Natural Root Grafting and Growth of Living Stumps of *Chamaecyparis obtusa**

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Despite the generally accepted concept that "individual" plants are discrete physiologic unit, there is considerable evidence that in many woody species two or more "individuals" are morphologically interconnected by means of fusion of roots. According to a bibliography compiled by BORMANN and GRAHAM (1957), there are numerous reports on intraspecific root grafting, or fusion of roots, of different individuals and on living stump as a result of it, and the oldest of them are dated 1833. Of Japanese species some examples are already reported (HARADA 1936, YOSHIOKA 1937, KAITO 1952, TOKUNAGA 1955, and KARIZUMI 1957). Of recent years, interest on this phenomenon has increased and many detailed studies have been made from various standpoints. Here is reported a study of natural root grafting and living stumps in a plantation of *Chamaecyparis obtusa* in Tokyo University Forest in Tiba, Southeast of Tokyo.

1. The stand.

The study was made in 1961 on a plantation which was established in 1922, with original density of 6000~6600 trees per hectare, on flat land of poor dry soil. At the time of the study, stand density ranged from 1400 to 2300 trees per hectare, mean height was 11~12 meters, and mean diameter breast high ranged from 12 to 18 centimeters, according to the data of several sample plots. As this plantation is very close to a main road, thinnings for the purpose of small-scaled utilization were frequently made in addition to scheduled thinnings.

2. Living stumps.

Stumps with healed cut surface, such as shown by the photograph of Fig. 1, which shows that stumps are still alive and growing despite the loss of their green tops, were found all over the stand. On some of them callus tissue covered entire cut surface, on some of them rings of callus tissue grew around their cut surface, and on the others only a sector of the cut surface was covered with callus tissue. When excavated, these healed stumps always had interconnections with one or more other trees by means of fusion of roots (Fig. 2). The fusion occurred in various ways and the fusion of roots occurred not only with directly neighboring trees but with trees of some distances (Fig. 3). Five plots, each 10×10 m, were set on the plantation covering an area of

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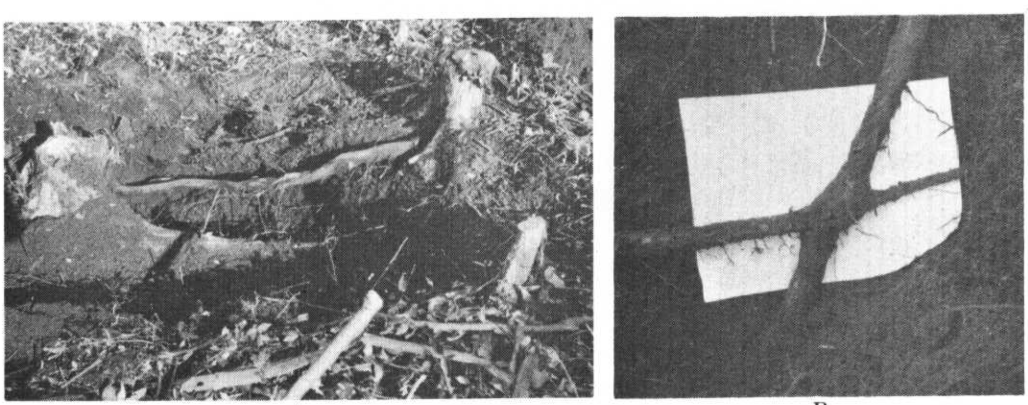
Table 1. Occurrence of living stumps and estimated number of trees with root grafting.

Plot	Number of trees standing	Number of stumps			Total	Estimated number of trees with root grafting
		Dead	Living	Total		
1	20	33	7	40	60	31.5
2	19	37	6	43	62	28.2
3	24	35	7	42	66	30.3
4	23	36	7	43	66	30.8
5	31	23	8	31	62	32.0
Mean	23.4	32.8	7	39.8	62.8	30.6

Fig. 1. A living stump.



A B

Fig. 2. Fusion of two roots.

4.56 hectares, and the number of standing trees and living as well as dead stumps were counted. As shown in Table 1, the number of living stumps was large and fairly uniform among plots, suggesting that root grafting is very common in this stand.

3. Estimation of the frequency of the occurrence of root grafting.

In addition to the root grafting revealed by the living stumps, which are shown in Table 1, there must be root grafting among the standing trees and also among the trees cut by thinnings, or stumps. To know the frequency of the occurrence of root grafting exactly, it is necessary to excavate the entire root systems in the sample plots, but it is too labor-consuming. Rough estimation of the frequency of root grafting was made with premises, that one tree connects with only one other tree, that the fusion of root happens at the same rate among all trees there, and that trees are cut randomly. The first premise is apparently not true, because a tree sometimes connects with two trees, as shown by Fig. 3, or, perhaps, more. But for the sake of simplicity of the estimation the first premise was made. The second premise has no evidence yet, but there is no reason to deny it, as living stumps were found fairly uniformly in all sample plots. The third premice is also not true, because trees were cut by thinnings or small-scaled utilizations. Smaller trees are apt to be cut by thinnings and larger ones are apt to be cut by small-scaled utilization. The number of trees having root grafting was estimated, with the premises mentioned above, by a formula

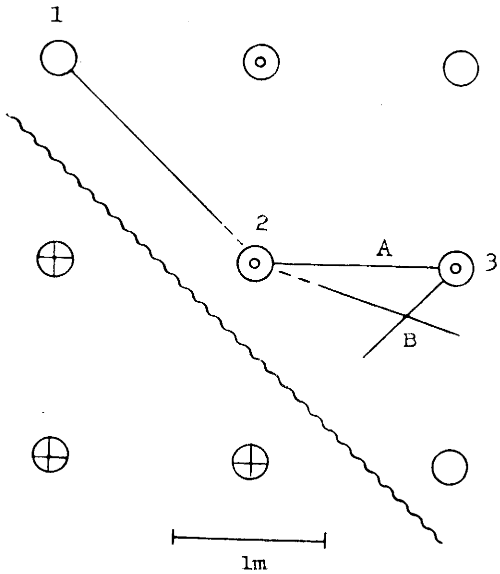


Fig. 3. Diagram showing connection of trees and stumps by root grafting.
Open circles: standing trees.
Double circles: living stumps.
Circles with cross: dead stumps.
Lines show the connection among trees and stumps.
A: connection between living stumps 2 and 3.
B: connection between standing tree 1 and living stump 3.
Roots of 1 pass through the dense root system of living stump 2, but root grafting did not occur.

$$q = \frac{aN^2}{n(N-n)}$$

where N is the total number of trees and stumps, n is the number of stumps, living as well as dead, a is the number of living stumps, and q is the number of trees with root grafting, in the plot. This formula was induced with aid of probability and also from a simple model.[1] The number was estimated as 28～32 trees or 14～16 pairs per plot of 100 square meters, as shown in Table 1. Thus, about one half of trees has connection with other trees through fused roots. This estimation might be too high, but it might be said that percentages of root-grafted trees are very high in this stand. KAITO (1952) and TOKUNAGA (1955) reported high frequency of the occurrence of root-grafted trees in plantations of *Cryptomeria japonica* and HARADA (1936) also reported

[1] The autor is indebted to Dr. T. HIRATA for his kind advises in inducing the formula.

the same on a natural forest of *Abies sachalinensis.* High rate of the occurrence of natural root grafting in various species of forest trees is presented in BORMANN's review (1962).

4. Gro vth of the living stumps.

Even after losing their green tops, living stumps grew and formed annual rings, though the wood formed in stumps after losing their tops seemed to be somewhat different in color and other features from normal ones, and easily distinguishable (Fig. 4). The nature of the wood is under study. Each five living stumps were collected from the five plots and the thickness of wood formed after losing their green tops and the number of annual rings therein were measured on four arbitary radii crossing each other at right angle. As shown in Fig. 5, average width of the annual rings was smaller in the living stumps having larger number of annual rings formed after losing the tops. This suggests that the width of annual rings grows narrower and narrower with lapse of time after losing their green tops. In some cases ring width after losing the top was larger than the one formed while the tree was standing. LANNER (1961) reported that in some cases ring width did not decrease after felling.

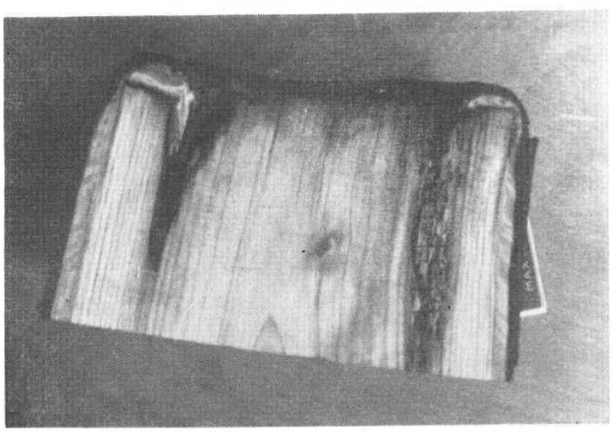


Fig. 4. Wood formation in a living stump.

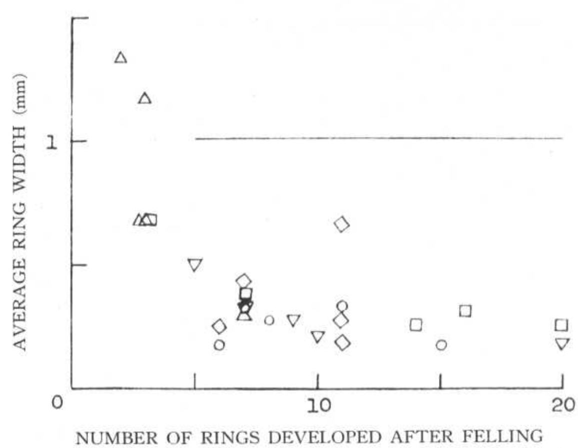


Fig. 5. Average width of annual rings formed in living stumps and number of rings therein. Different symbols show different plots. Horizontal line shows mean width of annual rings of standing trees for corresponding time.

From other twelve living stumps, microscopic sections were made and the width of rings formed after losing the tops was measured using a microscope of low power. As shown by the photograph of Fig. 6, it is clear that the width of the ring grew narrower year by year. The width of annual rings is shown in Fig. 7 as percentages of the mean width of the annual rings formed while the trees were standing. The width of annual rings formed in living stumps decreased rapidly at first and then very slowly. The fairly wide annual rings shortly after losing the tops and the decreases of growth thereafter suggest that the living stump utilizes foods which were reserved in roots and butt while it had green top.

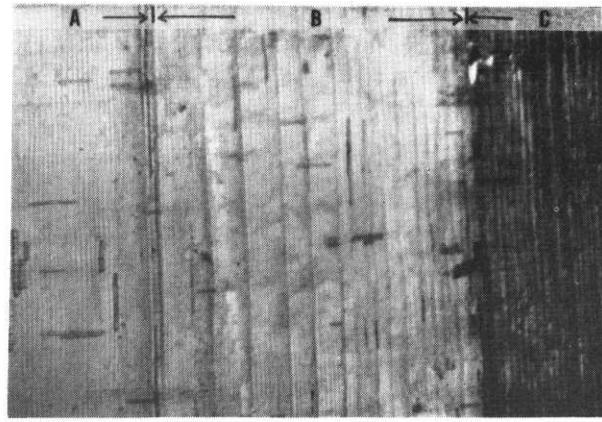


Fig. 6. Annual rings in the wood formed after losing the green top.
A: wood formed before losing green top.
B: wood formed in the stump.
C: bark.

5. The relation between the width of annual rings formed before and after losing green tops.

On the twelve samples, the width of the annual rings formed by the living stumps in various years after losing the tops was compared with the width of rings formed while the trees were standing. Mean value for three years was used for comparison, to avoid the effect of annual fluctuations in growth. As shown by Fig. 8, the width of annual rings formed by the living stumps had close relation with the ones before losing their tops until 3~5 years after losing the green tops. Correlation coefficients were $+0.7^{**}$. However, after then, the relation was not clear. This result shows that the growth or vigor of the tree before losing the top influences the growth of stump for some years after losing the top, suggesting that the living stump utilizes the foods reserved in the butt and roots while it was intact, in addition to the foods supplied from the connected intact tree, or trees, through the fused root, or roots. Reserve foods in the stump themselves are not sufficient to cause the growth, but another factor which stimulates the cambial activity which is given by another intact tree through the fused root is indispensable (BORMANN 1961 and 1962). When the reserve foods were exhausted and the stump was fed only by other intact tree, or trees, through the connected root, or roots, the growth of the stump has no relation with

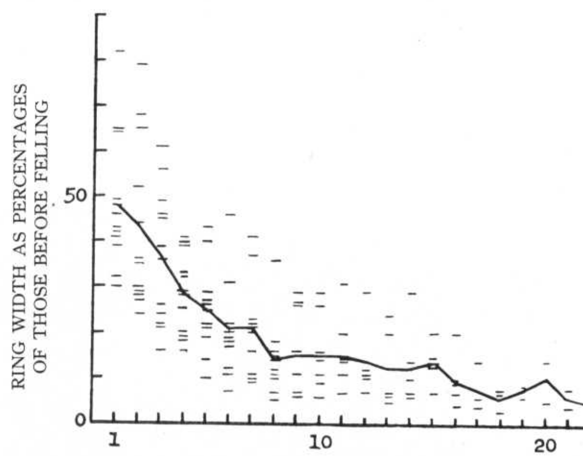


Fig. 7. Decrease of the width of annual rings in living stumps with lapse of time after losing their green tops. Solid line shows the mean of all measurements which are shown by short horizontal lines.

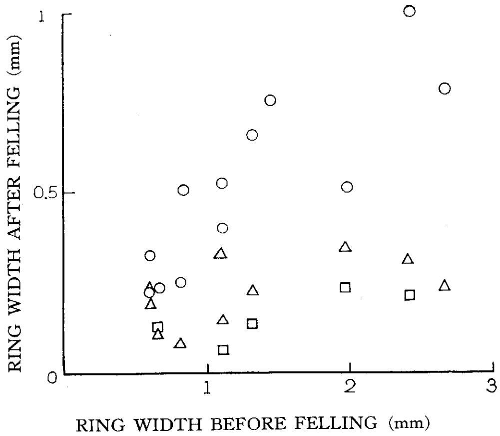


Fig. 8. The relation between the width of annual rings of living stumps before and various years after losing their green tops.
Circles: mean of three years for 1～3 years after losing the tops,
Triangles: for 6～8 years,
Squares: for 14～16 years.

the growth or vigor of the tree before losing the top, and the growth of the living stumps decreased to a level which, presumably, is limited by the capacity of the connected root, or roots, to translocate the foods.

6. Natural root grafting in other Japanese forest tree species.

In Japanese literature, the occurrence of natural root grafting of the following species of forest trees is reported: *Abies sachalinensis* (HARADA 1936), *A. mariesii* (YOSHIOKA 1937), *Cryptomeria japoncia* (KAITO 1952, TOKUNAGA 1955, and KARIZUMI 1957), *Chamaecyparis pisifera, Pinus densiflora, P. thunbergii, Tsuga sieboldii, Carpinus tschonoskii, Cinnamomum camphora, Quercus acutissima, Q. myrisinaefolia, Saphora japonica,* and *Zelkowa serrata* (KARIZUMI 1957), and *Fagus crenata* (YOSHIOKA 1937). Alos among exotic trees planted in Japan, *Pinus rigida, P. palustris* and *Taxodium distichum* are reported to have root grafting (KARIZUMI 1957). The present author himself observed natural root grafting of *Abies firma, Pinus densiflora* and *Tsuga sieboldii* in natural forests, of *Cryptomeria japonica* and other examples of *Chamaecyparis obtusa* in plantations, and of *Pinus densiflora, Chamaecyparis obtusa* and *Larix leptolepis* in nurseries.

7. Silvicultural implications.

Widespread occurrence of interconnection among individual trees which have been accepted as discrete physiologic unit, by means of natural root grafting, and translocation of foods, nutrient salts and water through the fused roots, indicate the need of detailed studies not only of biological interest but of practical importance. It may affect the idea of tree classification in thinning and selection of élite trees in tree improvement works. Comparison of growth of root-grafted and independent trees and study of the role of the extra root system added by felling of one of the union may be among the important subjects in this respect. Transfer of diseases and silvicides through fused root may also be among important subjects of study.

8. Summary.

Natural root grafting found in a 51-years-old plantation of *Chamaecyparis obtusa* was studied. Number of living stumps averaged 7 per 100 square meters. From the number of living stumps, dead stumps and standing trees, frequency of the occurrence

of natural root grafting in this stand was estimated as 14～16 unions per 100 square meters, with some premises. Width of the annual rings formed after losing tops in the living stumps decreased rapidly at first and then decreased very slowly. The width of the annual rings formed before losing the green tops, which is supposed to represent the vigor then, affected only for a few years after losing the tops, suggesting the role of foods in stumps reserved while having the green tops. Occurrence of natural root grafting of other Japanese forest tree species was listed. Silvicultural implications of this phenomenon were also discussed briefly.

9. References.

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**only in Japanese.

ヒノキ の 根 の クッツキ と キリカブ の 生長

教官 佐 藤 大 七 郎

あ ら ま し

51年生の ヒノキ の 造林地 で みられた 根 の クッツキ と キリカブ の 生長 を しらべた。生きていて キリクチ に マキコミ が おこっている キリカブ が 100 平方メートル あたり 7本 の ワリ で みられた。まきこんだ キリカブ，かれた キリカブ，および 立木 の 数 から，根 の クッツキ の オコリカタ を，いくつかの 仮定 を もうけて，推定する と 100平方メートル あたり 14～16回，はじめに 植えた 木 の およそ ナカバ が ほかの 木 と 根 が つながっている こと に なった，きりたおされて から キリカブ に できた 年輪 の ハバ は，はじめは すみやかに，あとでは ごく ゆるやかに，年 と ともに へって いた。きってから 数年の あいだ に できた年輪 の ハバ は きるまえ に できた 年輪 の ハバ と 関係 が あった。このあいだ は キリカブ に たくわえられていた もの が つかわれると かんがえられる。ほかの わがくにの 樹種 に みられた 根 の クッツキ の 例 や，造林 の シゴト との 関係 に ついて かんたんに のべた。