A study on the crown slenderness in *Chamaecyparis obtusa Endle*

Kunihiro SEIDO

ヒノキの枝張りについて

清藤城宏

Abstract:

A study was made on regularity, degree and heritability of crown slenderness in the forest of *Chamaecyparis obtusa* ENDLE. In order to express the relationship between stem diameter and crown diameter, regression approch was made along the idea of allometry. The 'a' and 'b' parameters were calculated and compared. The common slope (a) was tested by means of covariance analysis. F-test did not reject the hypothesis that each regression possesses the common slope, and the slope was decided to be 0.555.

A number of studies have been discussed on the reason of differences of the slope, but they seem to be resulted from unsuitabls materials selected. As the slope (a) is constant in each stand, it is emphsized to select individuals or populations possibly with smallvalues of level (b). Therefore, the formula to indicate the degree of level is shown as:

$$K'S = 100\left\{\log S - 0.555\ (\log D - 1)\right\}$$

where K'S: spacing value

S: crown diameter

D: stem diameter

The spacing value obtained ranges from 17 to 41, and the mean value is calculated as 30.4.

Heritability of crown slenderness was tested by Bertrett's method.The spacing value is hardly influenced by site factors, and the spacing value reasonably indicates the heritability of crown slenderness.

要旨： 枝張りの規則性、枝張りの程度のあらわし方、および遺伝性について検討するため、山梨県の南部（万沢林業地帯）のヒノキ林、3林分を材料としてデーターを収集した。その結果、ヒノキの枝張りについて、次のようなことがわかった。

1）胸高直径とクローネ幅について両対数方眼紙上にプロットすると、直線関係がみとめられ、高い有意な相関がみとめられた。

2）Allometryの式をあてはめ、共分散分析により共通の傾斜をもつかどうかを検定したところ、3林分において有意な差がなく、0.555が共通の傾斜であることがわかった。

3）したがって枝張りの程度は、高さによってきまるから、戸田（1953）があらわした式に変形すれば、

$$K's = 100\left\{\log S - 0.555(\log D - 1)\right\}$$

となり、枝張り数は17～41、平均30.4であった。

4）枝張り数の分散の均一性について、Bertrettの方法により検定したところ、均一とみなしえた。したがって枝張りは立地的な差に影響されることが少ないことがわかった。

Introduction

The following methods are usually employed for the purpose of forest tree improvement such as natural and induced mutation, cytoplasmic inheritance and selection. Open- or controlled-pollination, cutting and grafting techniques are used for propagation of improved materials.

However, selection of a superior tree or a group of trees may be the most fundamental approach for the forestry practice. Selection method can be subdivided into two, i. e. individual selection and mass selection, the former means to select out individual trees of excellent form and growth rate and the latter means to select a forest stand consisting of plus trees with comparatively uniform size and form. In all cases, these characters should possibly confirmed to be genetical. Therefore, what we want to have for reforestation is seed or nursery stocks with genetically excellent characters preferably of complex characters.

The major purpose of selecting such superior trees is naturally to increase the growth of stocks per unit area, which means that the fast-growing trees of slender crown are primarily considered to be most important for selection.

Studies on the crown slenderness by Zederaver (1912) showed that it was due to dioplasm. Dengler (1930) and Münch *et al* (1924) found that slenderness is an inherent character. Toda (1953) proposed the following formula induced from Reineke's (1933) on the relationship between stem diameter and the maximum number of stems in a unit area:

$$\log S = Ks + 0.803 \log D$$

where S: Crown diatmeter. Ks: Spacing values.
D: Stem diameter.

He showed that trees of the same genetic quality would be arranged on a straight line which is parallel to other lines plotted for the trees of different quality. He also showed (1954) that the coefficient 0.803 could not be applied to a clone of *Cryptomeria japonica* but 0.51 would be a correct value; and later (1956) mentioned that 0.51 was not the value for *Larix decidua* clone. He explained that self-pollinated seedlings have, when they are young, much broader crowns compared with the ortet plant and difference between them becomes smaller with age. This difference of crown slenderness seems to be the characteristics of juvenility.

Yamahata and Masuoka (1959) examined in *Pinus thunbergii* and *P. densiflora* and explained that the coefficient which range from 0.50 to 0.60 may be applied to all the tree species.

Yokoyama and Hatakeyama (1962) obtained the coefficient 0.75 for *Betula platyphlla* var. *japonica*.

According to Arita (1962), on the other hand, the relationship between crown diameter and stem diameter is expressed by linear equation of B=a+bD, and there is a constant value of ratio a/b throughout the different races. From such a presumption he proposed that the degree of crown slenderness is represented by the value of b′ in the formula b′=B/(D+K), where K: a/b derived from a general B=b (D+K).

The purpose of the present study is to find the regularity of crown slenderness, to determine the formula of crown slenderness, and to investigate the heritability of crown slenderness.

I would like to express my appreciation to Dr. Kozo Funabiki of Department of Forestry at Niigata University, for his kindness in reading the original manuscript.

Material and method

Materials were selected from each of three seedling stand in southern part of Yamanashi Prefecture (Manzawa Forest Zone) to know if the relationship between stem diameter and crown diameter is constant even when genetic component of the species or site factor are different among those stands. General situation of the studied stands and the habitats are summarized as follows:

Table 1. **—Situation of studied stands and its habitats.**

Stand No.	Stand age	Altitude	Azimuth	Dip gradient	Numder of trees per ha.
1	33	580m	NE20	15	2000
3	27	400	NE45	20	2000
3	30	240	SE20	25	1900

Number of tree measured trees	Mean tree height	Mean diameter breath height
40	15	19
40	9	16
40	13	18

Three of supressed or abnormal form were deliberately excluded at the time of measurement. Stem diameter is expressed by the mean value of cross measurement at 1.2m high above ground with a diameter gage, round the nearest 1 centimeter. Crown diameter was measured along the direction of the slope of the stand and also at right angle of it with a tape measure to the nearest 10 centimeter.

Results and discussion

1) Regularity and formula of crown slenderness

Huxley (1932) found the relationship between each organ for a certain organism and gave the formula:

$y = bx^a$ where y: quantity of a certain organ
x: quantity of other organ
b: initial growth index
a: equibrium constant.

This relationship is generally called 'allometry' or 'the law of relative growth'. Allometry is widely used all the organisms, and is applied to estimate forest productivity in the field of forestry. A number of formulae have been given which express the relationship between crown diameter and stem diameter.

In this paper, it is used as conception of the relationship.

Values of stem diameter and that of crown from each stand are plotted on bi-logarithmic section (Fig.1) .

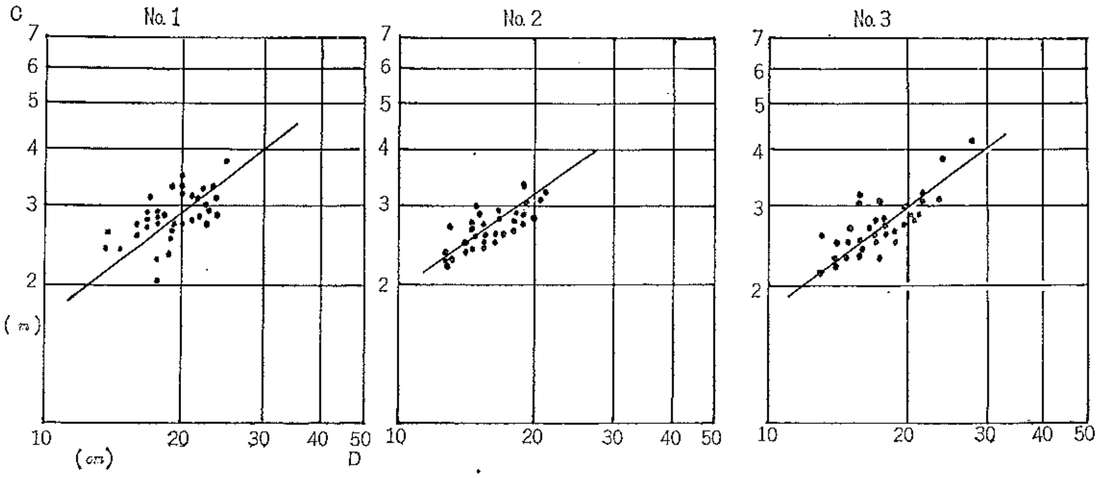

Fig. 1.— **Relation between stem and crown diameters in each stand.**

In each stand, relationship between stem diameter and crown diameter is found to be linear. Table 2 lists the correlation coefficients for stem diameter and crown diameter.

Table 2. —**Correlation coefficients for stem and crown diameters.**

Stand No.	1.	2.	3.
r-values	0.58***	0.71***	0.81***

*** Significant at the 0.1 percent level.

Highly significant correlations are found between stem diameter and crown diameter. Then, in order to express the relation between them, the following regression is given in the formula of allometry:

$y=bx^a$ where y: crown diameter

x: stem diameter

a, b: parameters

In the formula of allometry, as 'a' is an equilibrium constant and 'b' is an initial growth index, it is supposed that 'a' would be a constant within a species or among all the species even though 'b' varies among populations.

Accordingly, parameters 'a' and 'b' are calculated for each stand (Tab.3). The upper formula is changed by logarithm as follows:

$\log y=\log b+a \log x$

and 'a' and 'b' parameters are found by 'least square' method.

Table 3. —**Values of a and b in the allometric relation.**

stand No.	a	b
1.	0.452***	0.326
2.	0.518***	0.320
3.	0.647***	0.278

*** Significant at the 0.1 percent level.

Even if genetic component of species or site factors vary, the common slpoe (a) is supposed to be indicated. So, this hypothesis was tested by covariance analysis (Tab.4) .

Table 4. —**The result of covariance analysis.**

Line	stand No.	f	$\sum y^2$	$\sum xy$	$\sum x^2$	f	Residual Sum of squares	Residual Sum of square—mean
1.	1.	39	0.1122	0.0753	0.1665	38	0.0780	
2.	2.	39	0.0664	0.0647	0.1248	38	0.0327	
3.	3.	39	0.1505	0.1537	0.2374	38	0.0511	
4.					Total	114	0.1616	0.0014
5.				Difference of slope		2	0.0046	0.0023
6.		117	0.3291	0.2935	0.5287	116	0.1662	

$F_{(f2/114)}=0.0023/0.0014=1.64$

Not significant 1.O percent level.

Then, common slope is calculated as:

$$0.5287\ a = 0.2935$$

$$a = 0.555$$

and for the reduction sum of squares, it is calculated as:

$$\text{reduction sum of square} = 0.555\ (0.2935) = 0.1629$$

and the residual sum of squares, as:

$$\text{residual sum of squares} = \sum y^2 - \text{reduction sum of squares} = 0.3291 - 0.1629 = 0.1662 \qquad f = 116$$

This indicates that, when the regression is forcibly applied for each group which posesses the common slope, residual is obtainable, and the difference of this residual sum of square-mean (line 5) can be used to ascertain the hypothesis. The error term for this test (line 4) is the total residual sum of square-mean on each regression.

F-test does not reject the hypothesis that each regression possesses the common slope, and the regression is given as follows to express crown slenderness of *Chamaecyparis obtusa:*

$$\log S = Ks + 0.555 \log D, \text{ or } S = Ks\ D^{0.555}$$

where S: crown diameter

D: stem diameter

Ks: coefficient

Yamahata and Masuoka (1959) suggested that the slope (a) might range from 0.50 to 0.60 and could be applied to all the species; and the slope obtained coincides with this.

Considerable amount of discussion have been made on the slope, and differences of slope may depend on unsuitable formula applied or the method employed to select the materials for study. In this paper, regression function was estimated by the concept of allometry. Concerning the allometry, in the sense of 'equilibrium constant', the slope calculated in relation to stem and crown diameters is also considered to be equilibrium. Then, however different genetic constitutions or site factors may be, the regression lines are parallel on different stands and it is almost possible to apply to different species. Therefore, the differences of slopes may be considered to be resulted from unsuitable method of selecting the study materials.

Arita (1967) suggested on the methods: (1) materials must be abundant with varaition to some extent, (2) materials must be taken at random, and (3) materials must represent undisturbed characters for study.

Most of the methods employed to carry out this study used were collected from populations with genetical variations.

The slope was out of consideration, the reason was that if the line was calculated altogether, the slope would naturally vary being influenced by each level.

Arita's condition (1) suggests to include genetic populations consisting of younger trees to older trees. Accordingly it was not easy to find suitable stands for the study,and it was preferable to measure the stands consisting of stems with genetically narrower range of diameter variation. Consequently several stands of different age classes were studied.

If no large variance is obtained from above viewpoint,it is supposed that the common slope is a constant even when the stands have got older. On the other hand, Toda (1954) explained the reason why different slopes appeared. Namely, the crown projection area is much larger than the occupation area in younger stages, and on the contrary it becomes smaller with increasing ages. So,the stand with different genotypes within a species and different species will be shown by different slopes, because relation between crown projection area and occupation area may be different according to different genetic constitution of materials.

Arita (1967) gave a condition (2) to avoid this disadvantage. However, as isolated trees were found only in scarce forests, i. e. old or overmatured forert, it was difficult to obtain suitable trees from such forests.

Yokoyama and Hatakeyama (1962) measured all the trees in a stand and used only the crowns of above upper story, and the present authr employed this method.

Difference between crown projection area and crown occupation area will be shown in different slopes, and this may be excluded in this study.

In conclusion, the common slope 0.555, which was calculated on above viewpoint, is almost constant.

2) Heritability of crown slenderness

The correlation by which the phenotypes appear includes between-gene correlation and between-enviroment correlation, and the characters inherit possitively or negatively under the influence of environment at the same time.

For forest tree improvement, genetic correlation must be primarily taken into consideration. Avaraged values of phenotypic correlation was calculated as 0.70, but that of genetic correlation could not be obtained.

Sakai and Hatakeyama (1963) gave the values of genetic correlation on *Abies sachalinensis*. The highest value in all the genetic correlation was obtained for the relationship between stem diameter and crown diameter.

If any significant differences do not exist between different species on the heritability of crown slenderness, genetic correlation should show the high value in *Chamaecyparis obtusa.*

Sakai and Hatakeyama (1963) pointed out that if the stem diameter increment is emphasized for selection, the crown diameter comes to be of importance together with it, because there is a positive relationship between stem diameter and crown diameter, and this genetic relationship is an adverse condition for selection.

As no negative correlation was found between stem diameter and that of crown, and the slope (a) showed constant in each stand, it appears to be important to select individuals or populations with small value of level (b) as far as possible.

The method which indicates the degree of levels was proposed by Toda (1953) and called 'spacing value'.And this method was used for the study, i. e.

$$K's=100\left\{\log S-0.555(\log D-1)\right\}$$

where K's : spacing value
S : crown diameter
D : stem diameter

The table of spacing values was obtained by this formula (Tab.5)

Table 5. —**Mean standard deviation and coefficient of variance of spacing values.**

No. of stand	1.	2.	3.	Mean
Mean	29.35	31.85	29.95	30.38
σ	4.45	5.05	3.67	4.47
C.V. (%)	15.5	16.8	12.2	14.7

If crown slenderness in an heritable character, the variance of spacing values must be uniform. Therefore the uniformity of variance tested by 'Bartlett's method' (Tab.6).

Table 6. —**The analysis on uniformity of variance.**

No. of stand	S^2	$\log S^2$
1	20.7	1.31597
2	25.5	1.40654
3	13.5	1.13033
	$\sum S^2=59.7$	$\sum \log S^2=3.85284$
Mean	$\bar{S}^2=\sum S^2/a=19.9$	$\sum \log \bar{S}=1.29885$

$$a\log\bar{S}^2=3\ (1.29885)=3.89655$$
$$\sum \log S^2\ =3.85284$$
Difference　0.04371

$$\chi^2=\log 10\ (n-1)\ (a\log\bar{S}^2-\log S^2)$$
$$=2.3026\ (40-1)\ (0.04371)$$
$$=0.3925\qquad f=a-1=2$$

Supplementry coefficient:

$$C=1+(a+1)/3a(n-1)$$
$$=1+(3+1)/3(3)(40-1)$$
$$=1.0114$$

The corrected χ^2:

$$\chi^2=\chi^2/C=0.3803$$

Thus obtained values of χ^2 show that the variance of each stand is uniform.The conclusion is that spacing value is hardly influenced by the site factors and reasonably indicates the heritability of crown slenderness.

REFERENCE

SATO K. : Forest tree breeding. 1957.

ARITA M. : The differences of crown slenderness among races of Cryptomeria. Hokkaido Univ.For. 21 (2), 1962.

ARITA M. : The genetic nature of crown slenderness in Cryptomeria japonica. J. Jap. For. Soc. 46, 1964.

ARITA M. : Studies on the crown broadness in Cryptomeria japonica in view of genetical and ecological characteristics. Bull. Gifu Univ. Agric. 25, 1967.

MATSUO T. : Thremmatology. 1966.

SNEDECOR, G. W. : Statistical methods. 1952.

TODA R. : A method to indicate the degree of crown slenderness of individual trees. J. Jap. For. Soc. 35, 1953.

TODA R. : A method to indicate the degree of crown slenderness of individual trees Ⅱ. J. Jap. For. Soc. 36, 1954.

TODA R. : On the crown slenderness in clones and seedlings. Z. Forstgenetik, 5, 1956.

HUXLEY : Problem of relative growth. 1932.

YAMAHATA K. and MASUOKA M. : Studies on the management of the coppiceforest (VII). Jap. For. Lec. No. 69, 1959.

YOKOYAMA H. and HATAKEYAMA S. : Studies [on the breeding in broad leaf trees (I). Jap. For. Lec. No. 72, 1962.

BAKER : The theory and practice of silviculture. New York, 1934.

WILEY : Control techniques for management even-aged stand. J. Fov. 1959.

HATAKEYAMA S. and SAKAI K. : A new estimation of genetic parameter in forest trees and selection index. Bull. Hokkaido For. Tree Impr. Sta. No 2, 1963.