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## Approach to Intensive Culture and Forest Tree Breeding of *Cryptomeria* in Japan\*

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**Summary:** Local varieties of *Cryptomeria* are divided into two main types, the native cultivar and the improved one. The former is furthermore classified into two types the one that have been regenerated by layering or seeding in the natural stands as *Urasugi* type, and the other that have been cultivated for a long time by cuttings through repeated selection in the districts where the intensive culture have been carried out. The improved cultivar, rather new varieties, which have been propagated by cuttings selecting excellent individual trees from the planted forests originated by seedlings.

The native cultivar grows slowly in the early stage of the plantation, it is characteristics, however, that the cultivar keeps constant growth for a long time until the matured stage, and many of the varieties are also fine quality.

While the growth of improved cultivars are excellent from the early stage of the plantation. And forest fertilization brings a great effect on the improved cultivars, especially the fertilization in the early stage of the plantation causes to the close stand. Generally the improved cultivar by cuttings is very effective for increasing the growth and improving the tree form and quality, the plantation in mono clone, however, makes the scope of plantation smaller and brings unexpected damages caused by typhoon, snow, disease, insects, etc., and moreover the plantation of the improved cultivar in excellent growth tends toward the application of short rotation system. And it is apt to decrease the productivity of soil. Furthermore the viability will be decreased by the aging due to repetition of cuttings in mono clone, and the disappearance of many genes will be caused by the breeding of clone.

As described above, it is necessary to develop the intensive works under the consideration of various defections. And furthermore, the study on the breeding of new varieties should be performed by applying the hybrid vigor or establishing gene bank.

### Introduction

Sugi (*Cryptomeria japonica* D. Don) is the most important forest tree species in Japan. Its natural distribution is extended from Aomori Prefecture (40°42' North Lat.) the north end of Honshu, to Kyushu Yaku-island (30°15' North Lat.). Today the number of natural forests called pure forests has been decreased in propotion to increasing the number of planted forests.

Sugi is broadly divided into two climatic races, *Urasugi* and *Omotesugi*, for the tree is regionally varied by climatic and edaphic conditions in its natural distribution (Shirasawa, 1917; Murai, 1947). These two races, however, cannot be classified completely as ecotype, it is said that it is rather ecocline (Tohyama, 1960, 1961).

Suitable sites for Sugi reforestation, in general, are the places where annual mean temperature is 12–14°C and more than 3,000 mm of annual precipitation, especially moisture is much required, and the moisture relies not only on the soil moisture but also on the aerial humidity.

Sugi plantation is, at present, widely carried out in all over Japan from the southern part of Hokkaido to the south end of Kyushu, according to the latest result (Forestry Agency, 1968), approximately 40 % of the whole area of annual reforestation in Japan has been occupied by Sugi plantation. Some districts where planted forests have been carried out for a long time including whole Kyushu region have the reforestation area of using cuttings, and there are many cultivars as clone or clone-complex.

As it is comparatively easy to improve the variety of Sugi by cuttings, at present introduction of excellent native cultivars or raising up clone by the method of selecting the elite trees have been chiefly carried out in our country.

#### **Aims at Forest-Tree Improvement of *Cryptomeria***

##### 1) Increase of timber production

At present, a total demand of the wood in a year in Japan is about 82,000,000 m<sup>3</sup>, in which the domestic wood takes 52,000,000 m<sup>3</sup> and the imported wood occupies for the rest. It is national request, therefore, to plan the way of increasing the whole production of the wood. On the other hand, it takes a long time for foresters to produce a forest, therefore, in Japan, especially, there is the strong tendency of making the final age younger, for there are many small scale private forests (smaller than 5 ha about 90 %) in our country. Many of foresters made it the principal object to increase the growth by means of forest tree improvement, forest fertilization and improvement of such conditions as environment, etc. There are different responses in the native cultivars, strong or comparatively weak, to the soil nutrient. It has been also recognized, therefore, that the forest fertilization gives different effect on each cultivar (Miyajima *et al.* 1966a, 1966b).

##### 2) Improvement of tree form and wood quality

The wood is used mainly for building materials, furnitures, telephone poles, ship buildings and other general saw timber for construction, and the following properties for the trunk form and the wood quality are desirable.

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They are straight grown trunk, good cross section circle, long trunk with knotless or small, the less different the better of the diameter between upper and lower sides of the trunk and high density of annual ring, and also especially the reddish in the heart wood is desirable. Those properties will be improved in some extent by means of controlling of the density or management of the forest stand, the natures are, however, greatly due to the inherent tendency of the tree. A great attention is paid, therefore, to the selection of variety on account of producing the particular wood quality.

### 3) Expansion of planting area in various stand conditions

Adaptability of Sugi for the site is not so much as the other tree species, it is desirable, therefore, to raise up the varieties which grow in comparatively poor or dry soil conditions. And the varieties which have a great resistance to the damages from the cold and the frost in the cold districts and a great resistance to the snow damage in much snowy districts are necessary to be raised up.

### 4) Increase of resistant characters to various damages

As for major diseases of Sugi, there are *Guignardia cryptomeriae*, *Cercospora cryptomeriae* or the like, and as to the noxious insects, there are such as *Contarinia inouyei*, *Paratetranychus hondoensis*. Management of nursery or forest stand becomes easy by raising up the varieties which has a great resistance to such diseases.

## Breeding of Local Varieties Grown by Cuttings

In our country, in some of the districts where the intensive culture of Sugi has been adopted, the varieties have been bred by cuttings, as clone or clone-complex of Sugi, respectively depending on the conditions of the local weather and the soil or the wood usage. The characteristic of the major forestries and the typical local varieties (native cultivar and improved cultivar) are as follows:

1) Kitayama forestry (Ishizaki, 1959): Special district of forestry for producing the polished logs extended in the northern part of Kyoto city. In this district, from the middle of the 15th century, the tree in suitable nature for producing the polished log was selected and cut among the Sugi stand of natural afforestation by layers, and it is about 290 years ago, that the propagation of this Sugi by cuttings was started. There are *Honjiro*, *Mineyamajiro*, *Hōzukijiro* and *Shibahara* in the cultivars. *Honjiro* is the best among them, though its growth is comparatively slow, for the timber quality is fine and light yellowish white, its surface is smooth, its luster is rich, discoloration and crack occur a few times and rooting ability after cuttings is also excellent.

2) Sanbu forestry (Ishizaki *et al.* 1961): This is a forestry carried out in the whole Sanbu district, Chiba Prefecture, and a cultivar of Sugi which grows well even in the arid site condition of comparatively poor soil. *Sanbusugi*, as one of the cultivars, is the tree of clone-complex, having a great resistance to drought and

low requirement for soil condition. Moreover rooting ability after cuttings is good. The wood is used for furnitures, ship materials, etc.

3) Hita forestry (Satō *et al.* 1955, 1966): This is a private forestry producing the wood of medium and small diameter in the surrounding area of Hita city, Ōita Prefecture. Hita forestry is one of typical reforestation of Sugi by cuttings in Japan, and the short-rotation system (about 30-35 years) has been usually used for a long time adopting relatively wide planting distance (2,000-2,500 trees/ha) with cultivars specially selected. This wood is used for building materials and furnitures. *Yabukuguri*, one of the cultivars has been most widely reforested in this area, as the cultivar grows rapidly by comparison. There are also such cultivars in rapid growth as *Urasebaru*, *Hinode* and *Motoe*, and another cultivars such as *Ayasugi*, *Honsugi* are there having fine quality but growing slowly.

4) Yame forestry (Satō *et al.* 1958, Higuchi, 1967): Cultivated forest district of Sugi in Yame district, Fukuoka Prefecture. The wood in this district is used mainly for the purpose of medium and small diameter logs, for instance, not to speak of building materials, telephone poles and the like. The history of Sugi reforestation by cuttings in this district is relatively young (started about 100 years ago), the cultivars are mostly introduced one from Hita district contiguous to this district, and cultivars newly raised up selecting from good individual trees which grow rapidly in the stand by seedlings, the latter cultivars have started to rear about 50-60 years ago. Among them *Yaichi*, *Yamaguchi*, *Kiura*, *Koga*, *Nakama*, *Nagaeda* and *Shichizō* are excellent cultivars in growth, and such cultivars comparatively excellent in adaptability to the soil condition.

5) Obi forestry (Ishizaki, 1965, Toyama, 1950): The particular forestry with the purpose of producing the wood for the ship building materials in Nichinan city and its surroundings, Miyazaki Prefecture in the south end of Kyushu. Its origin dates back to about 300 years ago. For the reason that this district is frequently visited by typhoon, very wide planting distance (1,000-2,000 trees/ha) is taken up, and comparatively long rotation system (about 60 years) has become traditional work with the aim of counterplan for the damage from typhoon and the aim of production of special wood for ship building materials. Characteristics of the wood for ship building should be light, having not so many encased knots, rich in toughness and durability, little hygrosopics and being in rapid growth. Its typical cultivar is *Obiaka* which occupies a large reforestation area. Concerning this cultivar its heart wood is reddish and its character is apt to make false annual ring that adds toughness. Besides cultivars mentioned above there are *Arakawa*, *Mizorogi* and *Tanoaka* as the cultivars in rapid growth.

6) Other districts forestries (Satō, 1950, Satō *et al.* 1965): Since Kyushu is geographically situated in the south-west warm region in Japan and it is warm and pluvial region, the growth of Sugi is generally superior and propagation by

cuttings (especially direct planting by cuttings) has been put into practice from old ages. Both of *Aosugi* (*Higo-measa*) in Kumamoto Prefecture and *Measa* (*Satsuma-measa*) in Kagoshima Prefecture have been grown up by cuttings for several hundreds years, and it is presumed that they must be clone-complex selected from natural Sugi forest stand in some districts in Kyushu. These cultivars are widely distributed in the area of volcanic ashes soil, having a great resistance to drought and good rooting ability of the cuttings, though their growth is slow, they are well known for reddish heart wood and fine quality. And *Kumotōshi* in Kumamoto Prefecture, *Kijin* in Kagoshima Prefecture and *Iwao* in Saga Prefecture are famous for rapid growth. Especially *Kumotōshi* is pure clone propagated by cuttings selected particularly on excellent individual in growth from a reforestation by seedlings, this work was done by a forester about fifty years ago.

On the other hand, the Sugi in snowy districts in winter along the Japan sea has been afforested by layering in natural Sugi forest stand. In spite of the fact that these are clone-complex, they have been naturally selected for a long time in the influence of snow accumulation in winter, therefore they have common character of strong to much snow and for cold. At present, these varieties have been propagated by cuttings, as the native cultivars, *Kumasugi* in Nagano Prefecture, *Ryowasugi* in Toyama Prefecture, *Itoshirosugi* in Fukui Prefecture, *Okinoyamasugi* in Tottori Prefecture and *Ichikisugi* in Shimane Prefecture are well known (Satō, 1957).

### Intensive Culture of Cryptomeria

Local varieties of Sugi in our country are divided into two main types, the native cultivar and the improved one. The former is furthermore classified into two types, the one that have been regenerated by layering or seeding in the natural stands as *Urasugi* type, and the other that has been cultivated for a long time by cuttings through repeated selection under the suitable condition of environment for each tree in the districts where the intensive culture have been carried out including Kyushu region. The improved cultivars, comparatively new varieties (started about 50-60 years ago), which have been propagated by cuttings selecting excellent individual trees chiefly good in growth and tree form from the private forests originated by seedlings in various districts.

The native cultivars of Sugi in Kyushu region are *Honsugi*, *Ayasugi* and *Akaba* in the northern part of Kyushu, *Yabukuguri* and *Aosugi* in the central part and *Measa* and *Obiaka* in the southern part of Kyushu. Although their growth is generally slow in the early stage of the reforestation, they are characterized to keep constant growth until final age. As they have comparatively high character in equality for the density of annual ring, their wood quality is excellent in general.

On the other hand, most of the improved cultivars are excellent in growth from

the early stage of the plantation, take some of them, for instance. They are *Yaichi*, *Yamaguchi*, *Kiura*, and *Nagaeda* in Yame district, *Urusebaru*, *Hinode* and *Motoe* in Hita district, *Iwao* in Saga Prefecture, *Kumotōshi* in Kumamoto Pref., *Arakawa* and *Tanoaka* in Miyazaki Pref. and *Kijin* and *Haraigawa* in Kagoshima Pref. The cultivars described above have a great mean annual growth in the most suitable site for them respectively. For instance, they are *Yaichi*, *Nagaeda*, *Urusebaru* and *Hinode*, and their mean annual growth per hectare are 26.5m<sup>3</sup>, 22.0 m<sup>3</sup>, 28.8 m<sup>3</sup> and 29.0 m<sup>3</sup> respectively. The mean annual growth per hectare of the improved cultivars is indeed 1.5-2.0 times of the native cultivars (10-18 m<sup>3</sup>, average 14.4 m<sup>3</sup>). As through clone-test has not yet been done on these improved cultivars, the foresters try to carry out the plantation of mixed several cultivars or mono clone at very small area (usually within 1 ha) under the consideration of security for the surrounding condition or the damages from diseases or insects.

Especially, as for the counterplan for the damages, such cultivars which have the resistance to the attack by *Contarinia inouyei* outbreaken in the south of Kyushu as *Haraigawa*, *Obiaka* and *Kawashimasugi* were selected. And they can easily escape from the damage of *Cercospora cryptomeriae* that is apt to outbreak on seedlings or young trees of Sugi grown by cuttings. This fact will not be inherent tendency, but will be reasoned that it may be made by the influence of aging through repetition of cuttings.

Although, in recent years, Forestry Agency recommended, concerning the forest tree improvement, the propagation by cuttings selecting elite trees from forest stand reforested by seedlings of Sugi in various districts and these clones have not received progeny test, it should be considered to plant seedlings by crossing among clones or plantation of mixed clones.

In the last place, the author would like to give the following suggestions which should be paid much attention to for approaching to the intensive culture and tree improvement of Sugi by cuttings.

- 1) It is necessary for the cultivars to expand their suitable sites gradually together with progeny (clone) test in the comparing plantation with several cultivars before the introduction of the old native or the improved cultivars into another districts.

- 2) For the damages from typhoon or snow which are liable to be outbreaken to the plantation of mono clone. The managements of forest stands, such as arrangement of planting, planting distance, pruning and thinning should be carried out under careful consideration.

- 3) The counterplan for the utilization of wood should be considered for the deterioration of the quality (juvenile wood) caused by employment of short rotation system (under 30 years) with plantation of the improved cultivars that grows

rapidly.

4) As the counterplan for the prevention of productivity of soil decreasing caused by the repetition of short rotation system, the forest fertilization and the other managements concerning the forestry should be considered.

5) The problem of aging is necessary to be considered, because it is presumed that the decrease of viability (decrease of flower formation and growth rate) will be caused by the repetition of the propagation by cuttings in mono clone.

6) The establishment of gene bank should be considered for the danger of disappearance of many genes caused by raising up clones.

7) It is necessary for breeding the variety with resistance to unknown damages from diseases and insects to consider the application of hybrid vigor by crossing.

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## スギの集約栽培と育種の扱いについて

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要旨：スギの地方品種は大別して在来品種と育成品種の二つにすることができる。前者はさらに、ウラスギ型にみられるような天然林において、伏条や天然下種更新がくりかえされた結果、自然淘汰によって成立したものと、集約的栽培が営まれている地域で、古くから自然的人為淘汰が行なわれた結果として成立したものとに分けられる。育成品種は比較的新しい品種で一般には実生の林分（天然林、人工林を問わず）から形質や生長において、すぐれた個体が人為的に選択され、さらにさし木などによる遺伝子固定がなされて増殖されたものである。

古くからの在来品種は、概して初期の生長は遅いが、後年に至るまでよくその生長を継続する傾向があり、材質も比較的すぐれたものが多い。育成品種は、造林初期から生長の速いものが多く、しかも林地施肥の効果が大きく、特に、幼令期の肥培は林分の閉鎖を早めることができる。一般にさし木による育成品種は、生長量の増大、樹形や材質の改良をはかるうえに大きな効果が期待されるが、単一クローンの植栽は、適地の範囲をせばめ、風雪害や病虫害の異常発生を招きやすい。しかも、初期生長の速い品種の植栽は、短伐期作業への傾向を強める一因ともなり、したがって地力の減退を招来する恐れがある。他方では、同一クローンのさし木の繰りかえしは、Agingによる生育能力の低下が予想された、クローンの育成は他の多くの遺伝子を消滅させる原因ともなりかねない。

したがって、集約栽培をすすめるにあたっては、このような種々の欠点を常に考慮におく必要がある。さらに一方では、遺伝子保存林の設定や、雑種強勢の利用などによる新品種創成への努力が払われなければならない。