A Review

of the

Plus Tree Selection Programme

for Douglas-fir

in Coastal British Columbia

by J.C. Heaman
A REVIEW OF THE PLUS TREE SELECTION PROGRAMME
FOR DOUGLAS-FIR (PSEUDOTSUGA MENZIESII (MIRB.) FRANCO.)
IN COASTAL BRITISH COLUMBIA

by

J. C. HEAMAN
A Selected Plus Tree--Mesachie 66
ABSTRACT

The aims and progress of the plus tree selection programme in Douglas-fir, initiated by the British Columbia Forest Service in 1956, are described. Although the scope of the programme was at first small, the start of cooperative participation by the forest industry in 1959 and an expansion of the B.C. Forest Service commitment in 1960, led to the establishment of a comprehensive programme. The methods of selection used in the field are described. Discussion of the selection criteria follows. A descriptive summary is given of the work carried out by the Research Division between 1957 and 1965, and the role of the B.C. Forest Service in the cooperative phases is outlined briefly. The present status of the programme is reviewed.
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INTRODUCTION

The first moves by the British Columbia Forest Service towards the establishment of a selection programme for the improvement of coastal Douglas-fir were made in 1956 and since that time a very considerable amount of time and money has been devoted to this work. Although the B. C. Forest Service has played the leading part in the programme, a co-operative effort developed when the scope of the task was realized, and the forest industry has also invested heavily in the project. The primary aims of the programme have now been realized; sufficient material is available for the first stages of seed orchard development and although widely scattered, some selections of coastal Douglas-fir have been made from throughout the range of the species in British Columbia. Soon material from all the selected trees will be preserved by vegetative propagation in the B. C. Forest Service clone bank at Cowichan Lake and in the industry banks, and increasing emphasis will be put upon the production of improved seed and evaluation of the selected material. Therefore it was felt that a summary of the programme to date would be worthwhile.

THE AIMS OF THE PROGRAMME

In the broadest terms, the objective of the tree improvement programme is the production of a regular quantity of Douglas-fir seed of suitable provenance and of a genetic quality which will, through selection and breeding, be superior to that collected from natural stands. To attain this objective, three steps are required:

Firstly, a population of plus trees must be built up through field selection.

Secondly, the genetic material must be preserved through propagation of these individuals.

Thirdly, seed orchards must be established for production and the selections must be evaluated through progeny testing.

This report outlines the progress of the first step.
THE EARLY DEVELOPMENT OF THE PROGRAMME

In considering the present plus tree selection programme, it is worth recording the events which led to the interest in tree improvement in the province and to the initiation of this work.

The programme as a whole owes its origin largely to Dr. A. L. Orr-Ewing's report on a visit to the Institute of Forest Genetics at Placerville, California, in 1952 (3). Work being carried out in pine species was described and suggestions made as to how a breeding programme might be started in British Columbia. In 1954 a comprehensive assessment of the Forest Service plantations was made and the report (4) again emphasized the need for a tree improvement programme. It was not until 1956 that the opportunity came for some of these suggestions to be put into practice. However between 1952 and 1956, work on inbreeding of Douglas-fir, as well as on the variation within the species, had been started. Selection had been made in 1954 for trees showing good and poor characteristics of stem and crown and this study paved the way to the eventual selection of plus trees (7). It was at this time, too, that realizing the importance of vegetative propagation in any tree-breeding programme, grafting methods were developed for Douglas-fir (8).

In 1956 the shortage of high elevation Douglas-fir seed was causing the Reforestation Division some concern, and it was decided that a clonal seed orchard on a production scale should be established. This need was serious and, in order to bring the seed orchard into production as quickly as possible, criteria for selecting plus trees had to be drawn up at once and field work started.

At that time, the intensive plus tree selection programmes being carried out on Scots Pine and Norway Spruce in Sweden provided the best established model on which to develop a programme for coastal Douglas-fir in British Columbia. It must be emphasized however, that the programmes were quite different in many ways and the Swedish experience merely served as a framework for the British Columbia work. For example, in Sweden a detailed study of geographic variation had been undertaken before any attempt was made to select plus trees or establish seed orchards. Relatively firm seed transfer rules and seed zone maps had been developed for both species. Such information was almost completely lacking in Douglas-fir. Differences in objectives, as well as differences inherent in the species themselves, meant that the Scandinavian programme could not be followed in all its
details. Access problems and financial considerations differed strongly between the two programmes. For example, plans were made with just the single seed orchard in mind, and the selection was restricted to four carefully chosen stands from each of which the best five trees were to be used.

SCOPE

The original scope of the tree selection phase was therefore limited to providing 20 clones for grafting in the first B. C. Forest Service seed orchard. It was, however, soon realized that the number of trees was too small even for a single orchard since, although selected, these trees had not been tested and their performance was unknown. Apart from the possible lack of genetic superiority which can only be determined through progeny testing, many factors can make a clone unsuitable for inclusion in an orchard. Amongst these are graft incompatibility, low reproductive capacity, and extreme phenology. The addition of new criteria of selection, such as internal characteristics, would also greatly increase the number of initial selections required. Therefore, as the programme advanced, the need for greater numbers of trees per orchard became evident but these points have been considered in greater detail elsewhere (6).

There also were other reasons for enlargement of the scope of the tree selection programme. The seed requirements were not limited to the east coast of Vancouver Island provenance. Additional orchards had to be planned to provide seed for other parts of the coastal range. Seed orchard plans for the B. C. Forest Service (10) at present point to the need to establish at least four seed orchards whose priorities are given below:

(1) Vancouver Island (above 1,500 feet elevation)
(2) Lower Coastal Mainland (above 1,500 feet elevation)
(3) Lower Coastal Mainland (below 1,500 feet elevation)
(4) Vancouver Island (below 1,500 feet elevation)

In addition, a breeding population was required to permit a programme of wider intraspecific crossing and further enlargement of the scope was needed when the forest industry entered the programme in 1959.
These requirements made it necessary to obtain material from the whole coastal range of the species and the scope was enlarged from the modest 20 trees of the original working plan (5) to several hundred.

**THE FORMATION OF THE PLUS TREE BOARD AND PLUS TREE WEEK**

It was clear that progress in selection would be too slow if the Forest Service effort was not augmented in some way and that it would be difficult to build up an adequate breeding population for the programme especially when the widespread distribution of Douglas-fir (shown in Figure 1) was considered. However, by 1959 the forest industry showed an increasing interest in tree improvement work and the Plus Tree Board (or the Tree Improvement Subcommittee as it was subsequently named) was formed. This is a subcommittee of the Tree Farm Forestry Committee, which is an organization of companies holding Tree Farm Licences on the coast, and members of the Federal and Provincial Forest Services and the University of British Columbia. The objectives of the subcommittee were to encourage interest in the work of tree improvement and to bring about co-operative participation by interested companies through cruising for plus trees on their own holdings.

In order to give uniformity to the efforts, company foresters had to be taught the methods of selection and the standards which had been developed by the B. C. Forest Service crews. Accordingly, in 1959 an instructional cruise was organized. Companies participating in the tree improvement programme sent members of their field staff to combine for one week in cruising a suitable area of second growth. The candidates were discussed by those experienced in plus tree cruising and the aims of the whole tree improvement programme were explained. It was then intended that the company foresters return to their own areas and find plus trees independently. This instructional course became an annual event, known as Plus Tree Week, and was held each year from 1959 to 1965. As more foresters became conversant with the standards and procedures of selection, these special weeks fulfilled a secondary purpose. Concentrated cruising by up to 30 men made it possible to cover stands which were too extensive to be tackled by a single crew. The weeks became important for their contribution to the Plus Tree Register, as well as for an interchange of ideas on tree improvement and other forestry topics.
Fig. 1. Map showing the approximate distribution of Douglas-fir in coastal British Columbia.
As interest in tree improvement increased, the membership of the board expanded and so did the scope of the participation. In 1961, for example, the first industrial clone bank of plus tree material was started and by 1962, following a grafting course organized by the Forest Service, four more companies established clone banks. The industrial co-operators now have well advanced clone bank and seed orchard developments.

During the selection phases of the programme, the objectives of the B. C. Forest Service and of industry were practically identical and the whole effort was devoted to the single end—the registration of a reasonable number of plus trees as quickly as possible. The individual members were primarily interested in their own localities but there was no conflict over the distribution of the cruising to obtain the basic population. When the stage of seed orchard establishment and progeny testing was reached, however, the members diverged according to their own particular needs. Their programmes now are carried out independently with the advice of the technical advisor to the subcommittee.

METHODS OF TREE SELECTION

Selection of the General Area for a Cruise

The choice of areas in which selection has taken place has been governed by the overall aim of the programme and by the occurrence of suitable stands. The priority of seed orchards has had to be kept in mind, using the best available information on provenance as a guide. At the same time, the need to cover the species range has had to be interwoven. Ease of access played an important part, especially in the early stages of the programme and areas requiring boat access had to be covered when the facilities were available. On several occasions stands threatened by timber sales or selective logging were cruised specially in order that material from them should be preserved while it was still available.

Selection of the Stands

Selection can clearly be carried out most efficiently in pure or nearly pure, even-aged, stands of Douglas-fir. These stands should theoretically be as near the expected rotation age as possible. This is considered to be 70-80 years on moderate to good sites.

In practice, selections were made in stands from 40 to 150 years of age because of the shortage of those in the ideal age class. In stands
of less than 40 years. Lack of natural pruning may make it hard to see the characteristics of the stem and there is always the chance that the tree will be selected that possesses superior vigour at an early stage but which may not sustain this until maturity. In stands over 100 years it is sometimes difficult to separate the effects of environment from those of genetic origin, and past faults may be covered up by subsequent growth. Moderate to high sites are preferred as the phenotypic differences are more clearly expressed on these: selection of outstanding individuals on low sites proves difficult, again due to the greater influence of the environment. Stands originating from fires are preferred as these have a more even-aged structure and have not come under the influence of man. A certain amount of negative selection took place in the early days of logging when non-commercial trees were often left to produce seed for the next crop.

Information on the location of suitable stands sometimes came from foresters familiar with them. However, more frequently, areas showing desirable species composition, age, height, and stocking class were first located on the best available forest cover maps. The areas then were examined on aerial photographs and if their appearance confirmed that they might be suitable, they were visited by the field crew. The type maps giving good information for inventory could not be expected to have the precision required for selection work and the area covered by the crew was decided by them on the ground. Rangers, Forest District staff and, in particular, crews engaged in growth and yield studies, were a great help, while company foresters had an intimate knowledge of their own lands. Several logging companies also made available their most recent inventory maps.

**Selection of Trees within the Stands**

The suitable areas were then covered by a 100 per cent visual cruise using a two-man, or, latterly, a three-man field party. A compassman ran the line while the two cruisers covered a strip three chains wide, examining all potential candidate trees. The lines were marked with coloured flagging tape at frequent intervals and the full chainage points were given double flagging. The chain line provided a means of ensuring that the area was completely covered by a grid system so that the candidates could be identified, recorded, and relocated.

As trees showing the desired characteristics were met, they were recorded on the cruise-sheet and marked with tape. The whole stand
was cruised in this way. At the end of the cruise the candidates were critically re-evaluated. The age, height, and diameter at breast height inside bark of the candidate were compared with those of the three nearest dominant trees considered to be growing on the same site. As a rule these comparative trees were less than 100 feet from the candidate. The decision to accept or reject the tree was then based on its numerical superiority and on its form and appearance.

In the early stages of the programme, all candidates found by companies were checked and measured by the B. C. Forest Service crew. After 1962, however, the company foresters carried out the first culling of the candidates and took the measurements themselves. The Research Division forester responsible for registering plus trees inspects all candidates before registration in an attempt to give some uniformity of standard. This process enables the forester to form his own opinion of every tree in the register and satisfy himself on its strong and weak points.

Once accepted, the tree was assigned a registered number. The tape bands were replaced by a permanent paint identification and an access trail painted. Understory trees which would catch twigs falling from the crown of the selected tree, were removed to facilitate scion collections, which are made at the first opportunity after registration.

Registration and Records

The tree register for Douglas-fir was set up by the B. C. Forest Service in 1956 and is maintained by it to identify and record relevant details of all selected plus trees. A card is made up for each tree giving details of location, measurements and formalised comments. An example is shown in Figure 2. A duplicate copy of each plus tree card is prepared for the technical advisor to the Tree Improvement Subcommittee.

In addition to the selected plus trees, all those specimens of Douglas-fir that have been grafted into the B. C. Forest Service clone bank for use in the breeding programme as a whole are included in the register. The majority of these "research" trees have been chosen from outside the range of the species in coastal British Columbia with differing criteria of selection, and the remainder have unusual characteristics which may be of use to the breeder or are veterans representing a population no longer in existence and to which normal selection criteria cannot be applied. A second registration card is used for these trees and an example is shown in Figure 3.
Registered numbers are assigned to the trees as soon as they have been accepted for use in the programme and are given consecutively to prevent any possibility of duplication. The name of the locality has been added to the registered number for convenience.

Detailed maps showing the areas cruised and the location of all plus trees and their access trails, as well as rejected candidates are also maintained in Victoria. Figure 4 shows an example of such a cruise map.

Photographic records of the plus trees have been obtained in some instances but it was found to be difficult to take worthwhile photographs showing the whole trees and its characteristics without extensive clearing.

Table 1 gives a summary of the trees contained in the Tree Register on January 1, 1967.

Table 1. Summary of tree classes contained in the Tree Register, January, 1967

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of trees</th>
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<tr>
<td>Selected plus trees</td>
<td>414</td>
</tr>
<tr>
<td>Research and sample trees (Coastal B. C.)</td>
<td>75</td>
</tr>
<tr>
<td>Research trees from places other than coastal B. C.</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td>614</td>
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Local No. 317
REGISTRATION No. CAMP 43
Species. Douglas fir

Date of selection 1959
Land District Comox
Cover Map 92E-13-E
Selected by B.C.F.S.
Block 1008
Latitude 49° 52'
Longitude 125° 38'
Ownership Elk River Timber
Measurement date 1959
Origin of stand: Dog, burn, plantation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Plus</th>
<th>Dom. 1</th>
<th>Dom. 2</th>
<th>Dom. 3</th>
</tr>
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<tbody>
<tr>
<td>Age at 4.5 feet</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Total height (feet)</td>
<td>98</td>
<td>96</td>
<td>72</td>
<td>84</td>
</tr>
<tr>
<td>D.b.b. over bark (in.)</td>
<td>15.2</td>
<td>13.6</td>
<td>12.9</td>
<td>13.3</td>
</tr>
<tr>
<td>Double bark (in.)</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>D.b.b. inside bark (in.)</td>
<td>14.0</td>
<td>12.2</td>
<td>11.7</td>
<td>12.2</td>
</tr>
<tr>
<td>Diameter at mid-height o.b.</td>
<td>10.2</td>
<td>9.6</td>
<td>9.1</td>
<td>9.7</td>
</tr>
<tr>
<td>Double bark at mid-height</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Diameter at mid-height i.b.</td>
<td>9.6</td>
<td>8.9</td>
<td>8.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Calculated volume (cu. ft.)</td>
<td>50</td>
<td>36</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Per cent superiority of plus</td>
<td>28</td>
<td>45</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

Total

Horizontal. Acute.
Pruning: Good. Moderate. Poor.
Taper: Good. Moderate. Poor.
Cone production: Heavy. Light. None seen.
Pollen production: Heavy. Light. None seen.

Fig. 2. Example of a plus tree registration card.
Local No. 24 (593) Registration GOLD 78

Date found 1960 Country Canada Province or State B.C.
Ownership Tahsis Company Latitude 49° 52' Longitude 126° 06'
Elevation 700 ft. Age 620 yrs. D.B.H. 110.5 ins.
Height 263 ft. Standing X yes; no Checked X yes; no
Land district Nootka Block Lot 6 Section
Township Range Lot Section
District Wood data yes; X no File 021138

Form: The tree is free of limbs for 138 feet.

Comments:

Scale 1" : 2 miles

Fig. 3. Example of a research tree registration card.
Fig. 4. Example of a plus tree cruise map.
THE SELECTION CRITERIA

General Considerations

Initial selection in natural stands must, of necessity, be based on external phenotypic characteristics. More sophisticated selection and consideration of internal characteristics, if required, will have to be made at a later stage. The genetic gain obtained by using selected material will depend upon the intensity of selection and on the heritability of the character concerned. Some modification will also be brought about by the breeding system used. It would therefore be desirable to have some knowledge of the narrow sense heritabilities of the clearly defined characteristics of the phenotype before deciding which of these should be stressed most strongly in the selection programme. Such information is meager and only now beginning to appear in the literature (1) and (7). It must be remembered that, however desirable improvement in a given characteristic may be economically, the tree breeder will only be able to attempt improvement if a good proportion of the preferred properties are passed on to the succeeding generation. That is to say, the narrow sense heritability must be high enough to make selection worthwhile. Simultaneous selection for more than a very few characteristics reduces the possible gains in a geometric manner but, at the start of any programme, the selected population must contain sufficient variation to permit a slight change of emphasis should reliable information come later. These are problems which cannot be avoided at the start of work on a species whose genetic constitution is practically unknown.

If the selection programme should be held in abeyance until such information becomes available, precious time will be lost and many sources of potentially valuable genetic material may be destroyed through logging and fire. In this region there are at present even-aged, undisturbed stands resulting from old fires in which selection can take place and this gives an advantage over tree breeders in other parts of the world where such natural populations no longer exist. The criteria used in selection therefore had to be weighted according to general principles and a consideration of results available of work on other species.

Not only is it important to consider the number of characteristics used in the programme but also the basis of their influence. Such characteristics as overall growth or volume production in forest trees will be under the control of many different factors and, as such, are not likely to have a usefully high heritability. On the other hand, when volume is simplified into its components such as height growth, higher heritability
can be anticipated. It is by controlling the selection intensity that the breeder should be able to influence the genetic gain most easily. The decision to select one individual in ten or one in ten thousand is to some extent an administrative one. However, since trees are growing under natural conditions where competition has already played a considerable part, the intensity of selection cannot be absolutely defined. Assessment has to be relative and what is required is the tallest tree in the stand when the factors of environment, site, stocking, and so forth are taken into account. It is perhaps sufficient to say that the programme developed in British Columbia must be classed as one involving intensive selection.

The Criteria Developed for this Programme

Even at an early stage in a selection programme, it is not too difficult to describe the type of tree that is desired. What is required above all is a more efficient tree, a tree which will reach a given size on a given site in a shorter time than a normal seedling and a tree which has characteristics better suited to its eventual utilization. Greater uniformity of product alone is frequently highly desirable in intensively managed forests.

When the working plan for the programme was drawn up in 1956 (5) the selection criteria of the Swedish programme was used as a guide and seven points were listed for the assessment of phenotypes.

1. The tree should have rapid height and diameter growth. These values should be superior to three trees of the same age growing on the same site. (In Sweden the tree was expected to have 50 per cent more volume than its neighbours but no such exact limitation was placed on Douglas-fir.)

2. The tree should be resistant to disease and pests and should not show repeated non-parasitic injuries such as top damage.

3. The tree should have a narrow wedge-shaped crown and no tendency to form double leaders.

4. The stem should be straight, with minimum taper, and be reasonably clear of branches.

5. The branches should be light and short and at, or nearly at, right angles to the stem. Trees with internodal branches were to be avoided.
(6) Thin bark was desirable.

(7) The tree has to be a good cone producer.

These standards were established on the assumption that trees meeting them all would be reasonably easy to find. In fact, when cruising started, the difficulty of finding such a tree became evident and, although these criteria have served as a basis for the whole selection programme, emphasis has had to be modified slightly with the circumstances and in the light of field experience.

Emphasis has been placed most strongly on stem form and height. Measured volume was at one time used as a secondary criteria but, apart from theoretical considerations, the difficulty of obtaining a reliable figure for taper during the initial selection period of the cruise restricted its value. Height growth has been shown to be relatively independent of stocking, while diameter growth is closely related to competition factors and for these reasons greatest weight has been placed on height superiority. It is not denied that superiority in diameter growth is highly desirable but detailed considerations of competition are essential if diameters are to be compared. Straightness of stem is clearly advantageous and crookedness of stem has been shown to be genetically controlled in Douglas-fir (7). Environmental influences can lead to sweep in stems but selection against repeated sweep was carried out where straight stems could not be found.

Regarding factors of size in selected individuals, the first aim of the selector must be to discover a tree which is outstanding in this respect. He must then try to determine why the tree shows these characteristics. For example, if the tree in an even-aged stand has a large diameter he will use his experience to assess the effects of competition and site. This will, necessarily, be an estimate but will remove gross effects. If he can account for the characteristic by the environment, the apparent superiority will disappear. In another example it is fairly easy to find a large tree which has a large crown, but what is desired is a large tree with an unexpectedly small crown. Such a tree should be the more efficient wood-producing organism. However, it must be stressed that, in any selection in wild stands, a balance must be reached since sufficient uniformity of environment for direct comparison between individuals is unlikely to be found.

This brings in the subject of how many measurements should be taken in selecting these trees. Accurate measurements are time-consuming
and at an early stage the decision was made to restrict the measurements. Douglas-fir is a pioneer species establishing itself readily on mineral soil. Thus, in stands of fire origin, there is frequently little age variation. However, after working in such stands, it became clear that the earliest established trees did have a considerable advantage. Therefore, even in so-called even-aged stands, it is necessary to check the age of the selected and comparative trees and make some adjustments. Height, diameter outside and inside bark, and age were chosen as simple parameters and it was on these figures, and consideration of the other features of the tree, that the decision to retain the tree was made.

The density of selection in a single stand has not been mentioned. While the undesirability of selecting closely related trees is realized, no limits have been placed on the minimum distance between trees accepted for registration. In certain exceptional instances, two adjacent trees, both of which show some outstanding characteristics, have been registered. Care will certainly have to be used in selecting individuals for use in seed orchards and it would be preferable for such trees to be separated by a mile or more, but this is not reason in itself for rejecting closely located trees for registration. Progeny testing and other factors, such as graftability, could well lead to the elimination of one of such selections at a later stage.

It has been stated that originally it was planned to select five trees from each of four stands. In later cruising no such predetermined number was aimed at. It was felt that the standards were sufficiently defined so that the number of trees found in any stand would be automatically determined. This was found to be true in many stands but, where only a single tree was found, an attempt was often made to retain a second individual which showed at least some of the desired characteristics. Automatic elimination of trees, due to grafting incompatibility, phenology, and perhaps wood characteristics at a later date, would then mean that material from that area was lost. By retaining the second tree a safety margin was introduced. This was especially so where cruising was on the edge of the species range.

At this stage little weight has been given to the consideration of disease and pest resistance. By selecting for vigorous, unusually large trees such consideration is brought in automatically. Trees showing fire- or mechanical-damage scars are not eliminated on these counts. Selection is strong against any repeated defects but, in some stands that were visited, widespread damage had occurred from wind and snow, as indicated by kinks at a common height on many trees. Here there has been little hesitation in selecting trees which have suffered similarly.
As long as a strong, single leader has developed immediately after the injury, it is felt that there is little likelihood of picking a susceptible genotype.

The criteria covering crown and stem form, branch characteristics and bark, have been unchanged but obviously there is some variation in the type of tree selected according to the stand. Little or no weight has as yet been given to the cone production criterion. All the trees should have some sign of a cone crop but as yet no tree has been rejected on this count alone. From general observation it seems that the likelihood of selecting a complete non-producer is rare. Information is accumulated on cone production of the trees and their ramets for future reference.

The Criteria for Subsequent Selection

Field selection must, through force of circumstances, provide material for both immediate use in the initial seed orchards and for the establishment of a breeding population in which re-selection may take place as information becomes available. The criteria for initial selection given above do not represent a complete list of characteristics which might be considered. Volume is one of such unassessed criteria. It was originally hoped to include measurement of volume in the field selection but the need to climb the trees to obtain an accurate measure of taper meant that the figure could only be obtained by considerable additional work. This measurement was carried out originally and some 40 trees were assessed with volume figures available. These figures showed that the selection methods did lead to trees possessing superior volume. It was therefore felt that the time could be better spent on selection, while a check was made to ensure that no trees which appeared to have inferior volumes were accepted.

Internal characteristics also have not been considered in the initial selection process. Aside from uniformity of product, there is at present little general agreement on specific wood quality characteristics desired in Douglas-fir because of the variety of uses served by this species. However, it is probable that these criteria will assume importance in the future when more information is available and will have to be included. Co-operative efforts in this field are described later, but it appears that, as with volume, internal characteristics of candidates cannot be determined with sufficient ease for use in the initial selection process.
Once a tree has been registered and propagated, its possible inclusion in a seed orchard must be considered. The selection of clones for these initial orchards poses a problem when so little is known of the behaviour of the material. However, since the relatively large numbers of such untested clones are required for any orchard and there are but a few trees available from any one geographic area, the choice is inevitably limited. The clones for the B. C. Forest Service seed orchard at Campbell River, for example, were selected from the plus tree register on the basis of their distribution and after consideration of the numerical comparisons between plus trees and its dominants, aided by a subjective evaluation of the tree in the field. Greatest weight was given to obtaining a widespread geographic distribution within the provenance area.

SUMMARY OF CRUISING FOR PLUS TREES

Cruising for plus trees is a laborious and time-consuming process. Stands show great variation and one or many days' work may be necessary to locate even a single candidate tree that meets the established standards. Access and topography also affect the rate of progress. Frequently stands can only be reached by boat or by foot, traversing over considerable distances through forest and cut-over land. Another reason for the relatively slow progress is the time required for mapping and marking in the field candidate trees, so that it is possible to return to them at later dates for final assessment and for scion collection.

During 1957 and 1958, stands at high elevations in the south-east portion of Vancouver Island were cruised to provide material for the first seed orchard. By 1959 the decision had been made to include trees from a wider area and stands near Campbell River, Parksville, and in the San Juan drainage near Port Renfrew were visited. In 1960, cruising in low elevation stands was started at Elk Bay, near Campbell River. Cruising was still restricted to the eastern side of Vancouver Island.

The developmental aspect of this early cruising and the later confirmation of standards as experience increased must be stressed. After cruising had started, a better idea was obtained of the type of tree that could be expected. It is good to have a clear, preconceived ideal at which to aim, but how closely it may be approached can only be found through experience. A reappraisal of the early selections was made in 1961 and some trees, which had been accepted initially, were rejected
In 1961, both high and low elevation stands were examined in the Cowichan Valley. A large portion of the summer's work was devoted to the area at Powell River where the co-operative cruise with industry had taken place, and a joint cruise was carried out with the company foresters at Nimpkish.

In 1962, selections for the first time were made on the west coast of Vancouver Island in and around the Kyuquot Public Working Circle.

In 1963, work started on the mainland, an area from which trees had previously only been found during Plus Tree Weeks or by the University of British Columbia crew in Haney Forest. However, as selection of clones for the Vancouver Island seed orchard had not been completed, the main emphasis was placed on a thorough coverage of the best of the remaining stands on the island. Selections were made at Kelsey Bay, Campbell River, Courtenay, and Ladysmith. By 1964 it was possible to shift the emphasis to providing material for a mainland orchard, and two crews devoted almost the whole season to this end. Stands from Sechelt, Squamish, Vancouver, Chilliwack, Harrison, and Hope were visited. In addition, two outlying areas at Sarita River on Vancouver Island and at the head of Knight Inlet were cruised. Enough selected trees were then available to establish a high elevation mainland clonal seed orchard.

However, coverage of the coastal range was still lacking and, with the exception of those at Knight Inlet, the selected trees came from the lower mainland and Vancouver Island.

In 1965, a co-operative boat survey was organized with five company members of the Tree Improvement Board financing one crew and the B. C. Forest Service the other. Three isolated areas at Rupert Inlet, Kelsey Bay, and Jervis Inlet were examined, as well as stands of Douglas-fir at Dean River and Sechelt.

Even with three months' work this was an enormous task and it was agreed that some selections distributed as widely as possible over the range were desirable, even if in a few instances standards had to be relaxed. In general, however, it was possible to maintain the same high standards of selection that were used on the lower mainland coast and Vancouver Island.
Thus, by the end of 1965, selections were available for the seed orchards planned and at least some attempt had been made to cover the range of the species on the coast of British Columbia. It was therefore decided that, for the time being, the plus tree objective had been reached and that the B. C. Forest Service should now devote more time to the consolidation of the clone banks and to tree breeding and progeny testing.

A summary of plus tree selection by the B. C. Forest Service, by the forest industry, and by co-operative effort is given in Table 2. The distribution of selected plus trees is shown in Figure 5.
## Table 2. Summary of plus tree selection, 1957-1966

<table>
<thead>
<tr>
<th>Year</th>
<th>B. C. Forest Service Cruises</th>
<th>Co-operative Cruises</th>
<th>Industrial Cruises*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trees Registered</td>
<td>Locations</td>
<td>Trees Registered</td>
</tr>
<tr>
<td>1957</td>
<td>7</td>
<td>Ladysmith, Cowichan</td>
<td>-</td>
</tr>
<tr>
<td>1958</td>
<td>4</td>
<td>Duncan, Cowichan, Nanaimo</td>
<td>-</td>
</tr>
<tr>
<td>1959</td>
<td>4</td>
<td>Campbell River, Port Renfrew, Cameron Lake</td>
<td>5</td>
</tr>
<tr>
<td>1960</td>
<td>8</td>
<td>Kelsey Bay, Campbell River, Cowichan</td>
<td>1</td>
</tr>
<tr>
<td>1961</td>
<td>38</td>
<td>East half of Vancouver Island</td>
<td>8</td>
</tr>
<tr>
<td>1962</td>
<td>23</td>
<td>West coast of Vancouver Island</td>
<td>14</td>
</tr>
<tr>
<td>1963</td>
<td>30</td>
<td>East half of Vancouver Island, Howe Sound on coastal mainland</td>
<td>21</td>
</tr>
<tr>
<td>1964</td>
<td>36</td>
<td>Sarita River, Knight Inlet, coastal mainland, and Fraser Valley</td>
<td>16</td>
</tr>
<tr>
<td>1965</td>
<td>9</td>
<td>66</td>
<td>Hope and Powell River, Quatsino, Kelsey Bay, Dean River to Sechelt</td>
</tr>
<tr>
<td>1966</td>
<td>150</td>
<td>162</td>
<td>(Gold River, San Juan River, Powell River, Incomplete)</td>
</tr>
</tbody>
</table>

*Cruises by the University of British Columbia and by private individuals have been included.*
Fig. 5. Distribution of selected plus trees.
COLLECTION OF SCION MATERIAL AND PROPAGATION

Once the trees have been located and registered, they must be propagated. This represents the second stage in the programme and it is the aim of the B. C. Forest Service to propagate all the trees included in the Register at the Forest Experimental Station at Cowichan Lake. This clone bank will serve the double purpose of preserving the genetic material and providing a breeding arboretum where the essential stages of progeny testing through controlled crossing experiments may be carried out conveniently. In addition, some of the untested material must be used in the first production seed orchards. It is for this reason that the collection of scion material from the selected trees has been the responsibility of the B. C. Forest Service. Scions generally are collected from the upper crown by means of a .22 rifle, although some trees have been climbed.

Industrial co-operators in the Tree Improvement Board have also propagated the selections in clone banks and seed orchards. With ammunition and, in some instances, assistance supplied by company foresters, collections have been made for these banks by the Research Division staff. The first collection for company programmes was made in 1961 but many more requests for material were submitted in 1962. After 1962 the B. C. Forest Service obtained scion material only from newly registered selections for all those members of the board who indicated a desire to propagate the trees. Those requiring material from trees already propagated were expected to make their own arrangements. As the clone banks became established, an interchange of material became possible, while material from the new selections is still supplied on request to interested companies. In addition to the industrial participation, the University of British Columbia has also been provided material for a clone bank. Table 3 shows the clonal material distributed by the B. C. Forest Service since 1961. The members themselves selected the trees they wished to propagate and the number of bags of scion material distributed from each tree varied accordingly.
Table 3. Collection of scion material by B. C. Forest Service for distribution to co-operators, 1961-1966

<table>
<thead>
<tr>
<th>Year</th>
<th>Plus Trees Visited</th>
<th>Bags of Material Distributed</th>
<th>Number of Members Receiving Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>14</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>1962</td>
<td>70</td>
<td>138</td>
<td>4</td>
</tr>
<tr>
<td>1963</td>
<td>77</td>
<td>120</td>
<td>5</td>
</tr>
<tr>
<td>1964</td>
<td>63</td>
<td>118</td>
<td>7</td>
</tr>
<tr>
<td>1965</td>
<td>59*</td>
<td>101</td>
<td>9</td>
</tr>
<tr>
<td>1966</td>
<td>61</td>
<td>145</td>
<td>9</td>
</tr>
</tbody>
</table>

* Material from clone banks included.

WOOD QUALITY

In addition to the initial selection process, work in the specialized field of wood quality has required the co-operative approach and the work has been carried on in three phases.

The first phase was started in 1957 when a study was developed by the Forest Products Research Laboratory in Vancouver and the B. C. Forest Service. Cores were removed from the selected trees and submitted to the laboratory for measurement of several internal characteristics, including specific gravity, fibre length, and a measure of wood production. Within-tree variation had to be investigated and sampling procedures drawn up. Cores of five, twelve, and nineteen millimetre diameter were collected for analysis at different times in the programme. The 19-millimetre cores were extracted with a power borer developed by the laboratory (9). Some difficulties were met but a report was prepared in 1964 (2).

In 1961, arrangements were made by the Tree Improvement Board for analyses to be carried out at the Faculty of Forestry at the University of British Columbia, where technical assistance was provided by the Pulp and Paper Research Institute of Canada. Five-millimetre
cores were submitted by member companies and the B. C. Forest Service. Some results were forthcoming and a list of specific gravities and wood production values was circulated.

In a third phase, facilities were obtained at the University of British Columbia for post-doctorate research work on this topic. Some new cores were obtained and all the previous core material was made available for the study. This work is now progressing.

Table 4 gives a summary of the cores collected by the B. C. Forest Service from plus trees and their comparative dominants and submitted for analysis. The results of these analyses are not yet all available.

Table 4. Summary of wood cores submitted for wood quality analysis by the B. C. Forest Service.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Agency to Whom Sent</th>
<th>5 mm. Cores</th>
<th>12 mm. Cores</th>
<th>19 mm. Cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>F. P. R. Laboratory. Vancouver</td>
<td>54</td>
<td>74</td>
<td>102</td>
</tr>
<tr>
<td>II</td>
<td>University of B. C.</td>
<td>129</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>III</td>
<td>University of B. C.</td>
<td>446</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>629</strong></td>
<td><strong>74</strong></td>
<td><strong>102</strong></td>
</tr>
</tbody>
</table>

PRESENT STATUS

Plus trees have been selected from throughout the coastal range of Douglas-fir in British Columbia but coverage is extremely sparse in some areas and good stands remain for future examination. Concentration has been on the higher elevation stands for it is in these zones that seed shortage is most acute, due to the infrequent cone crops. Some lower elevation trees have been selected but areas which eventually should be examined remain at Vancouver, Squamish, and Sechelt, to name but a few. The distribution of selections has also been influenced by the availability of stands with suitable age and site quality for cruising. Table 5 summarizes
the distribution of the selections by elevation classes.

Table 5. Summary of plus tree register by elevation classes

<table>
<thead>
<tr>
<th>Elevation Class (Feet)</th>
<th>Vancouver Island</th>
<th>Mainland (Including North Coast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-750</td>
<td>104</td>
<td>50</td>
</tr>
<tr>
<td>751-1250</td>
<td>36</td>
<td>49</td>
</tr>
<tr>
<td>1251-1750</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>1751-2250</td>
<td>29</td>
<td>38</td>
</tr>
<tr>
<td>2250+</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

225                      189

Although selection of material for a base population is not a process which can reach a finite conclusion, the collection of plus trees is but the first stage in the tree improvement programme. The second stage of propagation and preservation of material is well advanced, and the time has now come when the Forest Service must concentrate on the third requirement, namely the development of production seed orchards required for their own needs and the processes of testing and evaluation. For this reason, full-time cruising on a large scale will be discontinued, although new selections will be examined and added to the register as and when they are found. Although, too, the selection phases of the programme are those best suited to close cooperation between interested members of the forest industry and the government service. Problems of mutual concern will continually arise and the cooperative approach, from which the programme has benefitted much in the past, will still fulfill an essential purpose.
REFERENCES


