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Relationship Between Growth of Individual Trees and Surrounding Density in Larch Stands *(Larix leptolepis)*[1]

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落葉松林의 單木生長과 週邊密度와의 關係[1]

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ABSTRACT

Individual tree growth in a given stand is considerably affected by its neighbouring trees or surrounding density. This trend is appeared more clearly in the unthinned stand. Relationship between growth of individual trees and density around them was analyzed by the use of the angle-summation method(AS method), and then multiple regression equation including variables of center trees and measures of surrounding density by the AS method was given for estimating diameter increment for the last five years and the next few years of center trees.

Key words: relationship; AS method; Larix leptolepis.

要 約

한 林分에 있어서 個體木의 生長은 그 林木 週邊의 週邊木들에 의하여 커다란 影響을 받는다. 無間伐 林分의 경우 이러한 傾向은 林木 相互間의 競爭을 통하여 더욱 顯著하게 나타난다. 本 研究는 1962年 Spurr가 提案한 角度合算法(angle-summation method)을 利用하여 落葉松林의 個體木 生長과 週邊木들과의 基本的인 生長關係를 調査하였으며, 이것을 基礎로 中心木으로 選定된 各 林木들의 最近 5年間의 直徑生長量을 推定하기 위해 重回歸式을 適用하고 그 結果를 分析 檢討하였다.

INTRODUCTION

An individual tree in a stand is the fundamental component for evaluating the effects of silvicultural treatments on tree characteristics as well as for making stand simulation models in the study of forest growth and yield analysis.

Many attempts have been made to quantify inter-tree competition in forest stands. Common forest stand density indices include number of stems per unit area, basal area per unit area, stand density index, tree-area ratio, and crown competition factor. All these measures represent average stand density, and variation in growth related to competition is based on averages of stands and trees. Even though average stand density is useful and practical, it tends to obscure cause-effect rela-

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tionships between competition and tree growth (Bella, 1971). The strength of competition, which plays an important role in the size of an individual tree and its neighbouring trees. Therefore, it is necessary to examine the basic tree-growth relationship for individual trees in stands.

The purpose of this study is to present the foundation for the prediction of forest growth and yield based on the simulation model in future by analyzing the relationship between growth of individual trees and density around them.

MATERIALS AND METHOD

This survey was conducted in the summer of 1985 from 19-year-old larch plantations (*Larix leptolepis*) in the Kangweon National Univ. Forests. In two identical larch stands, two permanent plots (30 x 30m, 15 x 15m), one in each stand, were established in 1982. The stands have had no silvicultural treatments after planting such as weed control, pruning, and thinning etc. All trees, including the dead trees, were recorded in each plot and ten trees were randomly selected as the center trees to estimate surrounding density. And immaginary circular subplots of radius 3.5m were established around the center trees. The distance from the center tree to other trees standing inside the circular subplot were measured diameter tape and steel tape to the nearnest 0.1cm and 0.01m, respectively. And the diameter increment for the last five years of center tree was obtained by the use of increment borer.

The measured results are shown in Table 1 and

Table 1. Tree distribution by D.B.H. class

D.B.H.(cm)	Plot 1	Plot 2	Sum
2.5 – 4.5	1		1
4.5 – 6.5	17	12	29
6.5 – 8.5	64	14	78
8.5 – 10.5	47	15	62
10.5 – 12.5	49	9	58
12.5 – 14.5	19	4	23
14.5 – 16.5	11	6	17
16.5 – 18.5	11	1	12
18.5 – 20.5	2		2
Sum	221	61	282

Table 2. Diameter, crown width, and diameter increment of center trees

No.	D(cm)	CW(m)	I(cm)
136	11.9	2.93	1.9
441	13.2	3.25	2.0
397	11.8	3.90	1.5
451	14.0	3.90	1.7
243	18.0	4.75	2.8
346	4.8	0.80	0.6
145	6.1	1.23	0.8
438	6.7	2.53	1.1
21	6.6	1.45	1.1
69	9.1	2.65	1.1

No. : Center tree number
D : Diameter
CW : Crown width
I : Diameter increment for the last five years

Table 2. In this study, angle-summation method (AS method) was employed for estimating point density or surrounding density on the center tree. And then regression and correlation analysis between diameter growth for the last five years of center trees and surrounding density measures estimated by the AS method were carried out.

ANALYSIS AND RESULTS

1. Determination of surrounding density

Spurr(1962) introduced a measure of point density influencing on a point or tree. This index is expressed by the basal area per unit area and calculated as follows;

$$B_{ij} = \sum_{j=1}^{n} (j-1/2)\left(\frac{D_j}{L_{ij}}\right)^2 \times 1/4n \quad \cdots\cdots\cdots\cdots\cdots (1)$$

B_{ij} = surrounding density estimates (m^2/ha)

D_j = diameter of *j*th tree competitor around center tree(*i*th)

L_{ij} = distance from *i*th tree to *j*th tree competitor

Because this index does not include the center tree, it can be mainly used as a measure expressing relationship between growth of the center tree and density around the tree. In order to examine this relationship, sets of point density estimates were compared for different center trees in Fig. 1. Fig. 1

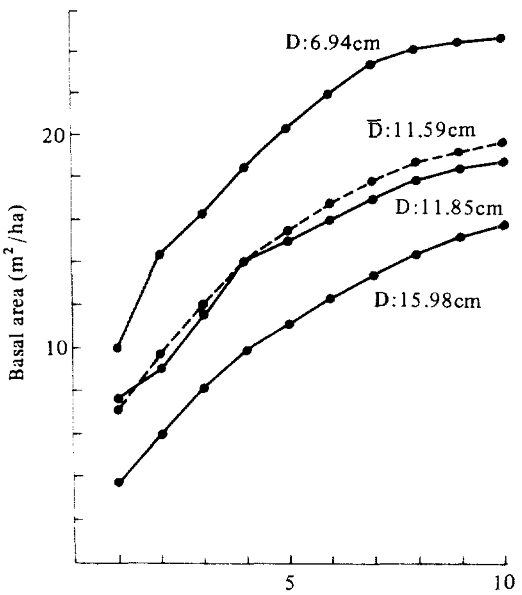

Fig. 1. Changes of basal area estimates excluding center trees with increasing sample size. D̄ is average diameter of center trees.

indicates clearly that point density estimates for the larger center tree are lower than those of the smaller ones. A negative correlation exists between diameter of center tree and surrounding density estimates. Therefore, it is obvious that the larger trees need more growing space than the smaller trees. However, it is very difficult to determine the sample size in point density sampling because point density estimates with increasing sample size show the rising trends and if the sample size is very small, point density estimates will be highly affected by sampling error while estimates based on many sample trees will be considered as stand density rather than point density. Toda(1964) have reported that, when the number of sample trees in point density test is 4, there is the highest correlation between point density estimates and stem diameter or crown width of the center trees. In this study, the correlation between point density estimates and average diameters of center trees was highest when sample size was 4(r=−0.769). This relationship is shown in Table 3. Hereby, surrounding density of the center tree was calculated by 4

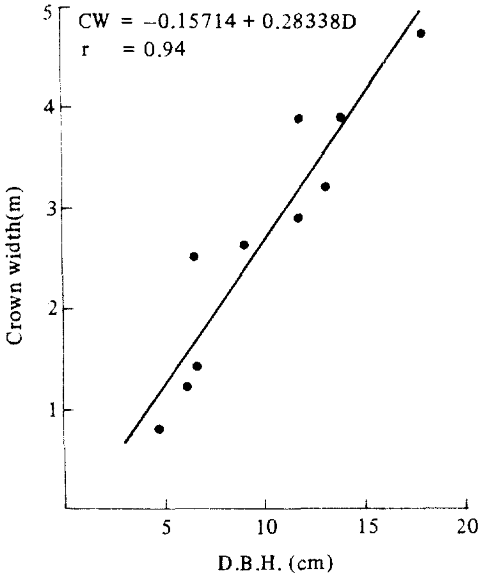

Fig. 2. Relationship between crown width and diameter of center trees

Table 3. Correlations between surrounding density estimates and diameters of the center trees

Sample size	Correlation coefficient
2	−0.759
3	−0.746
4	−0.769
5	−0.765
6	−0.721

adjacent stems around the tree. Nevertheless, as mentioned by Toda, sample size 4 does not mean the nearest 4 trees from the center tree, but 4 trees with the largest angle from the center tree or a certain point.

2. Relations among stand variables

When trees of different sizes compete in a forest stand, they do not equally affect on growth one another. To maintain a higher rate of growth, the larger trees must use the growing space considerably beyond what is proportional to their sizes. This relation is often expressed in terms of the measurable characteristics such as tree number, size, and distribution. The main problem here is the selection of the proper stand variables to describe relationship

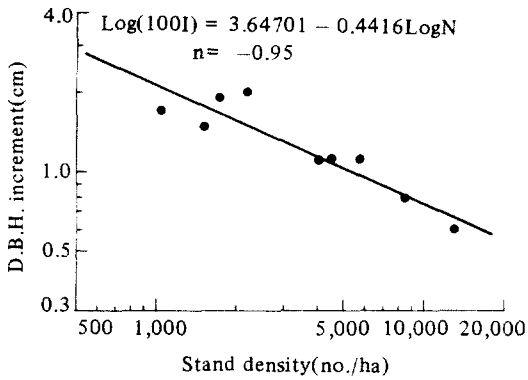

Fig. 3. Relationship between D.B.H. increments for the last five years of center trees and stand density estimates(no./ha) by the AS method

between individual tree growth and neighbouring trees. Diameter and crown width were selected as vigours of the center trees and analyzed in Fig. 2. Relationship between them shows a straight line. This means the larger the tree diameter, the larger the tree crown width. It is widely known that diameter growth of individual trees in a forest stand is highly correlated to the density. In order to examine this fact by the use of surrounding density, number of stems and basal area per unit area were used as the measures of surrounding density. They were calculated by the AS method which was used as a measure of expressing relationship between growth of the center tree and density around the tree(see Toda, 1964). Relationship between diameter increment for the last five years of center trees and surrounding density measures estimated by the AS method are shown in Fig. 3 and Fig. 4, respectively. Each index shows high correlation. That is, correlation coefficient is −0.94 on number of stems and −0.79 on basal area per hectare. In here, we can find that relationship between growth of the center tree and surrounding density measures is negative. This makes it a clear that the lower the density, the less the competition from neighbouring trees will be, and the faster the tree should grow. This trend is shown more clearly where number of stems per hectare estimated by the AS method is used as a measure of surrounding density (Fig. 3).

3. Multiple regression equations

Multiple regression equation was built for estimating diameter growth for the last five years and next few years of center trees. This equation include diameter and crown width of the center trees and measures of surrounding density estimated by the AS method. The fitted multiple regression model was as follows;

$$\text{Log}(100I) = a + b\,\text{Log}X + c\,\text{LogSDM} \quad \cdots\cdots\cdots (2)$$

I = diameter increment for the last five years of center trees

X = diameter or crown width of the center tree

SDM = surrounding density measures estimated by the AS method

a = constant, b,c = multiple regression coefficients

Table 4. Multiple regression equations of diameter increment for the last five years of center trees in Larch stand

Multiple regression equation (N = number of stems per ha) (B = basal area per ha)	Standard errors of estimate (SE)	Multiple correlation coefficient (R)	Test of gain (F value)
Log(100I) = 1.845182 + 0.738994LogD − 0.127756LogN	0.027	0.96	44.04**
Log(100I) = 1.537451 + 0.889398LogD − 0.233396LogB	0.025	0.97	47.89**
Log(100I) = 3.437825 + 0.092635LogCW − 0.391208LogN	0.072	0.78	31.18**
Log(100I) = 2.339363 + 0.566892LogCW − 0.360922LogB	0.089	0.74	19.13**

** : significant at the 1% level.

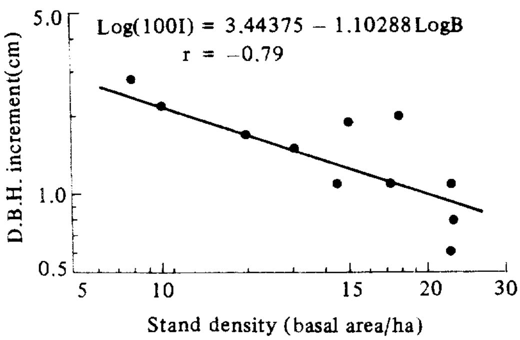

Fig. 4. Relationship between D.B.H. increments for the last five years of center trees and stand density estimates(basal area/ha) by the AS method

Setting Log (100I) = Z, LogX = X, Log SDM= Y, this equation can be rewritten by the general regression plane of Z on X and Y. That is,

$$Z = a + bX + cY \cdots\cdots (3)$$

In addition to multiple regressions, variance analysis was carried out(Table 4). Each regression coefficient was obtained by the least square method. For estimating diameter increment of the center trees, the use of their diameters was superior to that of crown width because multiple regression coefficients were higher in the former than in the latter. Also, in the equation(2), the test of hypothesis that

Table 5. Variance analysis of hypothesis that b = 0

Factor	Sum of Squares	Degree of Freedom	Mean Squares	F-ratio
Regression (1)	0.0106928	1	0.0106928	2.80
Error	0.0267	7	0.0038143	
Regression (2)	0.1111004	1	0.1111004	31.49**
Error	0.0247	7	0.0035286	

** : significant at the 1% level. regression(1) : SDM is no./ha regression(2) : SDM is basal area/ha

b = 0 was carried out (Table 5). As shown in Table 5, variable of the center tree does not affect the regression equation involving number of stems per hectare as stand variable, but affect considerably that involving basal area per hectare. Therefore, we can find that basal area per hectare was inferior to the number of stems per hectare as a measure of surrounding density by the AS method. Although number of stems per hectare by itself proved adequate for estimating diameter growth of the center tree, it is necessary to include diameter of the center tree for the higher goodness of fit.

DISCUSSION

Spurr's AS method is considered as an effective measure of surrounding density associated with tree growth, but it is not clearly defined limits of distance and size of potential competitors. Also, it is very difficult to determine the number of trees influencing the center tree because diameter growth is closely related to the vigours of center tree and age of the stand. It is the reason why sample size of surrounding density was determined by the correlation for estimating diameter growth of the center trees and density around them. In the analysis of multiple regression for estimating diameter growth of the center trees, vigours of the center trees and surrounding density measures were involved. Surrounding density measures estimated by the AS method play an important role for the predictors or controllers. As a result of variance analysis, number of stems per hectare was superior to basal area per hectare as a measure of surrounding density. This is equal to Nishizawa's report(1968) in *Pinus radiata* stands, although he used the AS method involving center tree for calculating number of stems per hectare. Therefore, it is supposed that number of stems per hectare by the AS method is a good measure for predicting and estimating diameter growth of the center tree.

It must be made further development of tree growth by analyzing relationship among vigours of individual trees(e.g., diameter, crown width, height, etc.) and density around them by the different methods and each age class.

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