VEGETATIVE PROPAGATION IN RELATION TO JAPANESE FOREST TREE IMPROVEMENT

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ABSTRACT

In some regions of Japan, **Cryptomeria** and some other conifers have long been propagated by cuttings. This has resulted in the differentiation of cultivars in these localities, since vegetative propagation reduced genetic diversity and increased the number of ramets of certain genotypes when foresters recognised that some morphological traits indicated the superiority of the genotypes. The problem of "varieties" was the principal concern of Japanese silviculturists during the earlier half of this century.

The planning of tree improvement programmes was also influenced by the practice of vegetative propagation and the existence of cultivars. Selected plus-trees of **Cryptomeria japonica** were prescribed to be propagated by cuttings, and it was expected that the best clones of them would be designated as new cultivars after clonal tests. This objective has, however, been abandoned because uniformity of planting stocks, involving lack of genetic diversity, is not necessary or desirable in silviculture. Even when mixed clones are planted foresters will easily select their favourite clones out of the mixture.

Vegetative propagation by cuttings is a useful tool in the study of forest genetics, but it is not prudent for a tree improvement project to employ ramets of a limited number of plus-trees directly in commercial forestry.

INTRODUCTION

Cuttings and grafts are two of the most important means of vegetative propagation. Although their planned application to genetic improvement of forest trees in Japan started only after the end of World War II, the techniques have long been in use.

Planting of cuttings was, and is, the usual way of propagating *Cryptomeria* (*Cryptomeria japonica* D. Don) and other conifers in some regions (Fig. 1). As a result the genetic structure of the conifer populations has largely changed, and numerous cultivars have been differentiated in these regions.

Propagation by grafting was often used in ornamental plant cultivation, especially in "bonsai" work (dwarfed potted trees). Since some of these species were used on a forestry scale,, the techniques of propagating forest trees by grafting were already well developed when modern tree breeding work started.

The Japanese practice of grafting as a tool in tree improvement is not much different from that practised elsewhere and will not be described here. The long-term effects on

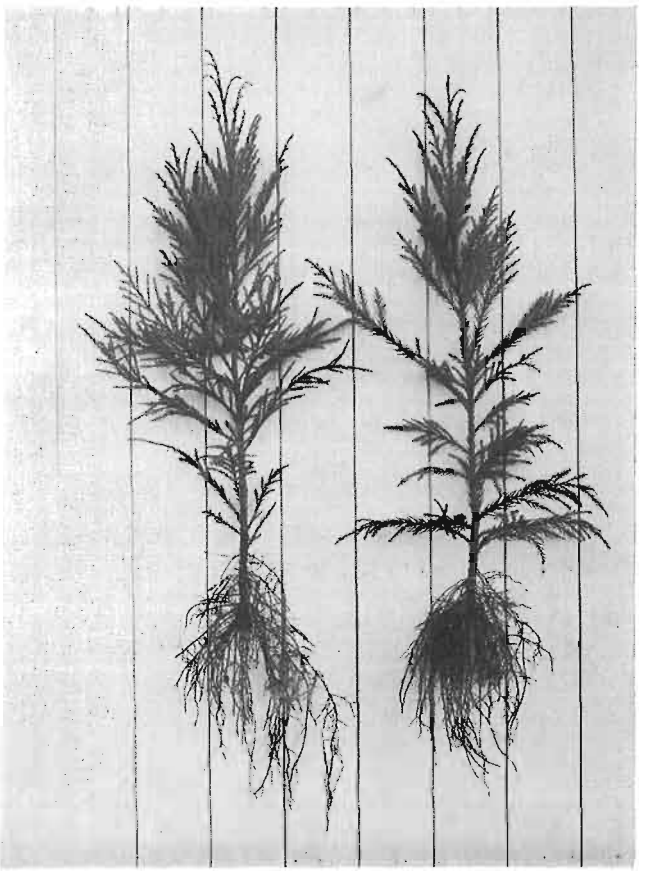

FIG. 1—**Cryptomeria** cuttings one year after planting. Right side: once root-pruned during the growing season. Left side: not pruned. (Photo by S. Huyuno.)

Japanese forestry of propagation by cuttings, and the influence of the history of this method on modern forest tree improvement, will be explained.

PRACTICE OF PLANTING CUTTINGS IN OLD JAPANESE FORESTRY

Although it has been known for more than a dozen centuries that *Cryptomeria* and other conifers can easily be propagated by cuttings, forest plantations were not established by this method until the beginning of the 15th century. The earliest record is for the Kitayama Forest, near Kyoto city, where *Cryptomeria* cuttings have been planted continuously since around 1400.

During the first half of the 17th century, *Cryptomeria* plantation establishment became popular in various parts of Japan, and most of these were established by planting cuttings. Localities shown in Fig. 2 are famous even now. The Noto province is known for its *Thujopsis* (*Thujopsis dolabrata* Sieb. et Zucc. var. *hondai* Makino) forests of

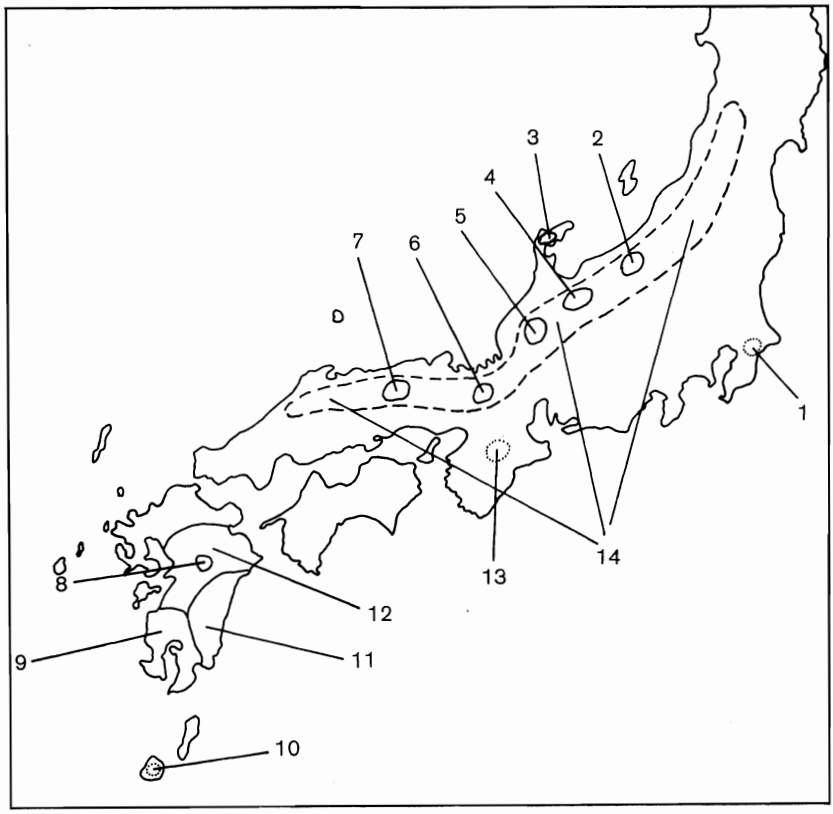

FIG. 2—Localities where **Cryptomeria** and other conifers are usually propagated by cuttings.
1, Sanbu district, Tiba prefecture; 2, northern Nagano prefecture; 3, **Thujopsis** forest area in the province of Noto, now included in the Isikawa prefecture; 4, a district in the Toyama prefecture where **Cryptomeria** is propagated by cuttings; 5, the same in the Hukui prefecture; 6, the Kitayama forest area at Kyoto; 7, Tizu forest area, Tottori prefecture; 8, a small area in the Aso district, Kumamoto prefecture where hinoki cypress is propagated by cuttings; 9, Kagosima prefecture, including provinces of Satuma and Oosumi; 10, natural **Cryptomeria** forest area of the island of Yakusima; 12, central Kyusu region, including Kumamoto, Ooita and Hukuoka prefectures, entirely or partially; 13, Yosino forest area, Nara prefecture, where seedlings are used; 14, areas distributed along the spinal mountain chain where **Cryptomeria** easily develop layers.

cuttings. Hinoki cypress (*Chamaecyparis obtusa* Sieb. et Zucc.) plantations of cuttings are found in the Aso district of Kumamoto prefecture.

There are several methods of using *Cryptomeria* cuttings for forestry practice. The most primitive was in the Tizu district of the Tottori prefecture, where foresters collected cuttings from natural layers of indigenous *Cryptomeria* trees growing in mixture

with broadleaved trees. This practice, which is more than 300 years old, ceased only recently because of the shortage of layers. It is easily understood that no cultivar has been differentiated in this district because numerous genotypes have always been introduced into plantations from natural forests, and the number of ramets of specific clones did not increase very much.

At Kitayama, forestry practice also originated with a natural *Cryptomeria* population of the layering type, but developed differently. Production of polished small logs of high quality became the main purpose, and a special management system, "daisugi", developed. In this method, basal branches of a stem are kept alive by heavy limb pruning and, after the felling of the stem, the stump is maintained and several new stems grow up from the retained basal branches. These procedures are repeated ,and selection felling is carried out on a single stump. This "daisugi" system, now almost abandoned, taught the old-time foresters that some trees were better than others for production of high quality logs. They propagated these favourable trees by cuttings, thus creating the Kitayama cultivars. These are still raised to some extent but, because most of them are slow in growth, have now largely been replaced by newly selected clones.

In Kyusyu, no natural *Cryptomeria* forests were known except in the southern island of Yakusima, which has giant *Cryptomeria* trees more than a thousand years old. *Cryptomeria* trees cultivated in Kyusyu seem to have been initiated from groves at religious places. These may be the relics of natural forests or may have been introduced from other parts of Japan. It is supposed that plantations were established at first by natural seedlings and layers from these groves but when these were exhausted people began to plant twigs without roots directly at the site. The warm and humid climate and the young age of the plants from which cuttings were collected favoured the development of this method of plantation establishment, although the area of such plantations was limited because the method needed fertile soil.

Thus propagation of *Cryptomeria* by cuttings became common in Kyusyu resulting in a reduction in the number of diverse genotypes and an increase in the number of ramets of particular genotypes. It is natural that any two traits controlled by different alleles can realise any possible combinations in a random-mating population but this independence of the traits is broken when the number of genotypes is reduced. When this actually happened in the vegetatively-propagated *Cryptomeria* people became aware that some morphological traits indicated favourable inherent qualities of a tree, such as better adaptability or greater rate of growth. This led to the selection of certain genotypes, which were then recognised as cultivars.

This process appears to have worked best in the province of Satuma, where establishment of plantations started earlier than in other regions. There, the selection of cultivars resulted in a single cultivar "measa" which was, and still is, planted elsewhere in the province, and secondarily later selections of new cultivars took place. However, although the trees of the cultivar "measa" at different localities in the province are very similar, they are not necessarily the same in their traits, thus indicating that their genetic natures are not identical. It is easily understood that such confusion is likely to occur in the course of the natural differentiation of cultivars as described.

Central Kyusyu region was in a less advanced stage of cultivar differentiation than Satuma. Numerous cultivars of more restricted distribution were differentiated at various localities, some synonymous and others homonymous. However, after recent studies

lasting for about half a century, selection of cultivars was largely simplified in this region also. At the same time, selection and trial planting of new cultivars, some of which seemed to be single clones, became very popular in some districts in this region. Fig. 3 shows a plantation established from one cultivar.

In the Hyuuga province, plantations established by direct planting of cuttings were larger than those in other parts of Kyusyu, and the reduction in genetic diversity of trees progressed slowly. It was only just before the end of feudalism in Japan that foresters in this province became aware of cultivars and started selecting more favourable ones. Thus, various cultivars were recognised as being mixed in each plantation, and it was only after World War II that pure stands of single cultivars became more popular.

Outside Kyusyu, there are several localities famous for their forestry practice of utilising cuttings. Among them, *Cryptomeria* forests in the Hukui and Toyama prefectures are thought to have their origin in the natural trees of their localities as at Tizu or Kyoto. However, in these two localities, scion collection from the natural forests ceased earlier and various cultivars were differentiated, as in Kyusyu. On the other hand, "kumasugi" at the northern part of the Nagano prefecture is thought to be a compound cultivar, recently domesticated from natural *Cryptomeria* trees of a layering nature in the locality.

In the Sanbu district of Tiba prefecture there is one important *Cryptomeria* cultivar, while in the Noto province there are several distinct cultivars of *Thujopsis,* all propagated by cuttings. Legends say that these cultivars have been initiated from a few seedlings or twigs brought from other localities. It is easily understood that vegetative propagation of a limited number of genotypes clearly demonstrates the genetic differences among clones.

FIG. 3—Young **Cryptomeria** plantations of a cultivar "ayasugi", in the Kumamoto prefecture. (Photo by S. Huyuno.)

With hinoki cypress, only one cultivar is known. This is in a small area of the Aso district, Kumamoto prefecture, where propagation of this species by cuttings has been practised for many years.

CRYPTOMERIA CULTIVARS AND PLANTING OF CUTTINGS UNTIL THE INITIATION OF THE TREE IMPROVEMENT PROJECT

Following the first contact with western forestry, Japanese foresters at the end of the last century were not greatly concerned with the problem of cultivars. However, interest revived about 1910, when propagation of *Cryptomeria* by cuttings started again as a countermeasure to the outbreak of *Cryptomeria* needle blight disease (*Cercospora sequoiae* Ellis et Everhart), which was fatal to young seedlings. The "re-discovery" of cultivars introduced some confusion into Japanese forestry because people could not explain how and why such cultivars had been first established. They were led into the erroneous idea that *Cryptomeria,* as well as all other forest tree species, consisted of separate "varieties" which had their own characteristics and could be identified by morphological traits. In addition, the two different concepts of "variety" and "heredity" were confused.

It was considered important to discover the supposed best "varieties" so that they could be propagated, possibly by seeds but better by cuttings, to maintain the superiority. Thus, intensive studies were made of planting cuttings of *Cryptomeria* and other tree species.

After World War II, the Genetics Section of the Japanese Government Forest Experiment Station analysed and criticised the erroneous concept concerning "variety", and developed a distinct system of tree improvement. In common with the Swedish system, it prescribed establishment of seed orchards by means of grafts of selected individual trees for the improvement of species not able to be propagated by cuttings. However, in the Japanese system, each seed orchard was planned to consist of two clones producing progeny as uniform as possible. In fact, this procedure was originally created as an alternative to the clonal selection practised in tree species propagated by cuttings, but found impossible in those trees difficult to root. Therefore, we at first conceived the establishment of new superior cultivars as a consequence of selecting superior trees, followed by clonal propagation by cuttings, mutual comparison between clones, and the final selection of the best clones. In other words, establishment of uniform cultivars by means of clonal selection was thought to be the ideal method of tree improvement. This belief, largely based on the examples in agricultural and horticultural crop plants, was surely encouraged by the existence of cultivars in the previously described localities.

The Japanese state government project on forest tree improvement started in 1954. The procedures, being influenced by the Swedish methods, were considerably changed from the first planned idea. The final situation to be aimed at was, however, not changed from the original Japanese system. Plus-trees of *Cryptomeria,* hinoki cypress, or *Thujopsis* were prescribed to be propagated by cuttings, and the ramets were to be planted in preliminary scion gardens where they were to be intensively pruned to maintain favourable size and shape for scion production. After the finish of clonal tests, superior clones were to be selected from among them, and the secondary scion gardens would then consist of single clones.

LATER CHANGES IN THE PRACTICE OF TREE IMPROVEMENT, AND PRESENT IDEAS ON EVALUATING PROPAGATION BY CUTTINGS

The policy of selecting clones as new cultivars was supported by foresters in general, and numerous *Cryptomeria* plus-trees, as well as those of other species, were selected by the efforts of field foresters. They were propagated by the officers in local organisations and were also accumulated at the newly-established regional forest tree breeding stations. These stations acted as coordinators among several local organisations in the regions, and propagated selected materials themselves.

Although it was planned to supply commercial forestry with a mixture of various clones during the tests, some foresters hastily demanded cultivars, considering the untested mixed clones as useless. Others were disappointed at the slow pace of cultivar selection. Thus the expectations of cultivars acted rather harmfully in view of the popular acceptance of the mixed clones of plus-trees.

On the other hand, the propagation of plus-trees was facing unexpected difficulty, namely in poor rooting of cuttings of the majority of selected clones. This difficulty was more serious in hinoki cypress than in *Cryptomeria,* and the procedure of scion gardens was soon abandoned in the cypress and switched to seed orchards. However, in *Cryptomeria,* the possibility of improving rooting ability was widely and persistently believed, and, as a consequence, many scion gardens of poorly rooting clones were left as a heavy load on the Japanese tree breeding project.

The disadvantages of establishing genetically uniform cultivars gradually became recognised. In plantations of such genetically uniform material, the risk of mishaps is very large. An example of a new clonal cultivar "kumotoosi" is quite instructive. The ortet of this clone was found in the Kumamoto prefecture around 1915, and it was propagated by a private forest owner who continued careful investigation on this clone until around 1950. Then, concluding that it was superior in growth and stem form, he started propagating it commercially. The clone was planted throughout western Japan and realised rapid growth and good stem form as expected. Unexpected faults were, however, also discovered. It was susceptible to stem canker (the chronic symptom of *Cercospora sequoiae* Ellis et Everhart) and foliage mites (*Paratetranychus hondoensis* Ehara). Such defects had not been found when the clone was planted on a small scale. Uniform stands of certain cultivars can only be allowed when those cultivars have been differentiated during long periods which enable all the risky clones to be eliminated by natural and artificial selection. Newly selected clones cannot be planted in a uniform plantation unless they have passed testing for at least two rotation periods with careful observation. Despite warning of these risks, the demands for "superior cultivars" are so large in Japan that there is pressure to designate some clones as cultivars after the observation of juvenile growth, and it is both easy and tempting for a forest owner to propagate single clones out of the mixed clones in his plantations.

Mixed planting of numerous plus-tree clones was favoured at first because it was theoretically expected that larger genetic gain could be obtained in comparison with the seed orchard seeds of the same clones. However, this expectation also became doubtful because a forest plantation has to undergo repeated thinnings during a rotation period and only a minor part of the initial stocks will be harvested finally. Considering that thinnings are also a practice of selection, the final harvest of the seedling offspring may

exceed that of the mixed parent clones, because the former population includes many individuals whose genetic nature is better than any of the parent clones.

This consideration, together with the poor rooting performance of cuttings, was reflected in government policy. Establishment of seed orchards was supplementarily planned in *Cryptomeria* and the conversion from scion gardens into seed orchards was encouraged.

The primary series of the tree improvement efforts by means of plus-tree selection ended in Japan around 1970, when about 800 ha of *Cryptomeria* scion gardens and 400 ha of seed orchards of the same species had been established. More scion gardens will eventually be converted into seed orchards.

Nevertheless, cuttings are still useful for the examination and evaluation of individual genotypes of plus-trees, and extensive clonal test plantations are now being established. From these plantations, and from the ramets of the clones, we can obtain useful information on growth habit, stem form, or responses to various injurious factors. Thus, we can conclude that propagation by cuttings is a very useful tool for forest genetics studies, but it is not a prudent tree breeding method to utilise cuttings of newly-selected clones directly in commercial forestry.