THE USE OF CUTTINGS IN THE BREEDING AND AFFORESTATION OF PINUS RADIATA
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SYNOPSIS

Commercial afforestation by rooted cuttings of superior trees of Pinus radiata offers a rapid method of plantation improvement in tree quality. Biological hazards to clonal plantations are considered unlikely to be greater than to seedling plantations. Establishment of clonal plantations is technically and economically feasible as rooted cuttings can be mass-produced cheaply from trees up to 15 years of age. Cuttings from older trees can be rooted after pre-severance treatment similar to girdling in air-layering. A time-table is proposed for performance testing of clones in an 11-year programme.

INTRODUCTION

The aim of tree improvement in Pinus radiata in New Zealand is to provide planting stock which will produce forests superior in growth rate, timber quality and other attributes to those of the present day. In addition to improvement in quantity and quality, it is very desirable to obtain uniformity in quality both within and between trees.

The breeding programme outlined by Thulin (1957) is designed to provide improved seed through selection of superior trees and their propagation by grafting in clonal seed orchards, where special management techniques are used for maximum seed production. Progeny, from open or controlled pollinations, are grown to enable further selection among the original parents of those that produce the most superior offspring. The removal of unsatisfactory parents from the orchards, the inclusion of only the best progeny-tested clones in subsequent replacement orchards, and further cycles of selection in plantations raised from orchard seed will ensure a steadily increasing improvement in radiata pine. The rate of improvement, apart from intensity of selection, will mainly be determined by the extent to which different superior characteristics of the select trees are passed to and expressed in their offspring. In sexual propagation by seed, the reshuffling of genetic constituents of select parent trees establishes numerous new gene combinations. Plantations raised from orchard seed will therefore still display considerable variation among trees.

As opposed to sexual propagation, vegetative propagation makes it possible to repeat again and again the exact genetic constitution of a superior tree. Cuttings usually closely resemble the “parent” trees and members of a clone exhibit far less variability than do seedlings.

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Vegetative propagation is used in many horticultural and agricultural crops to perpetuate specially valuable individual variants—e.g., in strawberries, potatoes, fruit trees. Rooted cuttings are used successfully in poplar culture in many parts of the world and Japanese foresters have for centuries used rooted cuttings to establish clonal plantations of Cryptomeria japonica and Chamaecyparis obtusa. The importance of rooted cuttings to forest tree improvement has been stressed for many years by Schreiner (e.g., 1939, 1966) and the use of rooted cuttings of Pinus radiata for direct afforestation has been advocated by Jacobs (1939) and Fielding (1964).

It has been generally recognized that cuttings of radiata pine from trees up to seven years of age can be rooted relatively easily, but that rooting ability decreases rapidly with age of ortet* (Field, 1934; Jacobs, 1939; Sherry, 1942; Pawsey, 1950; Allsop, 1950; Fielding, 1954, 1964; Libby and Conkle, 1966). Older trees can be propagated readily by grafting but this is too costly for commercial forest planting and the danger of rootstock influence on the scion is ever present. For the practical use of cuttings in tree improvement and afforestation, it is essential that economic methods be developed for rooting cuttings on a large scale from trees old enough to be evaluated with confidence.

ROOTING CUTTINGS OF PINUS RADIATA AT ROTORUA

Experimentation on rooting cuttings of radiata pine has been almost continuous at Rotorua over the past two decades (Anon., 1955, 1961) and investigations have been greatly intensified over the past three or four years. Results of recent trials are presented and discussed below.

Cuttings from trees aged 7, 9, 12, 15 and 20 years were set in April-May 1966 in open nursery beds of free-draining pumice soil and in polythene tubes of 2.5 in. diameter, filled with a mixture of soil and pine duff. In the nursery beds the cuttings were set 2 in. deep and 4 in. apart with 7 in. between rows. The tubes were placed on concrete slabs in rows 6 in. apart. No hormone treatments were applied to cuttings in the trials. Experience from former years' trials had proved that the best cuttings for rooting were those from branches grown in full sunlight, with dark green, healthy foliage, 5 to 7 in. long and with a base diameter of approximately 1/2 in. Where possible, this type of material was used but some poorer and thinner cuttings were included in the 7-year age group owing to the limited amount of optimum material produced on trees of that age. Approximately 600 cuttings from 15 trees were collected for each ortet age group. Half the cuttings were set with terminal buds intact and the buds were removed from the other half. Mist spray, sufficient to keep the foliage moist, was applied during the fortnight after setting. The cuttings in nursery beds were given a series of wrenchings consisting of vertical cuts between rows in January and March 1967 and an undercut at 5 in. depth with a sharp tractor-mounted V-shaped blade in February, followed by a fortnightly loosening of the soil with a straight blade during March and April.

*Ortet: Original tree from which the cuttings were taken.
The cuttings were lifted in May 1967 and those that had rooted were graded visually into two groups — those that were considered plantable and those that were not. Cuttings which were considered plantable had relatively large numbers of roots from the callus, compact, fibrous root systems and could generally be expected to survive and thrive if planted in the field. The percentages of rooted and plantable cuttings are illustrated in Figs. 1 and 2. Each point on the graphs represents a percentage from the setting of approximately 150 cuttings from 15 ortets.

Rooting percentages were, for all ages of ortets, higher for cuttings with terminal buds grown in nursery beds, than for other treatments. (The lower rooting from 7-year-old trees compared with the 9-year-old is probably due to the poorer material that was available from the former.) The decrease in rooting percentage with age of ortet is also less for the cuttings with terminal buds grown in nursery beds than for other treatments. On the former treatment, rooting of 70% or better was obtained in all clones from 7, 9 and 12 year ortets; in 14 out of 15 from the 15-year-old; and in only 8 out of 15 from 20-year-old trees.

The percentage of plantable stock from the wrenched cuttings with terminal buds grown in open nursery beds was much higher than from other treatments. The root systems produced were in no way inferior to well pre-conditioned seedlings (Fig. 3).
The effect of wrenching on cuttings of 17 clones from 7-year-old trees set in nursery beds was tested in a separate trial (see Table 1). The data from the trial are comparable with the results of routine setting and wrenching of more than 6,000 cuttings from 250 7-year-old trees: 91% were plantable from cuttings with a terminal bud and 33% from cuttings without a terminal bud. The wrenching did not affect height growth but it produced fibrous, well balanced root systems (Fig. 4), not only by inducing more lateral roots to form but also by producing more roots from the base of the vegetative shoot. This finding conflicts with the one by Libby and Conkle (1966) that in radiata pine the period of root initiation by a given cutting is relatively short and that the number of roots initiated can be determined shortly after it roots, with little error introduced by later root initiation.

Previous years’ experiments where no wrenching was done showed that as age of the ortet increased the number of roots per cutting decreased, an observation that is confirmed by other workers (Fielding, 1954; Libby and Conkle, 1966). No quantitative assessment was made of the wrenched cuttings from trees older than 7 years but there was no obvious deterioration in quality of root systems with increasing age of ortets, and clonal differences were small.

Radiata pine cuttings from ortets aged more than 20 years are generally recognized as being very difficult to root. A poor strike has generally been obtained at Rotorua from cuttings of older trees (Anon., 1955) although good strikes have been obtained occasionally from cuttings of 33 to 35-year-old ortets, in propagation.
Fig. 5: (A) Rooted cutting from a 7-year-old tree, 12 months after setting. (B) Well-conditioned seedling 18 months after sowing.

TABLE 1: EFFECT OF WRENCHING ON CUTTINGS OF 17 CLONES OF 7-YEAR-OLD TREES

<table>
<thead>
<tr>
<th>Type of Cutting</th>
<th>No. of Cuttings Set</th>
<th>Treatment</th>
<th>% Rooted</th>
<th>% Plantable</th>
<th>Ave. No. of Roots from Callus</th>
</tr>
</thead>
<tbody>
<tr>
<td>with bud</td>
<td>144</td>
<td>wrenched</td>
<td>100</td>
<td>98</td>
<td>&gt; 16</td>
</tr>
<tr>
<td>with bud</td>
<td>136</td>
<td>not wrenched</td>
<td>100</td>
<td>58</td>
<td>7.8</td>
</tr>
<tr>
<td>without bud</td>
<td>111</td>
<td>wrenched</td>
<td>92</td>
<td>53</td>
<td>7.3</td>
</tr>
<tr>
<td>without bud</td>
<td>119</td>
<td>not wrenched</td>
<td>96</td>
<td>10</td>
<td>4.1</td>
</tr>
</tbody>
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pits with bottom-heating (Anon., 1961). Experiments with air-layering during 1960-64 gave more promising results. Excellent callus was formed on the girdled shoots but the roots that developed were small in number and very thin and tender; most of the air-layers failed to survive when they were removed from the ortets and planted in the nursery. The observed good callus formation on air-layers led to development of a modified form of air-layering. Vigorous shoots were ringbarked about 6 in. below their terminal bud and a ½ in. wide section of the bark, phloem and cambium was removed similar to girdling in air-layering. The girdled area was covered with aluminium foil as protection against drying. Well developed callus formed at the base of the girdled shoots in 4 to 6 weeks, after which the shoots were cut from the trees and set as cuttings in tubes.

Fig. 4: Cuttings of one clone from a 7-year-old ortet, rooted in open nursery bed. Set in May 1966, lifted May 1967. (A) Unwrenched (B) Wrenched (root-pruned) from February 1967 onwards, classed as "plantable".
In preliminary trials, girdling was applied monthly from January to April as well as from September to November 1966 to shoots on grafted clones of nine 30- to 40-year-old trees. Close to 1,000 calloused cuttings were made. An average of 63% of the cuttings rooted rapidly and good root systems were produced. Differences in rooting with month of girdling were small. Clonal differences were evident in the length of time that callus took to form and also in rooting ability, though rooting was produced in all clones. Cuttings with terminal buds removed at time of girdling rooted generally better than cuttings with terminal buds intact. This applied particularly to cuttings girdled in the spring.

Non-girdled cuttings from the grafts of the older trees were not set as controls in the preliminary trials, but such cuttings have failed to root under similar conditions in previous years. Cuttings girdled on 40-year-old trees in the forest are included in trials now in progress; it is already apparent that these cuttings root at least as readily as girdled cuttings from grafts.

The methods described for rooting radiata pine cuttings have so far been tried at Rotorua only and until tested on a wider range of sites the results are applicable only to similar climates and soils. The data on rooting cuttings from trees up to 15 years of age confirm the results obtained in previous years' trials and are supported by interim results from other trials in progress. Improved rooting and root systems will no doubt be obtained from cuttings from older trees as the pre-severance treatment is refined, particularly by the selection of optimum cutting material and by the setting of the callused cuttings in open nursery beds. With the methods already developed, it is technically feasible to mass-produce cuttings, and the cost of production would be reasonable. From larger scale trials it has been calculated that plantable rooted cuttings from trees up to 15 years old can be produced in commercial quantities at a cost of $20 per 1,000 ex nursery, provided cutting material is reasonably handy for collection; the estimate allows for a collection expense of $5 per 1,000 cuttings. The production cost of $20 per 1,000 rooted cuttings compares with $7 per 1,000 seedlings. Pre-severance girdling of cuttings would be expensive if applied on mature trees in the forests, but would probably cost less than $10 per 1,000 cuttings if done on already established clones in seed orchards or clonal banks.

ADVANTAGES AND DISADVANTAGES IN THE USE OF ROOTED CUTTINGS

Use of rooted cuttings from superior trees for afforestation will enable the desirable qualities of these trees to be precisely mass-produced, provided that the qualities are under genetic control. There is good evidence from Australia (Fielding, 1953; Fielding and Brown, 1960; Dadswell et al., 1961; Nicholls, 1967) that the degree of genetic control of most commercially important characteristics of cuttings of radiata pine is high; for some morphological characteristics in the order of 60 to 80%.

A further cause of improvement in the morphological characteristics of cuttings is that they maintain the stage of development of the parent trees, e.g., cuttings from a tree older than 10 years will show, at ground level and above, the mature branching charac-
Fig. 5: Clones from rooted cuttings planted 1951 at Hall's Block, A.C.T., Australia. The row on the left is a clone raised by cuttings from a 16-year-old seedling tree. The first three trees in the row on the right were raised from 5-year-old clonal material originally raised from a 6-year-old seedling tree. Note the differences between clones and uniformity within clones; note also the adult characteristics in stem form, branching and bark thickness as well as the absence of basal swelling (Photo: J. M. Fielding).
teristics of the upper stem of parent tree, vide Fig. 5 and Fielding (1967). Hence, many serious defects associated with what Jacobs (1937) termed the juvenile and adolescent stages of growth during the first 8 to 10 years in radiata pine are avoided. These stages of growth are marked by strong “basket whorls” with thin leaders and other branch and stem abnormalities. Cuttings, even from unselected trees more than 8 to 10 years old, tend to be straighter than seedling trees, to have lighter and more horizontal branching, and to develop less forking; but they also have the disadvantage of stem cones produced low on the stem (Fig. 5).

The controlled replication of desirable features of select parent trees and the avoidance of the young growth phases offer silviculture and forest management considerable benefits:

(1) Uniformity of characteristics of trees within a plantation can be achieved, and it would be possible to create plantations for specific end uses.

(2) All cuttings of tested clones will be potential final crop trees from a quality aspect. The need for high planting densities currently used for radiata pine, to provide sufficient well formed final crop trees, will be largely eliminated. Pre-commercial thinnings can be avoided and later thinnings will provide high quality logs.

(3) Clones for “difficult” sites — e.g., cold or nutritionally deficient — can be produced by selecting and testing well-adapted and well-formed trees growing on such sites.

(4) Trees which prove to be resistant to a particular disease can be rapidly multiplied to provide disease-resistant planting stock.

(5) Plantations of rooted cuttings from progeny tested, superior trees would provide a source of seed equivalent in quality to that from seed orchards. Seed could be collected cheaply from thinnings and clearfellings.

(6) A clonal improvement programme will give more rapid and greater improvement in adaptability, quality and growth rate than at least the first cycle of a tree breeding programme aimed at production of superior seed in seed orchards and it is likely to be considerably cheaper.

The possible problems of using cuttings for afforestation are those of cost, the possible effect of parent tree age on growth rate of cuttings, and the risk of diminished genetic variation in plantations.

The cost of producing plantable rooted cuttings is about three times that of seedling stock. However, the difference in cost of planting clonal and seedling plantations will be small considering that the former will require fewer trees planted per acre to ensure an economical first thinning and a quality final crop. Elimination of pre-commercial thinning may well make clonal plantations cheaper to establish.

Some warning has been given that the growth rate of vegetative propagules is slower than that of seedlings and decreases with
increasing age of parent tree. Fielding (1964) suggests that cuttings of radiata pine may not grow as rapidly as seedlings, but he adds that, if such a difference in growth rate exists, it is a small one and limited to the first few years. Since cuttings from trees over five years old produce poor root systems if they are not wrenched, they would be subject to greater planting shock than well-rooted seedlings and consequently have a slower growth rate in the first few years after planting, as Fielding describes. Sweet (1964) reported that grafts made with scion material from 10-year-old trees were significantly bigger one year after propagation than those made with scion material from grafts of 30-year-old trees. However, indications were that the differences in heights were no longer significant four years after grafting (Sweet, pers. comm.). There is obviously an urgent need for both short- and long-term detailed studies of the effect of the age of parent tree on the growth of cuttings.

The uniformity of clonal plantations which is a technological advantage (Anon., 1966) may be regarded as a biological hazard, involving greater risks to attacks by "new" insects and diseases than plantations of seedlings, which are more heterogeneous genetically. The possible biological risks of clonal plantations could be reduced by using mixtures of clones as suggested by Fielding (1964). Clones of trees resistant to a particular insect or disease could be propagated rapidly; in fact, such action might provide a solution to the Dothistroma pini problem in New Zealand.

PROPOSED USE OF ROOTED CUTTINGS IN P. RADIATA AFFORESTATION IN NEW ZEALAND

Propagation from seed will probably remain the major method of raising radiata pine plantations, and large quantities of seed will be required for aerial sowing. Any programme of plantation improvement by clonal planting should, therefore, be considered as supplementary, not alternative, to breeding programmes aimed at improvement in the genetic quality of seed. However, the advantages of clonal plantations of radiata pine from cuttings are so attractive that they justify concentrated efforts to further improve techniques of rooting cuttings, to test these techniques in all parts of the country, and to gain experience in clonal selection and testing. Urgent investigation should also be made into the possible effect of parent tree age on growth rate of cuttings.

The following time-table is suggested for selection, propagation and clonal testing:

Year 0: Selection in 10- to 15-year-old seedling plantations of up to 500 superior trees at intensities of about 1 tree for 3 to 5 acres. Setting of 60 or more cuttings of each tree.

Year 1: Rooted cuttings of the 500 clones planted in tests on several sites. Surplus cuttings of all clones planted in a clonal archive for production of new cuttings in year 5, and in experimental plantations.

Year 3 onwards: Continue bulk propagation of untested clones for planting in experimental plantations.

Year 5: Preliminary selection among clones in the clonal tests. Set 200 or more cuttings from each of the best, say, 200 clones.
Year 6: Rooted cuttings of the 200 better clones planted in a clonal archive as source of material for propagation in year 10.

Year 10: Assessment of clonal tests (9 years old). Select, say, the best 50 clones ("tested" clones). Set 3,000 or more cuttings of each of these clones; material collected from cuttings planted year 6.

Year 11 onwards: Multiplication of tested clones. An annual production of 30,000 to 40,000 cuttings per clone would be possible by year 15.

The suggested re-setting of cuttings in year 5 recognizes the finding by Fielding (1964) that cuttings taken from recently propagated clones are, in general, easier to raise than cuttings taken from the older parent trees of the clone. The re-setting also provides sufficient cutting material for mass propagation in year 10.

The proposed time-table is tentative only. It is in fact the one proposed for a regional programme already commenced, which will also include testing of open pollinated progenies of the selected trees. As experience is gained in accurately selecting superior trees and in assessing young clones, it may be possible in future programmes to reduce the number of years taken for testing. Similarly, the reduction from the originally selected clones to 10% tested clones is speculative, and such drastic reduction may not be necessary in programmes directed purely towards clonal afforestation.

With the above time-table it would take about 15 years to provide large quantities of cuttings of tested clones — i.e., clones proven by tests as superior in specified environments and/or for special end products. However, it is suggested that commercial clonal plantations be planted in the interim from a mixture of clones, on sites similar to those of the parent trees. Mixtures of many clones will reduce considerably the risk involved in using untested clones and the restriction on sites will minimize the chance of possible clone/site interaction. Through early establishment of commercial clonal plantations, experience can be gained in mass production techniques of propagation of cuttings and in silviculture and management of this type of plantation.

The amount of improvement in afforestation that is possible by the use of clones from selected and tested trees will be limited to the standard of quality of the best trees that can be located in present plantations. Improvement above this level is possible only by seedling-based selection and breeding programmes. The introduction of material from the natural range of radiata pine and inter-specific, inter- and intra-racial hybridization are further avenues for improving the material from which superior clones can be selected. The use of rooted cuttings makes it possible to utilize superior individuals produced at any stage of a breeding programme. It is therefore not only a special means of plantation improvement but also an extremely valuable adjunct to tree breeding.

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