dry at all times during processing, as well as while lifting. We like to pull the seedlings on a cloudy day; 20 minutes of exposure to the sun's rays is disastrous.

Storage brings up another problem. We used to root-wrap the seedlings in plastic. Latest indications are that a bare-root, loose pack, air circulated storage in polyethylene bags is the best, (and without too much moisture). *Botrytis* is our biggest enemy in storage. We used to dip the tops in fungicide but now we spray in the fields just prior to lifting. Storage temperatures are just above freezing. We have successfully stored *C. deodara* seedlings for three months by this method.

We feel it is very important that the customer know how to take care of the stock when he receives it — and to know when it is coming. Care instructions are enclosed for new customers, along with notification of the shipment.

A few months after shipping, we send a questionnaire to selected customers for comments. Returns are usually low, but they are effective. There always seems to be need for improvement.

Through the years, while working with *Cedrus deodara*, I think we have learned some basics which we can apply to our other seedlings, to a greater or lesser degree, depending upon the cultivar. They are:

1. Be in control of plant growth at all times.
2. Do not dig until ready.
3. Minimize shock at harvest time.
4. Instruct customers as to proper care after receiving the stock.
5. Give customers a chance to let you know if they have any problems.

DOUGLAS FIR CULTIVAR IMPROVEMENT PROGRAMS

J.C. HEAMAN

Research Branch, British Columbia Ministry of Forests
1450 Government Street
Victoria, British Columbia V8W 3E7 Canada

In British Columbia, where fifty cents in every dollar earned is said to come directly or indirectly from the forest industry, the raw materials for that industry, the trees on the hillsides, represent a truly enormous investment. Farmers and horticulturists have for centuries used both intensive management and genetic improvement to increase their yields, and foresters are now having to apply the same principles and techniques. Intensive management here means using all the tools that are available, which can include choice of the most suitable species, site preparation, control of spacing throughout the life of the crop, possibly fertilization, and use of the best available genetic material. Improvements in the latter will influence all the other techniques and while they must be seen as an integral part of intensive management, they may well be the most important one.

In B.C., about 10 million Douglas fir seedlings are planted each year on the coast and at any time there may be 20 million seedlings passing through the Ministry of Forests' Nurseries. As exploitation of the forests continues into the less accessible areas on the West Coast, species priorities will change. In 1980, for example, about 4.3 million cubic metres of Douglas fir were harvested on the coast while western hemlock at 9.5 million, represented the leading producer (1). However, predictions show that by 1995, 6 million Douglas fir seedlings will still be needed annually and, as the second growth stands established after the earliest logging are cut once more, the need for Douglas fir will increase again. A few percentage points of genetic improvement in product quality, volume production for a given site, or reduction in the time to reach a given size, can therefore have a great impact on the wood supply for the forest industry. These considerations have been used to justify investment in projects of cultivar enhancement within the species.

What is involved. In general terms, breed enhancement can be seen as the genetic manipulation of a chosen population through successive cycles where selection is followed by selective mating and the establishment of a new population in which further selections can be made. This is by no means the only option open to the breeder but it represents the most common and conservative approach. It can be applied to trees just as it has been to dairy cows or grain, but with such long-lived organisms there are differences which can help and hinder the process. Individual genotypes can be vegetatively propagated, maintained, and multiplied and, as many trees, including Douglas fir, are monoecious and produce large numbers of offspring; "litter-size" may be no problem and dam-sire relationships can provide greater flexibility of mating and testing designs.

Against this must be seen the problems of slow maturation giving long generation intervals and slow development periods which can amount to potentially poor juvenile-mature correlations. Scale and time are important considerations and no program can be designed and implemented overnight — history plays an important part. Techniques available later must be incorporated and such changes can only be brought into a flexible program

All breeding and improvement programs must rely on the manipulation of the available genetic variation for the species and the environment of utilization The breeder has to decide which characteristics he would like to change, examine the economic impacts of such changes and examine the available traits and their inter-relationships. He can then work to move the population means for these characteristics in the desired direction. If the traits are strongly inherited and under simple genetic control, advance may be swift but for the more complex traits, slow but steady advances can be expected Disease resistance might be simply inherited, while growth-rate is more complex and may be harder to manipulate.

The Douglas Fir Program. Turning to the Douglas fir program, improvements in growth rate and form are the major goals, while disease resistance at present plays a smaller part on the coast. The root rots represent the most serious disease problem and genetic resistance to these has not yet been established Two levels of variation must be used. Douglas fir as a species extends from north of Fort St. James in Central B.C to Central Mexico, a range of over 30° of latitude, and even for a program restricted to the coastal form, raw material extends from Kemano to central California. With such a distribution, population variations can be expected. However, growth potential at any site for material from these parts of the range cannot easily be predicted. Estimates of inherent variation between populations can be looked at through isoenzyme analysis, but there is no safe substitute for field observation of performance over a number of years. These provenance tests, trials of population performance on a number of sites, should be established in advance of a breeding project, but even if the information appears later, it must be used to modify breeding strategies. Until it does become available, relatively conservative approaches to population variation are needed. In coastal Douglas fir, a major test was established in 1966 and this is now producing information For example, on a wide range of sites, material from western Washington and from the Johnstone Straits area on the north of Vancouver Island are presently outperforming local sources.

The breeding programs must then make use of the within-population variation at the individual tree level. Here, then, is an advantage in working with a native species and, as soon as reforestation by planting becomes a major enterprise, selection can start to bring about some genetic improvements. Following early studies of variation and of inbreeding, Dr. Alan Orr-Ewing started the plus tree selection program for coastal Douglas fir in 1957. He started to build up a collection of selected individuals which could be used for early seed production and for future breeding, testing, and reselection. At that time intensive phenotypic selection was chosen. Growth rate and form were the traits given most weight and, although the heritabilities were not known, an adequate relationship between phenotype and genotype was assumed.

Any tree breeding program must follow a similar series of steps. Trees must be selected in natural stands; these genotypes must be accumulated in a convenient location through vegetative propagation and, when cones and pollen appear, these individuals can be evaluated by progeny performance tests. The best individuals can be identified and new selections made. At best this is a slow process and problems can be relied upon to appear. In the Douglas fir program, problems of delayed graft incompatibility soon showed up and complicated the process. Early cone and pollen production was expected from grafted mature material, but the partial rejuvenation following grafting and the role of the environment had been underestimated and buds to produce the test generation were slow to appear. Rootstock research has done much to reduce the incompatibility problem (2,7) and cone stimulation techniques, both physical and biochemical, are also being developed to influence the latter problem (9).

For these reasons, the Douglas fir program between 1957-1966 consisted largely in the selection of trees from across the coastal range (using 100 percent visual cruising of good second-growth stands), collection of the material in the Forest Service Breeding Arboretum at Cowichan Lake and in the establishment of the first seed-producing orchards. A cooperative effort brought the forest companies and the University of British Columbia into the project. About 500 trees which were outstanding for form and volume growth were collected (3). Work on inbreeding and variation were continued as well as a major pioneering study by Dr. Orr-Ewing on wide inter-racial crossing (8), but it was not until the early 1970's that the present recurrent selection project could be started. As this project represents the present major effort in coastal Douglas fir cultivar enhancement in B.C., I will follow this approach.

By the early 1970's, reproductive buds were appearing on the grafts of the selected trees and a breeding program was designed to meet several specific objectives. The overall goal was to improve the form and growth rate of the planting stock for reforestation as quickly as possible but the program has to address more specific technical objectives. The most important of these is the production of pedigreed material for reselection following a conventional recurrent selection approach. With the early lack of knowledge of heritabilities and the efficiency of field selection, provision of a more precise selection method to give rise to a second generation of material and increase gains, had to receive first priority. As a second objective, there was a need to study genetic relationships and values within the species and by controlling the mating patterns giving rise to the progenies, these two objectives could be met together. Provenance information was starting to appear but adaptability and, in particular, the flexibility of response of this material across the variable environment of coastal British Columbia, where the seed would be used, also needed to be looked at. The size and importance of genotype-by-environment interactions had to be examined and this meant the progenies should be tested widely. Some families can be expected to do well on a variety of sites, while others will have specific requirements and may only perform well on — say — the better growing sites. As a final objective some evaluation of the parent trees themselves was needed so that the first orchards could have the poor performers cut out, giving an intermediate level of gain.

With these specific objectives in mind, the decision was made to bring together a population of about 350 of the selected plus trees from coastal B.C. and from northern Washington in a rigid mating design. The disconnected, modified diallel design met these objectives (4). From that time, the main work of the coastal Douglas fir program has been devoted to making the crosses required by the design and planting and maintaining the progenies across the area where improved seed will eventually be used. This is time consuming, labour intensive and costly but there are now 77 test sites, mostly of about 3.5 ha, spread from Hope to Tahsis (5). As the seedlings grow and become established information will start to come in. Early indications can be useful but it will not be before the seedlings have been in the field for ten years that reliable information will make program decisions possible.

This project represents only one of a variety of options available to the breeder and, as it advances, its strengths and shortcomings become clearer. The strength lies in there now being over 200,000 seedlings of known parental origin scattered widely, whose relationships are covered through a balanced mating design and with an adequate, if not ideal, field test design. These seedlings will provide factual and precise information on which to make future breeding decisions. Some weaknesses lie in the inevitable restriction of the sample population and the way that population has been defined. More efficient designs could be used to meet smaller specific objectives — the single project approach is at best clumsy. It is, however, fair to say that in 10 or 15 years time there should be some answers to the questions we now would like to ask and these should be reasonably reliable. At the same time there should have been some advance towards the goal of genetically improved seed for reforestation.

So far, the conservative approach has been looked at but, as this is a meeting of plant propagators, it would be shortsighted not to include a reference to the exciting possibilities for other approaches. There has been a session on tissue culture and, although we are still waiting for the techniques to be developed for Douglas fir, if and when mass propagation by tissue, cell, or organ culture become available, many new prospects are opened up These would not merely facilitate the more conventional approaches by perhaps by-passing graft incompatibility, but also would make new breeding strategies possible. It is important for the breeder to be aware of the state of these advances and be prepared both conceptually and in terms of material availability to take advantage of these developments.

In ten years time, quite different approaches to cultivar enhancement in forest trees may be possible but, in the mean time, the present project will produce information and steady improvement toward high yielding cultivars on which further work can be based.

LITERATURE CITED

1 Anonymous 1981 Ministry of Forests Annual Report, 1980, Victoria, B C 60 p

2 Copes, D L 1967 A simple method for detecting incompatibility in two-year-old grafts of Douglas fir *U S Dept Agric For Serv Res* Note PNW-70 8 p

3 Heaman, J C , 1967 A review of the plus tree selection program for Douglas fir in coastal British Columbia, *B C Forest Service Research Note* #44 27 p

4 Heaman, J C 1978 Choosing strategies for a breeding program in Douglas fir (*Pseudotsuga menziesii* (Mirb) Franco) for coastal British Columbia A case study Special invited paper in Proceedings 3rd World Consultation on Forest Tree Breeding Canberra, Australia March, 1977, 1205-1214

5 Heaman, J C 1981 A breeding program in coastal Douglas fir (*P. menziesii* (Mirb) Franco) in Proceedings of 18th Meeting of the Canadian Tree Improvement Association (Part I), Duncan, B C , 1981 (in press)

6 Illingworth, K , 1979 Douglas fir provenance trials in coastal British Columbia results to six years after planting Proceedings of the IUFRO joint meeting of working parties, Vancouver, Canada, 1978 (Volume I) 411-426

7 Karlsson, I , 1980 Cowichan Lake Research Station — Compatibility testing of Douglas fir rootstocks (E P 648 02) in Proceedings of 17th meeting of the Canadian Tree Improvement Association (Part I) Gander, Newfoundland, 1979 214-215

8 Orr-Ewing, A L and F C Yeh, 1978 Survival and growth traits of racial crosses with Douglas fir *Research Note #85 B C. Forest Service* 46 p

9 Webber, J E , 1977 Cone enhancement in Douglas fir and lodgepole pine — problem analysis B C For Serv , Res Div , Working Plan E P 799 Unpublished Manuscript Report

IMPROVING SEED GERMINATION IN *ABIES*

D.G.W. EDWARDS

Canadian Forestry Service
Pacific Forest Research Centre
Victoria, B.C., Canada, V8Z 1M5

Abstract. A procedure is described for drying stratified *Abies* seeds that allows stratified seeds to be safely stored and which promotes higher germination rates Seeds, dried to a moisture content of 35%, were stored for 12 months without losing the beneficial effect of stratification or without their viability being adversely affected After certain storage periods, germination of dried seeds was increased well above that in routinely stratified samples The use of this procedure in nurseries is discussed

Seeds of many north-temperate Coniferae plants germinate more rapidly, and sometimes more completely, following a cold-moist treatment period known as stratification (or pre-chilling) This treatment is designed to overcome germination blocks caused by internal seed dormancy mechanisms or poor germination conditions (7), the within-seeds processes that remove such blocks being collectively referred to as after-ripening (4). There are three main prerequisites for successful stratification· a) a moisture source to hydrate the seeds so that the necessary biochemical changes occur, b) near freezing temperatures that favor certain biochemical changes and morphological developments, but delay sprouting of individual seeds that have completed after-ripening, reduce microorganism activity, and prevent damage from respiratory overheating, and c) adequate aeration to allow respired carbon dioxide to escape and also to help minimize heat accumulation (4). To this should be added a fourth criterion, the correct period of treatment. This study concerned primarily the first and last of these factors.

In many forest tree nurseries, the method of stratification is usually some version of the so-called "naked stratification" technique described by Allen and Bientjes (1), in which seeds are soaked in water at room temperature. After hydrating for 1 to 2 days, excess water is drained off, and the seeds are placed in plastic bags and refrigerated at 1° to 5°C for periods of a few weeks to several months, depending on the species, before being sown. This treatment results in relatively high seed