

ヒノキ林地下部の生産と構造(I)

樹根解析による根の生産量の推定

誌名	日本林學會誌 = Journal of the Japanese Forestry Society
ISSN	0021485X
著者名	山倉,拓 斎藤,秀樹 四手井,綱英
発行元	日本林學會
巻/号	54巻4号
巻号補足	
掲載ページ	p. 118-125
発行年月	1972年4月

農林水産省 農林水産技術会議事務局筑波産学連携支援センター

Tsukuba Business-Academia Cooperation Support Center, Agriculture, Forestry and Fisheries Research Council
Secretariat



論 文

Production and Structure of Under-Ground Part of HINOKI
(*Chamaecyparis obtusa*) Stand (I)

Estimation of Root production by means of Root Analysis*

Takuo YAMAKURA**, Hideki SAITO***
and Tsunahide SHIDEI**

ヒノキ林地下部の生産と構造 (I)

樹根解析による根の生産量の推定*

山倉 拓夫**・斎藤 秀樹***・四手井綱英**

要 旨: 積みあげ法をその方法論的基礎として森林の生産力を推定する際、根の生産量は測定が困難であることから、従来、間接的方法によって推定される場合が多かった。そこで根についても樹幹解析と同様な測定を試みて根の生長量を実測した。

調査林分は 1966 年以來研究を継続している滋賀県日野町綿向森林生産組合所有の 30 年生ヒノキ人工林である。

林分当たりの根の生産量を推定するために相対生長関係を検討した。根の生長量 (ΔW_R ; kg/yr) は根量 (W_R ; kg) との間に安定した回帰関係を示した。回帰式は次のようになる。

$$\Delta W_R = 0.0322 W_R^{1.242}$$

この回帰式は幹の生長量と幹の量との間に成立する相対生長関係とまったく同一であった。この $\Delta W_R \sim W_R$ 関係が 幹生長量 $\sim$ 幹量関係と同一であるという現象は 根の生長量の推定を容易にすると思われる。

$\Delta W_R \sim W_R$ 関係と毎木調査資料に基づいて推定した林分当たりの根の生長量は 2.3ton/ha・yr であった。この量は幹生長量の 26%, 根現存量の 5.3% に当たる。純生産量中に占める根の生長量の割合は 15% であった。

Summary: When the primary productivity of woodland ecosystem is measured by the harvest method, the increment of under-ground part or the root system has been estimated by indirect method, since the direct estimation of root increment requires many troublesome procedures for investigation.

This paper deals with the first and easiest step towards the estimation of root production.

The direct measurements of root growth by root analysis, based on the same principle as stem analysis, were tried for six sample trees in a plantation of *Chamaecyparis obtusa* aged 30 years.

For the purpose of estimation of root production per plantation, the allometric relations concerned with root increment were scrutinized. The most reliable correlation was observed between root increment per tree (ΔW_R ; kg/year) and its root weight (W_R ; kg). This $\Delta W_R \sim W_R$ relation was approximated by following equation:

$$\Delta W_R = 0.0322 W_R^{1.242}$$

This formula was just the same as what was obtained for the relation between stem increment per tree and its stem weight. This phenomenon might simplify the estimation procedure of root growth per plantation.

The calculated value of root increment based on $\Delta W_R \sim W_R$ relation and census of tree size was 2.3ton/ha・year. This amount was 26% to stem increment, 5.3% to root biomass and about 15% to net production.

* Contribution from JIBP-PT No. 131

** Fac. of Agr., Kyoto Univ., Kyoto 京都大学農学部

*** Kamigamo Exp. For. Sta. of Kyoto Univ. For., Kyoto Univ., Kyoto 京都大学農学部付属演習林上賀茂試験地

Introduction

In Japan, many studies on the primary production and production structure of woodland ecosystems have been done in the past twenty years, and steady progress has been made in the methodology for analysing the primary production of various types of natural and artificial plantation. There may be various methods to investigate the primary production, but these methods are divided into two main categories. The one is based on the measurements of the total canopy photosynthesis and respiration by means of gas-analyzer and other apparatus. The other is based on the cumulation of net assimilation (net dry matter production of green part) over the year(s) or vegetation period(s). This latter estimated method is called "summation method"¹⁾, and net primary production can be determined by sum total of the following three items estimated periodically through the year(s): A) Biomass change of photosynthetic plant; B) Plant losses by death and shedding of parts above and below the ground; C) Consumption of photosynthesizing plants by animals. In terms of mathematical symbols, two procedures may be expressed as follows²⁾, when the net primary production of a stand is intended for estimation by summation method:

$$P_n = \Delta Y + L + G \quad (\text{Method 1})$$

$$P_n = Y_{2N} + L_N + G_N \quad (\text{Method 2})$$

ΔY = Biomass change during a certain period

L = Plant losses by death and shedding during a certain period

G = Plant losses by consumer organism during a certain period

Y_{2N} = Amount of plant matter newly formed during a certain period

L_N = Amount of losses of new component by death and shedding during a certain period

G_N = Amount of grazing of new components by consumer organism during a certain period

If it is intended to assess the productivity of plantations based on the summation method (Method 2), first of all it may be necessary to estimate annual dry weight increment of each tree organ. The tree body is composed of four main organs, that are leaf, stem, branch and root. Generally speaking, it is comparatively easy to estimate the annual dry weight increment of three organs except root, but the estimation of root increment is most difficult among the four. The problems on root system and on root growth have been discussed from various points of view in biological sciences^{3,4,5)}, and many studies or investigations have been reported. Although the knowledges on root growth obtained

from these studies are of no use in the direct estimation of the annual dry weight increment of root, that is, there is no appropriate estimation method of root increment from reliable sources. Therefore, in view of the many studies progressing on the production ecology, it becomes very necessary to give rational estimation method of root increment. For the above reason, this review is intended to introduce the result obtained by root analysis and to discuss the estimation method of root weight increment per stand.

Material and Method

A) Plantation and Field Survey

The investigation was made in the forest on the flattish slope of Mt. WATAMUKI in HINO, SHIGA Prefecture. On the slopes of Mt. WATAMUKI *Chamaecyparis obtusa* plantation patches of various ages occupy the greater part. The longitude and latitude of the study area are 35°0'N and 136°20'E, respectively, and the altitude is about 440 meters above the sea level. According to the observation of 1968 at the nearest meteorological station, annual mean temperature was 13.5°C with highest and lowest 33.2°C in August and -7.2°C in February, respectively, and warmth index of the year was 110°C. Mean annual precipitation was 1550mm and maximum snow depth about 50cm. Generally speaking, the meteorological records indicated comparatively mild climate. In this study area, a series of investigations⁶⁻⁹⁾ on the production ecology of *Chamaecyparis obtusa* plantation have been conducted since 1966.

A sample plot, in which the root analysis was tried, about 20×15m size, was selected in a plantation aged 30, in late April of 1968. The crown closure was fully complete, so that there were no plants under storey through the vegetation period. In this plot, diameter at breast height and tree height were measured on each tree in May and November. According to the census on each tree, six sample trees were selected so as to cover the whole range of diameter distribution in early November, of 1968. They were cut by stratified clip technique in which the depth of stratum was one meter, and then each stratum was separated into stem bole, branches and leaves. The samples for the estimation of annual increment of stem and branch were extracted from each stratum. Small samples of each part of respective tree components were oven dried at 80°C, and conversion factors from fresh weight to dry weight were determined.

After the investigation on the above-ground part of sample trees, the root systems were dug out by stump pulling apparatus and then weighed with

beam balances suited to their size. The roots smaller than 2 millimeters in diameter were torn off at stump pulling. For the estimation of root amount which was torn off, ten trenches, $0.5 \times 0.5 \times 1.0$ m, in which the depth of stratum was 10 centimeters, were dug out. All roots were carried into laboratory for the estimation of annual growth.

The biomass estimated by using the allometric relation of sample trees and the distribution of tree size is given in Table 1. Some other characteristics of the stand are given in Table 1 together with the estimated value of biomass.

Table 1. Biomass and other properties in plantation

Ages	years	30
Number of trees	ρ /ha	3500
Mean stem diameter at breast height	$\bar{D}$ cm	12.8
Basal area at breast height	$\Sigma(\frac{\pi D^2}{4})$ m ² /ha	46.7
Mean tree height	$\bar{H}$ m	10.4
Biomass in oven dry weight		
Stem	y_S ton/ha	115.4
Branch	y_B ton/ha	11.9
Leaf	y_L ton/ha	12.0
Root	y_R ton/ha	43.0
Above-ground	y_T ton/ha	139.3
Sum total	y ton/ha	182.3

B) Procedures of Root Analysis

The annual increment of stem or branch has been measured by stem or branch analysis. However, root analysis which is based on the same principle as stem or branch analysis, has not been made in the studies hitherto reported, because of the difficulty in counting annual rings of root systems.

The procedures of root analysis introduced in this report are as follows:

A whole root system dug out by stump pulling apparatus was conveniently divided into three parts, that were stump, lateral roots and other small roots (Fig. 1).

Generally speaking, it is very difficult to classify the rooting characteristics of different species of trees, because site and soil conditions sometimes modify root growth so much so that species characteristics become obscure. Recently emerged seedlings of forest trees have a positively geotropic radicle which subsequently either becomes taproots, is suppressed or dies back. *Chamaecyparis obtusa* retracts taproots, that is, the initial taproots of this species are replaced in early years by roots with predominantly lateral roots.

It is very hard to measure annual growth increment of stump by root analysis because the stump

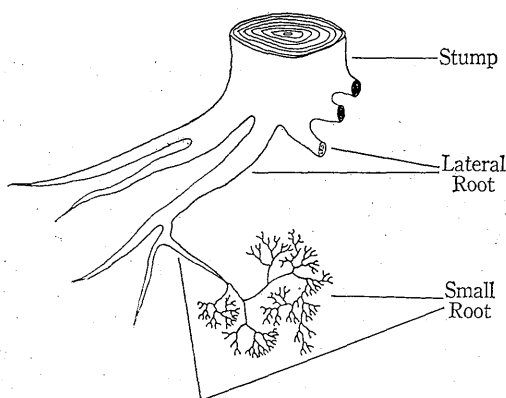


Fig. 1. Schematic representation of a root system of *Chamaecyparis obtusa*

forms are too complex to estimate volume increment by sectional measurement. Therefore the stump growth increment was conveniently estimated by using the growth ratio of stem (Stem growth increment in weight/Stem weight; kg/kg. year) in this investigation. The stem growth ratio in each stratum is different from each other. As an example, Fig. 2 shows the trend of change of stem growth ratio associated with the change of height of stratum. The growth ratio of each layer decreases gradually according to the increase of distance from the tree top. In this paper, the stump growth was estimated indirectly by using the growth ratio of stem at the height ranging 0.0~0.3 meter above ground, that is, stump growth increment was estimated by the following assumption:

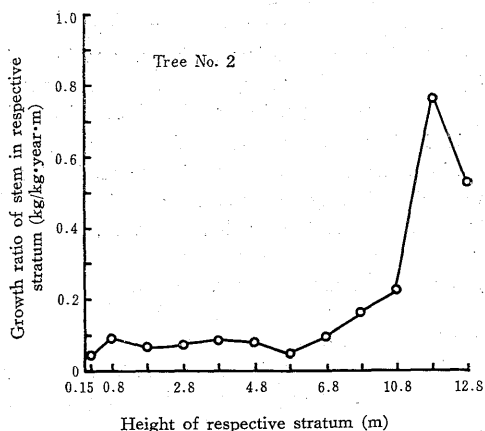


Fig. 2. Vertical change of stem growth rate (Stem increment/Stem biomass; kg/kg. year) in each stratum

Stump growth increment of each sample tree

$$= \frac{\left(\frac{\text{Stem growth increment at the height ranged } 0.0 \sim 0.3\text{m above ground}}{\text{Stem weight at the height ranging } 0.0 \sim 0.3\text{m above ground}} \right)}{\times (\text{Stump biomass})}$$

The estimation of growth increment of lateral roots was made in the following way. Five lateral roots were extracted for the purpose of root analysis, and then they were cut at every 10 centimeters in length. After the cutting, the annual ring width of each cross-section of samples was measured and recorded. The volume increment was calculated by sectional measurement based on the data of annual ring width. The volume increment was transferred to weight level by using specific gravity. The growth increment of total lateral roots included in each sample tree was calculated by the following procedure:

Growth increment of total lateral roots of each sample tree

$$= \left(\frac{\text{Growth increment of sample lateral roots}}{\text{Biomass of sample lateral roots}} \right) \times (\text{Biomass of total lateral roots})$$

The small roots (other parts except stump and lateral roots) were first of all cut at every 5 centimeter in length, and then divided into four classes; smaller than 0.2, between 0.2 and 0.5, between 0.5 and 2.0 and larger than 2.0 centimeters in diameter. Five samples were extracted from each diameter class, and then, their annual ring widths were measured by the same method as lateral roots. The volume increments were calculated by sectional measurement based on the data of annual ring width. The volume increments were transferred to weight by using specific gravity. The growth increment of total small roots were calculated based on the same procedures as lateral roots, that is

Growth increment of total small roots of each sample tree

$$= \left(\frac{\text{Growth increment of sample small roots}}{\text{Biomass of sample small roots}} \right) \times (\text{Biomass of total small roots})$$

Result

1) Root Growth in Relation to Distribution of new Component into each Organ

The result obtained by the above-mentioned procedures is shown in Table 2. Table 2 shows that, against growth increments of whole root system, about 11% distributed to the part smaller than 0.2 centimeters in diameter, about 64% to the part larger than 0.2 centimeter in diameter (lateral roots), and remaining 25% to stump. The growth increment of parts smaller than 0.2 centimeter in diameter may have been under-estimated, because a certain quantity of that parts was torn off when the whole root system was dug out. The ratio of distribution of root increments into stump, 25%, might have no reliable foundation, because the stump increment was estimated by indirect method.

Table 2. Growth increment of root of each diameter class (kg/year)

Diameter class of root	Tree No.					
	1	2	3	4	5	6
0.0~0.2cm	0.027	0.062	0.086	0.137	0.059	0.046
Lateral root (0.2cm~)	0.308	1.134	0.316	0.378	0.227	0.101
Stump	0.082	0.451	0.049	0.203	0.071	0.085
Total	0.417	1.647	0.365	0.718	0.357	0.232

Table 3 shows the growth increment of each organ of sample tree in connection with root increment. In Table 3, stem and branch increments were estimated by the same method which has been employed by many investigators in Japan. The leaf increments were estimated indirectly based on the following assumption that leaf increments may coincide with leaf litter falls in stable state of forest stand. Therefore leaf increments were estimated by measurement of leaf litter falls, in which measurement was performed by wrapping the whole crown of each sample tree with large bag made of hempen net during defoliation periods. That the larger the growth increment of tree (sum total of each organ) the larger the distribution of new component into root was found out. This trend of change of

Table 3. Growth increment & biomass of each organ of sample trees

Tree No.	Growth increment (kg/year)				Biomass (kg)			
	Stem	Root	Branch	Leaf	Stem	Root	Branch	Leaf
1	1.676	0.417	0.314	0.523	28.900	8.120	2.670	3.079
2	4.702	1.647	0.933	1.039	54.669	18.300	7.314	5.655
3	2.119	0.365	0.325	0.714	27.523	7.100	2.007	3.061
4	3.701	0.718	0.461	1.122	42.768	13.530	4.539	3.987
5	1.369	0.357	0.240	0.476	20.137	5.800	1.570	2.302
6	0.680	0.232	0.178	0.428	16.575	4.540	1.438	2.158

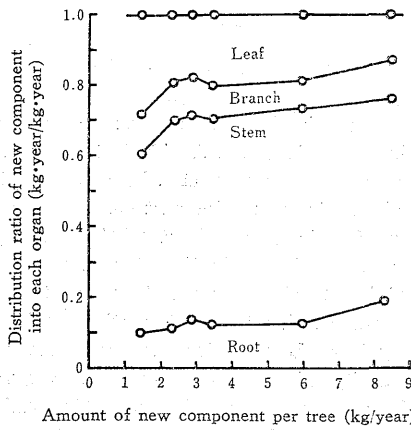


Fig. 3. Profile diagram showing distribution ratio of new component into each organ

distribution into root was contrary to distribution into leaf. This relation between root and leaf was the same phenomenon observed in seedlings¹⁰⁾ (Fig. 3).

2) Allometric Relation

For the estimation of root increments per stand, the allometric relation is an available method as in the case of biomass. Acting under this idea a series of allometric relations concerned with root growth was scrutinized. Fig. 4 shows the regression between root growth increment (ΔW_R ; kg/year) and its root weight (W_R ; kg) at respective diameter class.

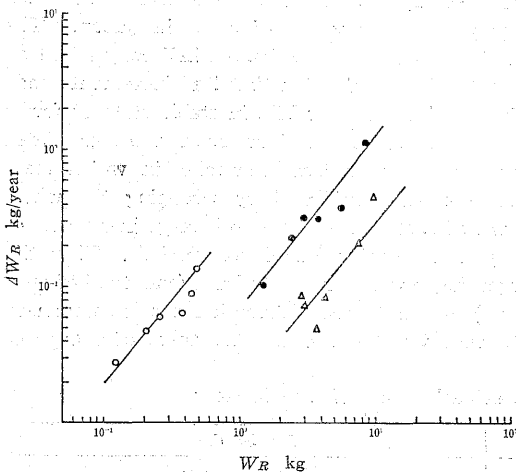


Fig. 4. Correlation between growth increment of root (ΔW_R ; kg/year) and root weight of respective diameter class (W_R ; kg)

○; Roots smaller than 0.2cm in diameter
●; Lateral roots
△; Stump

obtained for the three parts of root; the parts smaller than 0.2 centimeter in diameter, lateral roots and stump, as follows:

Roots smaller than 0.2 centimeter in diameter:

$$\Delta W_R = 0.337 W_R^{1.242} \quad (1)$$

Lateral roots:

$$\Delta W_R = 0.0712 W_R^{1.242} \quad (2)$$

Stump:

$$\Delta W_R = 0.0178 W_R^{1.242} \quad (3)$$

As seen in equations (1), (2) and (3), allometric constants were stable regardless of the parts of root system, but the constants given by the value ΔW_R at $W_R=1$ were different from each other. This departure of allometric equations make clear the differences of growth process based on the differences of character of each part. The increment of roots smaller than 0.2 centimeter in diameter was about 4.7 times that of lateral roots, and 18.9 times that of stump, when we assumed that three parts had the same amount in weight.

In Fig. 5, linear regression in log plot shows the allometric relation between the growth increments of root obtained by summation of three parts (ΔW_R ; kg/year) and the root weight (W_R ; kg). The inclination of root growth increment~root weight regres-

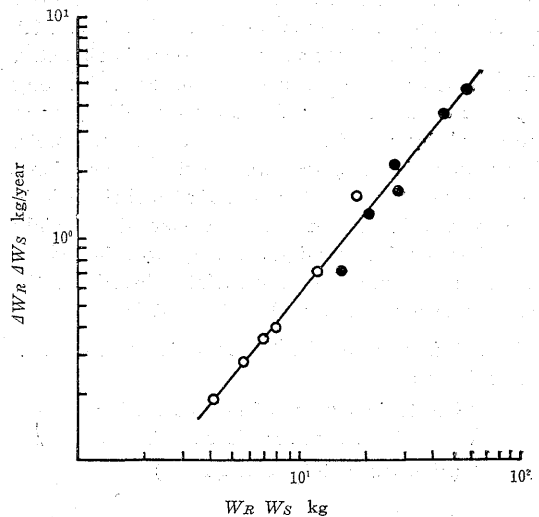


Fig. 5. Allometric relation between growth increment of root (or stem) and root weight (or stem weight)

ΔW_R ; Growth increment of root (kg/year)
 ΔW_S ; Growth increment of stem (kg/year)
 W_R ; Root weight of sample tree (kg)
 W_S ; Stem weight of sample tree (kg)
○; $\Delta W_R \sim W_R$ relation
●; $\Delta W_S \sim W_S$ relation

sion was identical with the value of allometric constants in equations (1), (2) and (3), and the equation of this regression is shown approximately by the following formula:

$$\Delta W_R = 0.0322 W_R^{1.242} \quad (4)$$

The equation (4) is the same equation as what was obtained from the allometric relation between the stem increments and the stem weight.

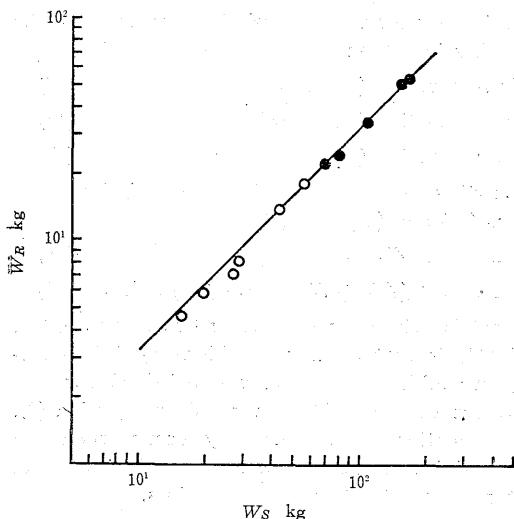


Fig. 6. Allometric relation between root weight of sample tree (W_R ; kg) and stem weight (W_S ; kg)

- ; Relation in 30-year-old stand
●; Relation in 40-year-old stand

Generally speaking, there may be no separation in the regression line of the relation between root and above-ground part of tree. As is obvious from Fig. 6, the relation between root weight and stem weight could be approximated by linear regression line in which the inclination was nearly equal to 1.0, and separation in the regression line due to the difference of forest stand was not found. The formula of this relation is expressed by the following proportional function:

$$W_R = 0.339 W_S \quad (5)$$

where, W_R : amount of root in weight per tree (kg)

W_S : amount of stem in weight per tree (kg)

The relation between root increments and stem increments is shown in Fig. 7, in which the tangent of regression line is nearly equal to 1.0. The regression of this relation is approximated by the following proportional expression:

$$\Delta W_R = 0.261 \Delta W_S \quad (6)$$

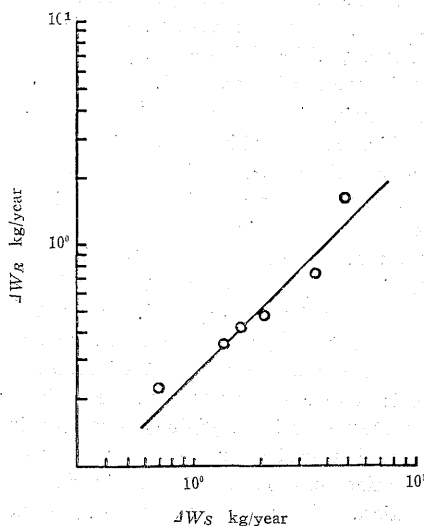


Fig. 7. Allometric relation between growth increment of root of sample tree (ΔW_R ; kg/year) and growth increment of stem (ΔW_S ; kg/year)

where, ΔW_R : amount of root increment per tree (kg/year)

ΔW_S : amount of stem increment per tree (kg/year)

All parameters in equations (1), (2), (3), (4), (5) and (6) do not contradict from each other.

The above-mentioned relations existing among four variables, ΔW_R , ΔW_S , W_R and W_S , may simplify the estimation procedure of root growth increment. Especially, if the phenomenon, in which the relation between ΔW_R and W_R is approximated by the very same equation derived from $\Delta W_S \sim W_S$ relation, is found in other cases of investigation on root analysis, the amount of root growth per stand will be easily estimated by $\Delta W_S \sim W_S$ relation.

Discussion

Almost three decades have passed since KITTEDGE ('44) introduced the equation,

$$Y = AX^h \quad (7)$$

to show the relation of leaf weight to tree diameter. The formula is now generally called a simple allometric equation; and many example of allometry are known, although whatever biological principle may underly the equation remains obscure to this day. According to this equation, the relative growth rates of growth of X and Y are expected to be proportional, or

$$\frac{1}{Y} \frac{dY}{dt} = h \frac{1}{X} \frac{dX}{dt} \quad (8)$$

In this equation, h is the proportionality constant between the two growth rates and called the allometric constant, while A is the integration constant given by the value of Y at $X=1$.

For the estimation of production of root and branch, which are too difficult to estimate by direct measurements, the procedures based on equation (8) have been employed by many investigators in Japan. In these cases, the following two conditions must be satisfied: The one is $dA/dt=0$, that is, A is not related to time (t). The other is the condition that h is not related to time as well as A . In forest stand, A and h are not always invariable but changeable with the growth and development of forest trees. Although it has been assumed that the variation of two parameters may be negligibly small during a short vegetation period or one year. Practically this assumption may be allowed considering rough approximation. Acting on the above mentioned idea, a simple equation for the estimation of increment of root can be easily derived from $W_S \sim W_R$ allometry, or

$$\frac{dW_R}{dt} = 0.339 \frac{dW_S}{dt} \quad (9)$$

The estimated value of root growth increment per plantation is 3.0 ton per hectare per year when we calculate root production by using equation (9). This value is larger than the value, 2.3 ton per hectare per year, which is estimated by equation (6) obtained from the result of root analysis. The overestimation of root increment by equation (9) is obvious from the contradiction of parameters between equations (6) and (9). This discrepancy arises from the property in which $dW_R \sim W_R$ allometry or $dW_S \sim W_S$ allometry is not in direct proportional relation. Namely the influence of allometric constant, 1.242, in equation (4) appears on the value of parameter A , 0.261, in equation (6). Therefore the estimation of root increment by equation (9) is not appropriate, and then another condition must be assumed beyond two conditions that are $dA/dt=0$ and $dh/dt=0$, when the estimation by equation (9) is employed.

In terms of mathematical symbols, the following explanation may be considered: Now let three relations between four variables, dW_R , dW_S , W_R and W_S , be expressed by the following allometric equations, or

$$W_R = A_1 W_S^{h_1} \quad (10)$$

$$dW_R = A_2 W_R^{h_2} \quad (11)$$

$$dW_S = A_3 W_S^{h_3} \quad (12)$$

Differentiating equation (10) with respect to time (t), we get

$$\begin{aligned} dW_R &= A_1 \cdot h_1 \cdot W_S^{h_1-1} \cdot dW_S \\ &= A_1 \cdot A_3 \cdot h_1 \cdot W_S^{h_1+h_3-1} \end{aligned} \quad (13)$$

From equation (10), (11) and (12) by eliminating W_R , we get

$$\begin{aligned} dW_R &= A_2 \cdot (A_1)^{h_2} \cdot (dW_S/A_3)^{h_1 \cdot h_2/h_3} \\ &= A_2 \cdot (A_1)^{h_2} \cdot W_S^{h_1 \cdot h_2} \end{aligned} \quad (14)$$

Considering that equations (13) and (14) agree precisely, there may be necessarily many conditions. Let three conditions obtained by the above-mentioned result for root analysis be expressed by the following formulae:

$$\text{From equation (5), } h_1=1 \quad (15)$$

$$\text{From equation (4), } h_2=h_3 \quad (16)$$

$$\text{From equation (4), } A_2=A_3 \quad (17)$$

Inserting equations (15), (16) and (17) into equations (13) and (14), we get

$$dW_R = A_1 dW_S = A_1 A_2 W_S^{h_2} \quad (18)$$

$$dW_R = A_2 (A_1)^{h_2} (dW_S/A_2) = A_2 (A_1)^{h_2} W_S^{h_2} \quad (19)$$

What is evident on comparing two formulae, (13) and (14) is that another condition— $h_2=1$ is necessary in addition to $dh/dt=0$ and $dA/dt=0$ for employment of the estimation based on equation (9). Above-mentioned problems may occur when the items of investigation increase, so that we had better to pay attention to these points.

Table 4. Net Production* in Plantation
(ton/ha. year)

Stem	8.9	59%
Branch	1.7	11%
Leaf	2.3	15%
Root	2.3	15%
P_n	15.20	100%

* $P_n = Y_{2N} + L_N + G_N$, $L_N=0$, $G_N=0$

The net production of this stand is shown in Table 4, in which losses of new component by grazing and death are neglected. The calculation was made based on summation-method-2. The root occupied 15% of net production and this value was 26% of stem productivity. The ratio of production to biomass of root—relative growth rate was 5.3% per year.

Acknowledgements

Authors wish to express thanks to the members of the forest owners' association of Mt. WATAMUKI for their permission to use the field. Thanks are also due to members of our Forest Ecology Laboratory, Faculty of Agriculture, Kyoto University, for their useful help and criticism.

Literature cited

- 1) Hokkaido, Tokyo, Kyoto, Osaka City and Shinsyu Univ.: Studies on the Productivity of the Forest. Part III, Productivity of Sugi Forest. (in Japanese). Jap. For. Tech. Asso., Tokyo, 1966
- 2) NEWBOULD, P.J.: IBP Handbook No. 2, Method for estimating the Primary Production of Forests. London, 1967
- 3) WHITTINGTON, W.J.: Root growth. London, 1968
- 4) YAMADA Isamu and SHIDEI Tsunahide: On the Root Biomass of *Cryptomeria japonica* Stands. (in Japanese with English summary). Bull. Kyoto Univ. For. 40: 67~80, 1968
- 5) KARIZUMI, Noboru: Studies on the Form and Distribution Habit of Tree Root. (in Japanese with English summary). Bull. Gov. For. Exp. Sta. 94: 1~205, 1956
- 6) SAITO Hideki and TSUTSUMI Toshio: ヒノキ林の落葉枝量の空間分布について. 森林の一次生産測定法の 研究中間報告: JIBP-PT-F: 61~64, 1967
- 7) SAITO Hideki, YAMAKURA Takuo and SHIDEI Tsunahide: 日野地方ヒノキ林の物質生産力. 森林の一次生産力の比較研究中間報告: JIBP-PT-F: 24~28, 1969
- 8) YAMAKURA Takuo and SAITO Hideki: ヒノキ林の樹根生長量と枝生長量. 天然林の一次生産力の 比較研究中間報告: JIBP-PT-F: 1~6, 1970
- 9) YAMAKURA Takuo, SAITO Hideki and SHIDEI Tsunahide: Investigation on the Primary Production of *Chamaecyparis obtusa* Stands. (in Japanese with English summary). unpublished
- 10) KAWANABE Saburo and SHIDEI Tsunahide: Ecological Studies on the Influence of Light Intensity upon the Growth and Development of some Coniferous Seedlings. (in Japanese with English summary). Bull. Kyoto Univ. For. 40: 111~121, 1968

(Received 22 October, 1971)

抄 録

○ヨーロッパアカマツの耐凍性 I. 電気伝導率測定による耐凍組織の検査および傷害評価の条件 (Frost hardiness in Scots pine (*Pinus sylvestris* L.) I. Conditions for test on hardy plant tissues and for evaluation of injuries by conductivity measurements) ARONSSON, A. and ELIASSON, L.: Studia Forestalia Suecica Nr. 77: 1~30, 1970

林木の耐凍性を簡易に検定する方法を考案し、ヨーロッパアカマツの苗木および成木の葉、芽、茎の組織を材料として検査した結果を報告している。

組織を 4°C に 18~19 時間おき、のち 6 時間、-12°, -22°, -32° あるいは -44°C で凍結後、組織を切断して水を加え、25°C にて伝導率測定 (x_{frozen})、また 10 分間煮沸してさらに 18~20 時間振とうした後 2 度目を測定 (x_{boiled})、比較伝導率 $RC = \frac{x_{\text{frozen}}}{x_{\text{boiled}}} \times 100$ で表わし、これを耐凍性の尺度とした。組織が凍害によって破

壊し電解質がより溶解していれば、価が高くなるはずである。

樹齢別の葉、茎、芽について RC 価はそれほど著しい相違のないことがまず確かめられた。二年生苗の芽、葉、茎について肉眼的観察による凍害の度合を次の項目について 1 点から 4 点まで採点をして加算する。(1) 芽の内部の変色 (2) 落芽の難易 (3) 葉の変色 (4) 落葉の難易 (5) 葉の乾燥度 (6) 茎の形成層の変色 (7) 形成層の柔軟度 (8) 木部の変色 (これのみ 1~2 点)。

1 月から 5 月までのこれらの採点と RC 価との相関は非常に高い。また冬期 20 年生マツ葉について凍結処理区 -44°C で他の低温と異なって高い RC 価を示し、10 年生の芽、茎、葉でも同様 -44°C では高い価を示す。2 年生の若い苗木では -44°C ばかりでなく -32°C で茎と葉組織について高い価を示す。

凍害については細胞間隙の結氷による細胞質の脱水ばかりでなく、細胞質内の結氷が原因となり、これら機械的な損害が基因となるのであろうと述べている。

(畑野 健一)