Fig. 5. The relation between branch angle and node position from bottom to top.

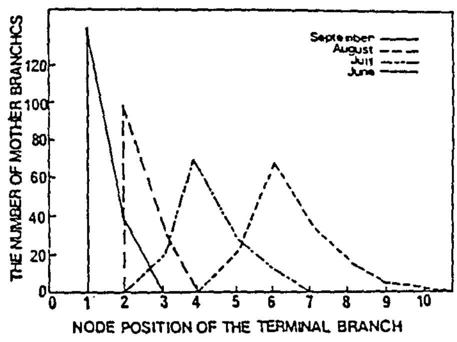

Fig. 6. Distribution of the terminal daughter branch in the mother branch of node position.

tinguished into deterministic architecture and opportunistic architecture. Both aspects are expressed by environmental and genetical interactions with herbs. A herb's morphology is consequence of these interactions. The deterministic architecture is the genetic information of the individual which is typically most clearly seen in the phenotypes. The opportunitic architecture is the sum of modifications according to the herb's response to its environment. The defferences between branching geometry and leaf distribution within the canopies of herbs ard the result of those two aspects of architecture(Fisher and Hibbs, 1982).

SUMMARY

This study was carried out to analyze quantatively of the terminal branching patterns, and maximizing effective spreading stems and leaf surface area of herbs such as crabgrass, *Digitaria sanguinalis* and Korena lawn, *Zoysia japonica*.

Two dimensional positions of the end-points of the branches could be calculated lengths using the branching angles and the relative ratio of the branch lengths. The branching angles and the relative ratio of the branch lengths were well fitted to analyze effects on the whole canopy structure of herbaceous individuals and communities. The branch pattern were interpreted through the experimental data observed in nature and simulated plots.

In order to clarify how the number of the terminal branching points grows with time, the positive feed back theory with cybernetic rhythm was accepted as branching growth. The order of the node position of the terminal branch was changed from bottom node to top node as growing season has been changed from the spring to the autumn.

Growth of branching angle, time variant angles, between the mother branch and the daughter branch have an asymptotic final degrees, average 50° and 59°, in the case of crabgrass and Korean lawn, respectively.

The shapes of herbs and the arrangements of their leaves have been related to the adaptive importance of light interception by the leaf suface. Therfore, those simulations for canopy architecture of plants are also useful in designing the maximizing effective leaf area, sunlight interception, photosynthesis and matter production.

LITERATURE CITED

1. Fisher, J. B. and D. E. Hibbs. 1982. Plasticity of tree architecture:specific and ecolological variations found in aubriville's model. Amer. J. Bot. 69(5):690-702.
2. Honda, H. 1971. Description of the form of trees by the parameters of the tree-like body:effects of the branching angle and branch length on the shape of the tree-like body. J. Theor. Biol. 31:333-338.
3. Honda, H and H. B. Fisher. 1978. Tree branch angle: maximizing effective leaf area. Science. 199:888-890.
4. Honda, H., P. B. Tomlison and J. B. Fisher. 1981. Computer simulation of branch interaction and regulation by unequal flow rates in botanical trees. Amer. J. Bot. 68(4):569-585.
5. Whitney, G. G. 1976. The bifurcation ratio as an indicator of adaptive strategy in woody plant species. Bulletin of the Torrey Botanical Clu. 103(2):67-72.

6. Park, B. K. and H. S. Choi. 1984. Computer simulation of branching pattern in *Magnolia denudata* Desr. Kor. J. Ecol. 7(1):1-9.

7. 7. Chang, N. K., C. D. Jin, and Y. S. Kim. 1984. A study on the change of photosynthesis patterns by the cladode orientation of *Opuntia lancedata* Haw. Kor. J. Ecol. 7(3):99-108.