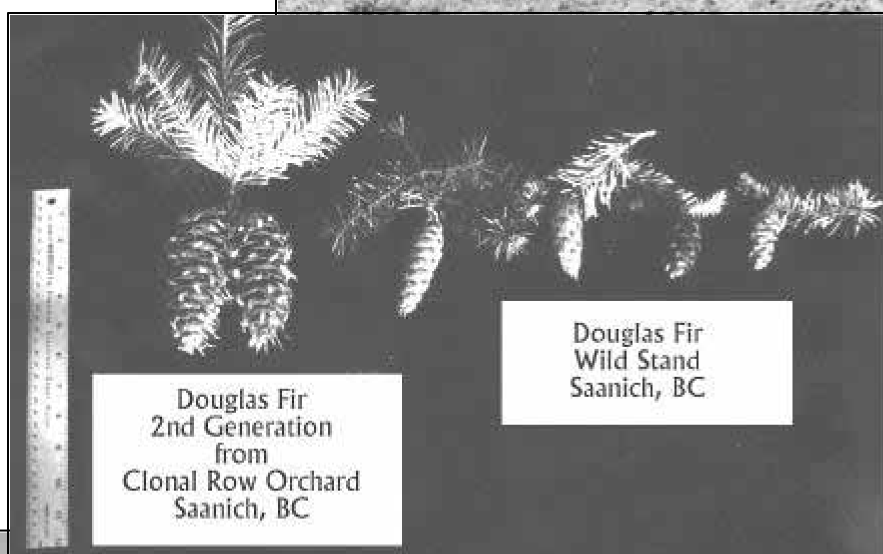
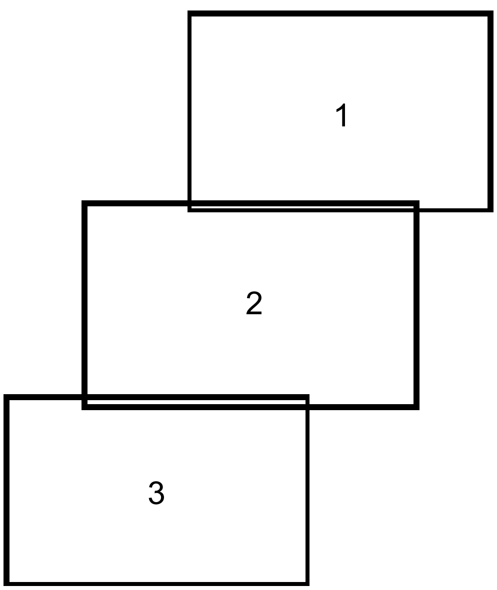
Forest Renewal BC Operational Tree Improvement Program



Project Report
1999/2000

Front Cover Interpretations



The Douglas-fir micro orchard, located at Saanich Seed Orchards, was established in 1991 to test the effects of orchard design and management practices on the production of high genetic worth seed lots. The orchard is arranged in clonal-rows with ramets spaced at 2.5 x 4m. Cone induction and crown pruning are done biennially to produce crops that are more readily accessible for management. Supplemental pollination (SMP) is done to maximize genetic worth.
The estimated yield from this orchard is about 1.5 million seed per hectare per year. Selfing, a concern with clonal row orchards, is not much greater than in conventional orchards (8% vs 5%, respectively). Most significant, is the high supplemental pollination efficacy. Rates can be obtained as high as 80%, but the actual rates observed are very dependent on the competing pollen cloud density.

Plate 1. An overview of the clonal-row, crown-pruned orchard

Plate 2. A comparison of cone size from the micro orchard (larger), and natural stands (smaller). The micro orchard trees can produce good cone size and seed quality.

Plate 3. Another view of the orchard showing the pollen cloud monitoring device and a whole tree bagging technique used to test-exclude non-SMP pollen sources

Forest Renewal BC Operational Tree Improvement Program

Project Report 1999/2000

Coordinated and compiled by:

Mike Crown, Reports Unlimited
and Roger Painter,
Tree Improvement Program
British Columbia Ministry of Forests

Acknowledgements

The Operational Tree Improvement Program (OTIP), in its third year, continues to provide support for current production facilities, and development of the provincial breeding programs. Much work has been undertaken during the year, expanding on the previous two years of investment. During this time, the tree improvement community has progressed considerably. The Forest Genetics Council (FGC) has restructured itself, and continues to provide considerable leadership and direction, and to develop a provincial business plan to meet the goals and priorities established for tree improvement. On-going financial support from Forest Renewal BC, lead by Janet Gagne, has provided a truly province-wide program for FGC. The Technical Advisory Committees have continued to provide strong technical leadership for Council, through development of species plans that reveal a clear direction for investments. They have also provided review committees that have performed technical evaluations for the funding proposals.

As in the past, my thanks must go to the Project Leaders, who have committed themselves to finishing their portions of this Report. As has been stated in past publications, this really is their report, and their opportunity to provide us with a view of their accomplishments. I hope they will be pleased with the results. This is a busy period for most, and I appreciate their making time to contribute. I would also like to acknowledge the work of the editorial review team: Nola Daintith, Don Summers, Hilary Graham, and Ron Planden for cleaning up the presentations. Thanks also goes to Island Eyes Images for compiling this report.

This year we are pleased to have Michael Stoehr and Joe Webber provide the material for the front and back covers. Their program has long been a standout in our province, and part of the success story of tree improvement in BC. It is a pleasure to be able to showcase their work. There are many successful programs and activities involved in tree improvement in BC, and we hope that a visual display of projects, and the people, who do the work, will add to the quality of this publication.

It has been another productive year. The effects of three years of investment are starting to show, as tree improvement becomes recognized as a stronger part of mainstream forestry. Thanks to all participants in the OTIP program for their patience and understanding, as we went about the job of administering the program on their behalf. It is my continuing goal to ensure that this program provides Forest Renewal BC with its needs for accountability, while allowing the tree improvement community to get on with the work.

I hope the coming year will be a very successful one.

Roger A. Painter
Tree Improvement Coordinator
Forest Genetics Council

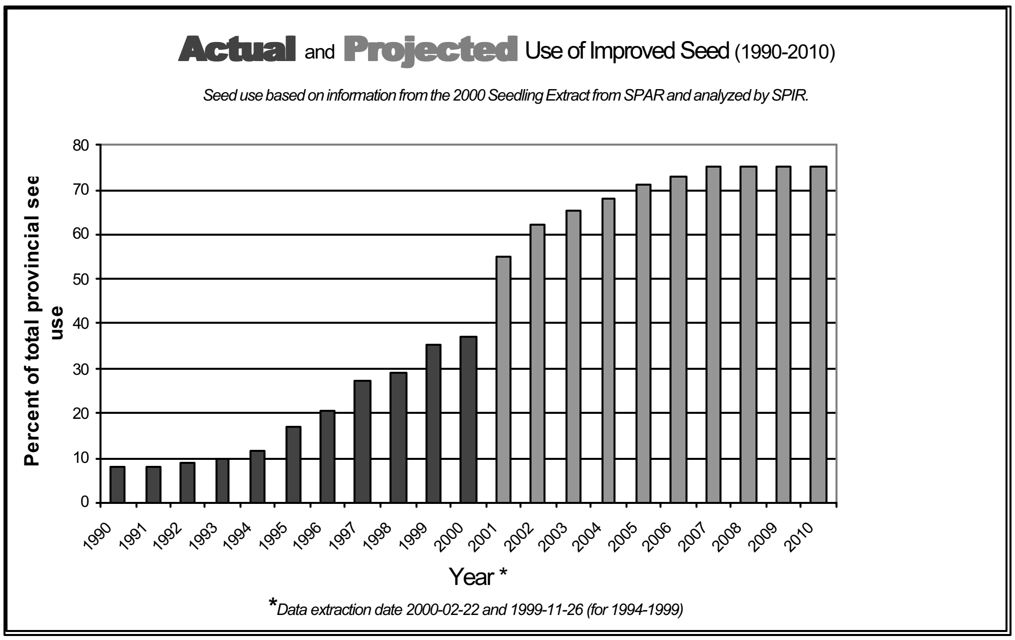
Introduction

Dale Draper, and Shane Browne-Clayton, Co-Chairs, Forest Genetics Council of British Columbia

This report marks the third anniversary of the Forest Renewal BC–sponsored Operational Tree Improvement Program (OTIP) delivered by the Forest Genetics Council (FGC). The operational program enhances existing tree improvement investments in British Columbia, and moves toward the FGC goals of:

- doubling the average gain in potential harvest volume (from 6% to 12%), by using improved seed;
- increasing the use of genetically improved seed to 75% of total provincial sowing by 2007;
- managing a gene conservation program to maintain genetic diversity in commercial tree species; and,
- supporting the long-term production capacity needed to meet the priorities of the FGC's business plan.

The Seed Planning and Registry System (SPAR) is the means used by the FGC to track progress toward operational seed production goals. Province-wide improved seed use increased to 37% of the total year 2000 sowing requests.



This percentage use is somewhat below expectations, and can be traced to low improved seed yields from lodgepole pine seed orchards in the Okanagan. These pine orchards are just reaching production age, but have not yet provided the expected seed yields. Possible reasons for this delay in production are under-active examination by the FGC, and include ministry and university researchers, and seed orchard managers.

Introduction *(cont'd)*

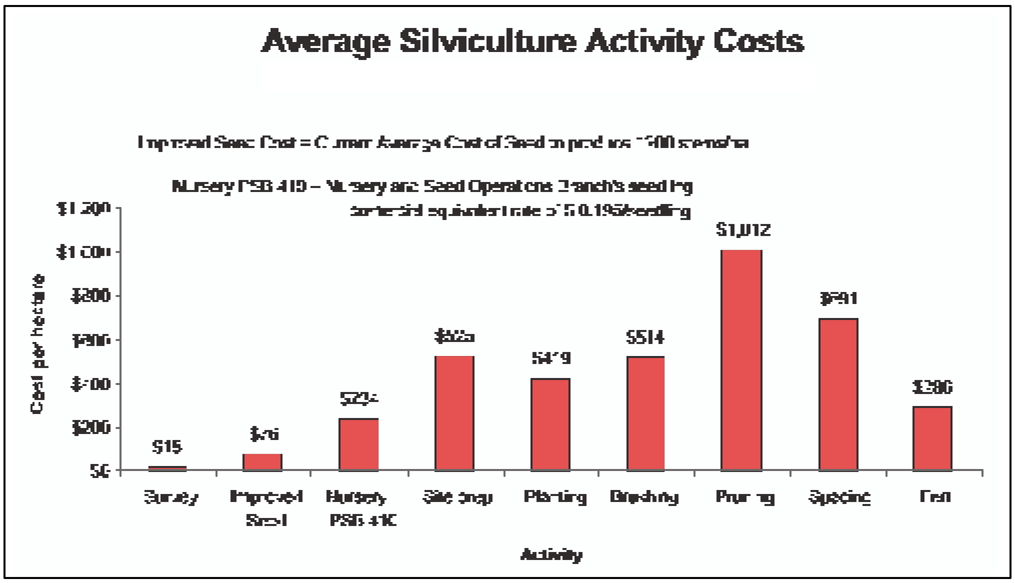
Increases in select seed availability include an early crop of larch seed from ministry seed orchards, which met nearly half of the year 2000 larch sowing requests, and an increase in western hemlock select seed sowing, of nearly 10% over the previous year.

Another major objective of the FGC program is to continually improve the genetic worth (GW) of seed lots used in reforestation in British Columbia. Average select seed GW, at the onset of the FGC 10-year-plan (1997-2007), was 6%. This means that this material could be expected to produce 6% greater volume at rotation age than standard seed.

Data from the year 2000 sowing year indicates that average GW is now approaching 8% and is on track with the 12% goal set for 2007.

Tree improvement remains an attractive forest management investment due, in part, to the relatively low cost per hectare of select seed. Average Silviculture Activity Costs have been updated to reflect costs shown in the 1997/1998 Ministry of Forests Annual Report.

This report discusses activities of interest to land managers concerned with forest productivity, and with the importance of



short and long-term fibre supply at competitive prices. Whether your goals originate from Enhanced Forest Management Pilot Projects, or the Innovative Forest Practices Agreement, or, more broadly, from Jobs and Timber Accord – Fibre Targets, or British Columbia's Incremental Silviculture Strategy – operational tree improvement has a place in your strategy. The FGC appreciates the continued support of the forest industry, academia, the Ministry of Forests and Forest Renewal BC. Each of these stakeholders plays a critical role in the planning, development, funding and implementation of this program.

The FGC invites you to review the projects described in this report and to return questions or comments to:

The OTIP Project Administrator
Ministry of Forests
Tree Improvement Branch
PO Box 9518 STN PROV GOVT.
Victoria BC V8W 9C2

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1.0 Forest Genetics Council - Future Direction

1.0 Forest Genetics Council (FGC) and Forest Renewal BC (FRBC) Tree Improvement Program - Future Direction

Jack Woods

FGC/Forest Renewal BC Program:

FRBC recognizes the importance of the genetic resource to the long-term well-being of the British Columbia forest environment and economy. The multi-stakeholder FGC business planning process guides the investments in this important area. This provides stakeholders, represented in the FGC, with substantial input to FRBC investment priorities.

FRBC has invested in forest genetics activities since its inception. In 1998, the FGC provided FRBC with a 10-year plan that outlined investments needed to meet Council objectives through to the year 2007. FRBC has agreed, in principle to support this ten-year plan, and has subsequently developed its Tree Improvement Program. This program moves funding through three administrative paths:

- Operational Tree Improvement Program
- GenSeed (for orchard expansions)
- Gene Conservation

The Operational Tree Improvement Program (OTIP) is a component of the Ministry of Forest's (MoF) *Forest Renewal BC Contribution Agreement*. Project approval decisions in the OTIP program are delegated to FGC committees, and the MoF administers the financial disbursement process.

Forest Renewal BC Due Diligence:

FRBC investments are directed to advance their corporate objectives, while meeting technical and fiscal standards. Consequently, FRBC has hired a program monitor, to work with the FGC and associated groups, and to develop and track progress through performance monitoring and management.

A performance monitoring system was set-up on behalf of the FGC, to meet requirements of FRBC, and is reflected in the 2000/01 OTIP Call for Proposals.

This performance monitoring system covers all tree improvement work funded by FRBC. The performance monitoring system breaks activities down to logical groups such as gene conservation or seed production (see Figure 1). These groups are further subdivided to more specific activities. Within each activity, simple performance indicators are developed to measure progress. These performance indicators will simplify reporting for project proponents, and allow quantitative measures of progress within each activity across multiple projects.

Reporting on projects in the 2000/01 fiscal year will be at six-month intervals. Reports will use performance indicators, with further detail required only where planned progress deviates substantially from actual progress, and for technical support projects, which do not fit readily into the system of performance indicators. At a provincial level, reports will take two basic forms:

- Planned and actual progress by activity group, summed across all provincial projects.
- Improved provincial seed use and average genetic gain.

Seed Planning Units:

During 1999, Species Committees, working under the Coast and Interior Technical Advisory Committees, became increasingly focussed on a comprehensive strategy for each Seed-Planning Unit. These strategies guided OTIP review committees in their evaluation of projects for the 2000/01 fiscal year. Standardized species plan formats will continue to be used, allowing development of a comprehensive Forest Genetics Council Business Plan.

In the 2000/01 fiscal year, planning will begin for 2001/02. For all activities within the Tree Improvement programs (WBS 200 and 300 levels), the species plans, produced by Species Committees, will form the basis for funding provided by the FRBC Tree Improvement Program.

This process allows broad stakeholder input at the most basic level of planning. Species plans will also describe progress expectations for the amount and genetic quality of material produced. It is against these expectations that actual progress will be measured.

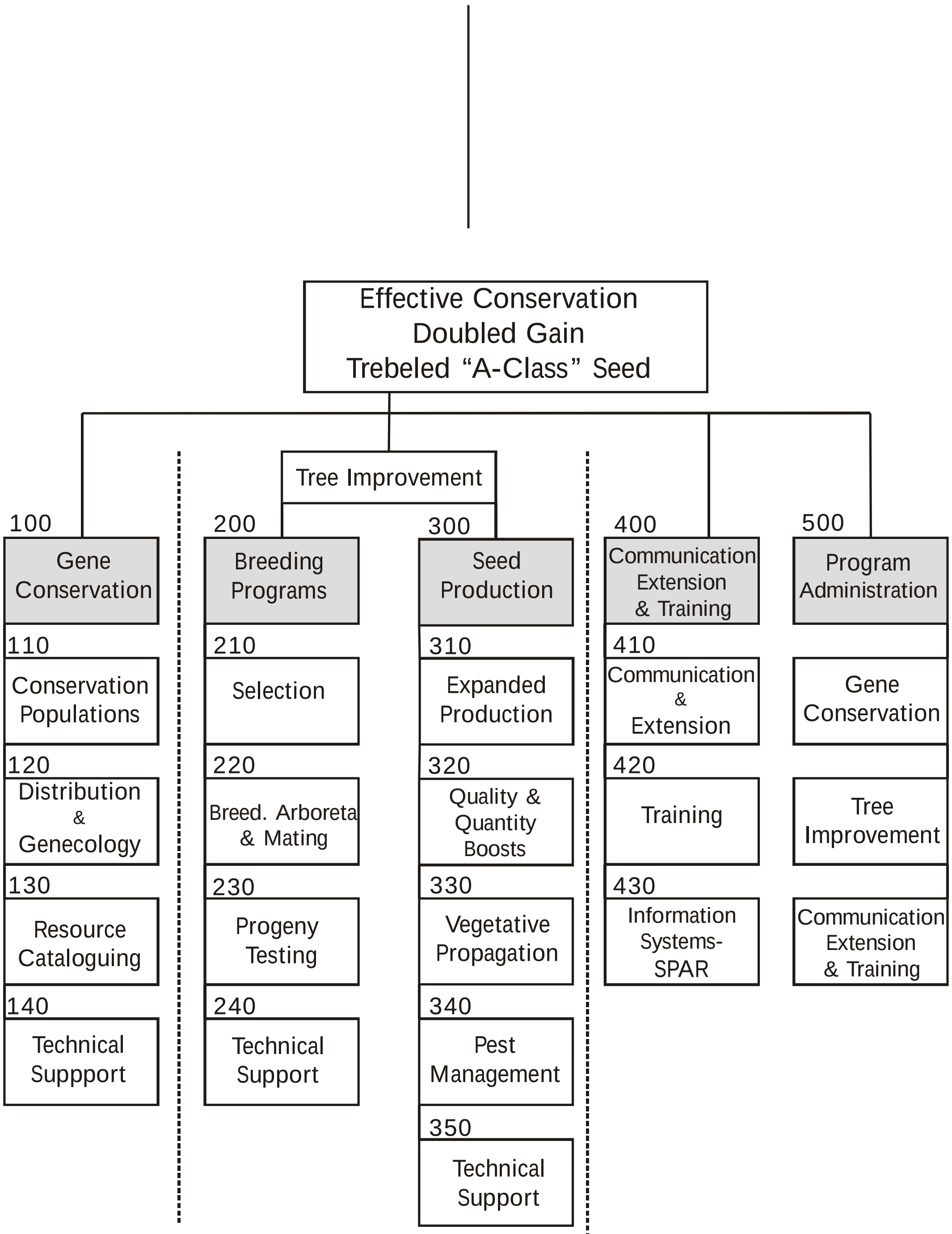


Figure 1. Work breakdown structure for forest genetics activities.

2.0 The Call for Proposals

2.0 The Call for Proposals

Roger Painter

In 1999/2000, the Operational Tree Improvement Program Call for Proposals was issued on November 23,1998. A wide audience of interested individuals and organizations associated with tree improvement was mailed copies of the Call for Proposals. The distribution list was kept as broad as possible, and included people associated with universities, the forest industry, the provincial and federal governments, private research organizations and individuals. This document is traditionally sent out as early as possible to allow for proper business planning, and to ensure that funds will be available for the early spring, when a large portion of the key biological activities occur. Proponents put in 153 proposals, totalling $5.1 million in 1999/2000. This is down from the previous year ($5.4 million), and is due, in part, to a better definition of the application criteria to follow Council's goals and priorities. Council approved approximately $3.7 million in 128 projects. The review process followed a similar approach to previous years with both Coastal and Interior Technical Advisory Committees striking review committees to technically evaluate the numerous proposals.

3.0 Evaluation Criteria

3.0 Evaluation Criteria

Roger Painter

Evaluation of proposals is done by committees from the Coastal and Interior Technical Advisory Committees of the Forest Genetics Council. Final ranking of proposals is consistent with the investment priorities.

Since the first year evaluation, priorities have been altered to place greater focus on impact and value of the products produced. The committees were asked to rate the proposals according to the three criteria as listed:

Cost Effectiveness	30%
Impact and Value of the Product	50%
Feasibility or Chance of Success	20%

Cost Effectiveness - 30%:

Where innovative approaches were used, a detailed description of the technique was required. Questions to be considered:

- Are the cost per unit or overall costs comparable to the per unit or overall costs of current accepted alternatives?
- Are the budget figures in line with normal acceptable operating costs?
- Is the project financially viable? Can it be done for the amount specified?
- Is the proponent contributing in a meaningful way to the project, in terms of financial and/or manpower resources?

Impact and Value of the Product - 50%:

Evaluation of the products that will be produced, the need for the product, and the impact or value. Questions to be considered:

- Does the product meet an immediate and specific seed need?
- Does the product improve the overall ability of the program, or the ability of the orchard to produce greater amounts of, or better quality, material?
- Does the proponent have the support of a seed user?

Feasibility or Chance for Success - 20%:

Evaluation of the technical feasibility of the proposal based on current practices, knowledge, and available research, and the chances for success.

3.0 Evaluation Criteria (cont'd)

Questions to be considered:

- Is the proposal technically sound?
- Is it based on current, accepted techniques or sound published research?
- Is the time frame realistic?
- Are the resources requested (and provided) adequate for the project?

In addition, the reviewers evaluated the capabilities of the proponents to implement the proposal. If the capabilities of the proponents were deemed to be inadequate for meeting the stated goals and objectives, then the proposal was disqualified from further consideration.

Following the review meetings, the results from the two committees were presented to the FGC. The FGC received the recommendations of the Review Committees in early March, ratified their findings and passed them on to FRBC for final approval.

4.0 Project Rating

4.0 Project Rating

Roger Painter

91 to 100 points: Excellent

- Provides specific opportunities that meet investment priorities and provides improved material in areas that are in specific need.
- Includes, and is targeted to meet, specific seed users' needs.
- Is both cost-effective and involves use of proponents' own resources.
- Is well thought out and technically sound.
- Excellent team capabilities which either includes seed users or evidence of their support.

81 to 90 points: Very Good

- Provides improvements to specific aspects of listed priorities for investment in tree improvement and/or geared to general benefits and long-term goals.
- May not meet specific seed needs in the short term, but clearly enhances orchard capabilities for improving genetic quality and quantity over time.
- Is cost-effective with a technically sound action plan.
- Includes some resources supplied by the proponent and is supported by good, balanced team capabilities.

65 to 80 points: Good

- Provides improvements to general aspects of priorities of tree improvement.
- Will be geared to general benefits and long-term goals.
- Provides for improvements to general production and quality (in relationship to orchard capabilities).
- Is both cost-effective and technically sound with a capable project team.

50 to 64 points: Fair

- Likelihood of funding is very low.
- Lacking some aspects of the key elements of criteria.
- Lacking in terms of meeting priorities and goals for general or specific tree improvement investment (may not be completely suitable for funding).
- Likely requires some changes before being funded.
- Projects may be related to production of seed where seed requirements are adequate, but supply of specific lots may be advantageous, or where low increases in genetic worth are advantageous.

Below 50 points: Poor

- Not recommended for funding.
- Lacking in two or more areas of criteria.
- Poor relationship to overall priorities.
- Poor cost relationship compared to the benefits obtained.
- Poor time lines with doubtful ability to deliver as planned.
- Product does not provide improved benefits to current situations.

The final decision on the funding of projects rests with the FGC and is based on program priorities and the availability of funds.

5.0 The Third Year in Review

Roger Painter

Three years of investment from Forest Renewal BC has provided a much needed boost to tree improvement in BC. It has allowed for a steady source of funding and helped move our industry towards its overall objectives. This is a long-term program that will provide greater economic stability to the forest industry, over time. It will also help mitigate long term timber supply issues, and has the potential for adding increased genetic and ecological diversity to our forests. Forest Renewal BC has strongly embraced investment in tree improvement, recognizing these values. It continues to maintain a strong level of funding in 1999/2000. This year, a total of 122 of the 155 proposals were recommended by technical review committees for funding. The total amount of proposals received was just over $5.4 million, which is consistent with last year. Slightly over $3.7 million in proposals were approved.

This program is divided into Coastal, Interior and Provincial regions. Funding for each is fairly evenly distributed between these areas. Although the Coast represents a smaller area overall, the tree improvement programs in this region are more advanced and diverse. The Interior, however, did receive a substantial amount of funding and will be expanding in the future. The breakdown by region is as follows

Number of Projects and Funding by Region		
Interior projects	64	$1,460,315
Coastal projects	43	$1,725,669
Provincial related projects	15	$574,322
Overall Total	122	$3,760,306

As with the first two years, the support provided is consistent with the early phases of investment that the Forest Genetics Council (FGC) has identified as necessary. Breeding and Testing will continue to receive considerable funding in the early years of the program. Considerable genetics development is needed to provide the necessary production stock for new orchards that will provide seed for the various Seed Planning Units where capacity is low, and/or where priorities for genetic quality seed are high. It will also help produce stock to replace older less advanced orchards. With the development of a long-term investment program through *Genseed* starting in 2000/2001, work in Breeding and Testing, will make sure that the necessary genetic material is available to establish the new orchards that are expected in the very near future. Technical Support is an integral part of tree improvement. Tree improvement has a strong need for constant development of better methods for operationally delivering its product. Operational Production provides support for increasing and enhancing existing crops. A project breakdown by areas of investment is as follows:

Number of Projects and Funding by Area of Investment		
Breeding and Testing	30	$1,838,329
Operational Production	54	$738,372
Technical Support	29	$992,584
Gene Conservation	4	$122,530
Communications and Extension	5	$68,491

There are many partners in the tree improvement industry. These include forestry companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies, and individuals. The Operational Tree Improvement Program included 41 separate proponents representing all parts of the industry. With the work that has gone into preparing its goals and priorities, the FGC has provided direction to the technical advisory review committees (TAC's) for selecting acceptable proposals. As a result, the approved proposals reflect the direction that the Council has indicated for meeting those goals. The Council, through its TAC's, has continued to review and update its planning documents. The initiation of Species Planning Units (SPU) (see Appendix 2) is a good example of the intensity of effort and change, that are necessary to better define the business planning required to successfully manage a diverse provincial program, and partner with Forest Renewal BC.

The proposals submitted for funding under the 2000/2001 Call for Proposals have recently been reviewed, and another year of operational projects will start this spring. This is the fourth year of the program, and with the introduction of SPU's, and an improved business management process in place, this coming year's proposals have close links to the long-term goals and objectives set out by the Council. To complete the final and long-term goals of the Operational Tree Improvement Program, the final phase of initiating new orchards through *Genseed*, is awaited.

6.0 Project Descriptions

6.1 Breeding and Testing

Projects funded under this section involve identification, development, and production of genetically improved sources of material for reforestation. It also involves the study and development of techniques and genetic processes for improving breeding capabilities and methods.

6.1.1 Twenty-Year Assessment of Long-Term Grand Fir Provenance Tests

Cheng C. Ying

Progress:

Four long-term provenance tests were established in 1981 (one near Chilliwack and three on Vancouver Island). The 20-year measurement will be completed before March 31, 2000. The results will provide the information basis for seed transfer guidelines update, selection of superior provenances and gene conservation. Grand fir occurs in small and isolated stands , or as a minor component in mixed stands, and thus vulnerable to population extinction. The primary seed source area along eastern Vancouver Island is particularly vulnerable due to urbanization. Its conservation should be the first order of concern. [OTIP 400]

6.1.2 Screening Western Redcedar for Natural Durability

John Russell

Background:

Currently, 12 million western redcedar are planted annually in BC. Natural durability of these future second growth cedars is of concern. Tropolones (a group of compounds found in plants), in particular the thujaplicans, have been strongly correlated with decay resistance. It thought that old growth trees are, on average, more durable than second growth because of higher concentrations of tropolones. However, the tropolone content of both old and second growth western redcedar show considerable phenotypic variation from tree to tree, with some second growth trees showing as much as old growth. There is the potential for selecting second growth trees with higher than average tropolone content, resulting in enhanced durability similar to average old growth trees. These selections can be incorporated into breeding and seed production populations, ensuring minimal failure in future durable redcedar products from second growth trees.

Objectives:

The objective of this project is to screen western redcedar clones for enhanced natural durability by analyzing wood cores for tropolones (in particular the thujaplicans) using chemical analysis, and rot resistance using wood blocks inoculated with fungi. 300 clones from 18 year-old parent trees will be screened for natural durability. Six copies from each clone, one half from the respective seed orchard (Mt. Newton, Lost Lake) and the other half from clone banks at CLRS, will using fungi block tests. Data will be analyzed for genetic differences in natural durability among clones, and clonal values will be calculated.

Results:

Over 40 trees have been sampled for potential durability extractives, using wood discs collected at breast height and at regular intervals up the stem for a subsample of trees. Analyses of the data from these samples have yielded the following interesting observations:

- Significant phenotypic variability in individual extractives.
- Some second growth trees have extractive levels greater than some old growth trees.
- Consistent rankings among trees across stem positions for extractive levels.
- No correlation between growth rate (ring area) and extractive content (Figure 2).
- Ten-year-old trees from progeny trials have heartwood with measurable amounts of extractives.

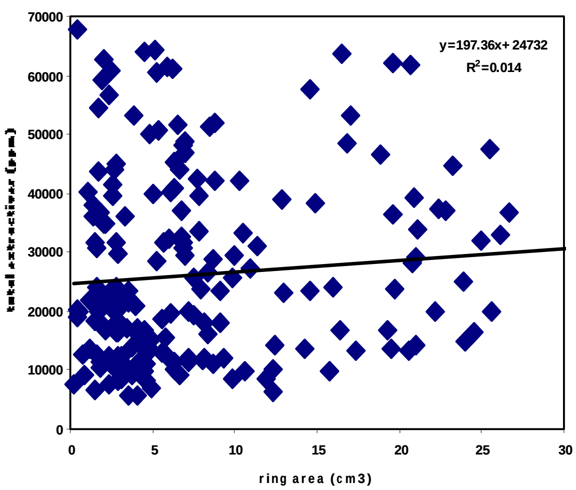


Figure1. Total heartwood extractives and average ring area for second-growth western redcedar

The above results give us confidence in analyzing durability extractives, using increment cores taken from 20-year-old parent tree clones. Sampling is currently ongoing. It is anticipated that, at the end of this project, we will have clonal values for durability for 300 parent trees. These values can be incorporated into second-generation orchard and breeding populations. [OTIP 392]

6.1.3 Western Redcedar Genetic Tests for Identifying Elite Populations

John Russell

Background:

Twelve million western redcedar seedlings are planted annually in BC. Of this, nine million are planted in the wet maritime under 600 metres, which is the target area for the Coastal industrial seed orchards. These orchards provide up to 100% of the seed to meet the reforestation needs in this area. Currently, genetic gain in volume growth for these first generation orchards is estimated at 2%. An FGC-endorsed western redcedar breeding program involves progeny testing of 600 polycrossed parent trees. Selection of the top parents in existing orchards, or developing new 1.5 generation orchards based on progeny testing, will result in a 1-year reduction to reach free growing minimum heights on productive redcedar sites (TIC Progress Report to 1996), and a 10% to 15% volume gain at rotation for western redcedar reforested sites. Improving or maintaining the wood quality of elite redcedar populations will also be a priority.

Objective:

The objective of this project is to provide up to 100% of the low elevation wet maritime western redcedar seed needs with genetically-improved seed. This will deliver 10%-15% volume gain and reduced time, until free growing by the year 2005, through: i) progeny testing of existing seed orchards, and ii) roguing of existing orchards, or developing new 1.5 generation orchards based on 5-year test results.

Progress:

Four annual series of trials, each composed of 150 families whose female parent has been crossed with a mixture of 20 unrelated males, will be established in low elevation wet maritime sites. Included in each annual series of tests will be five groups of wild-stand seedlots (each group containing three seedlots) from representative biogeoclimatic subzones for i) checks across sites and series, ii) comparisons to select families, and iii) as a baseline for measuring adaptive responses to environments. In addition, each year one or two smaller sites with a subset of families and all of the controls, will be planted at higher elevations in the wet maritime seed planning zone or in the submaritime seed planning zone.

This year's project was the third of four annual series of western redcedar polycross progeny trials. Three main sites were planted on low elevation coastal sites using an incomplete block design with 15 tree blocks, 10 blocks per replication and 35 replications. The sites were located at:

- Jordan River (200m), WFP South Island Division.
- Rainbow Main (300m), MB Powell River Division.
- Rupert (250m), WFP North Island Division.

Three smaller sites were established at:

- Callahan Creek (500m) in the south sub-maritime, WFP South Division.
- Copper River (650m) in the north sub-maritime, Skeena Cellulose Terrace Division.
- Copper Bay (100m) in the Queen Charlottes, J.S. Jones.

All sites will be maintained to minimize competition and deer browsing.

The first series of sites were well maintained and had excellent survival with no deer browsing. It is anticipated that five-year growth data will be collected from each series, and orchards upgraded based on calculated breeding values. [OTIP 393]

6.1.4 Physiological Measurement and Screening of Selfed Western Redcedar

Steven Grossnickle, Raymund Folk, Shihe Fan, and John Russell

Background:

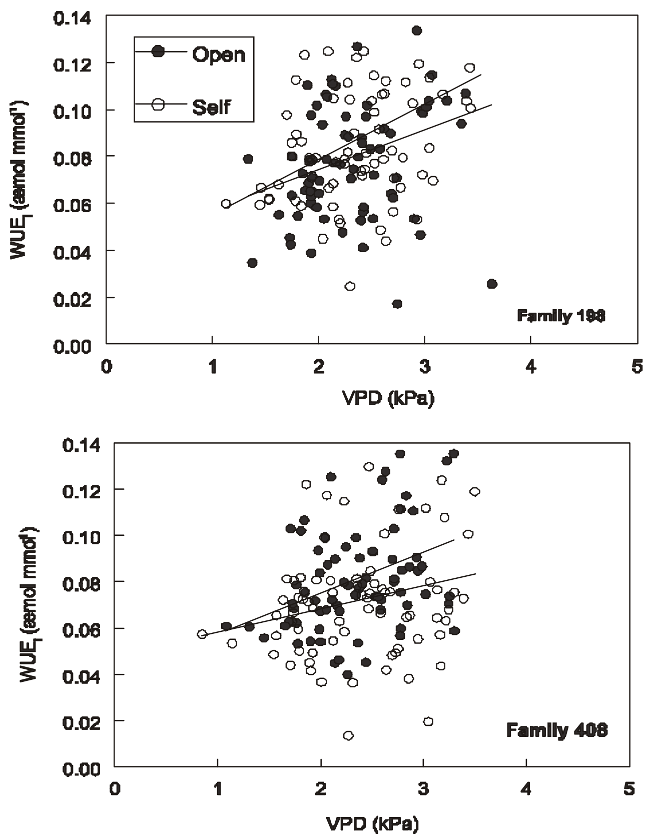
Inbred western redcedar has reduced fitness that is not measurable until seedlings are in their third to sixth year of growth. It is hypothesized that inbred families, compared to outcrossed families, are more sensitive to environmental stress. Site limitations of water and nutrients are considered the primary environmental factors that affect the physiological performance and subsequent growth of plants throughout the growing season. Inbred families are believed to perform poorer under conditions of resource (i.e. water and nutrients) limitations. This hypothesis is based on the presumption that, as trees grow bigger, internal competition for resources intensifies, which disturbs physiological functioning and subsequently causes reduced growth. Exactly how inbreeding affects the overall fitness of inbred plants is not well understood. By defining the physiological mechanisms of inbreeding depression, one would be able to quickly identify western redcedar populations that have inbreeding depression prior to a reduced growth response that is detected in older field trials.

Objectives:

- To define the physiological mechanisms underlying inbreeding depression for growth, under a range of environmental conditions, during the summer growing season.
- To examine gas exchange responses to vapor pressure deficit (VPD) during the summer growing season, on a field site located near Jordan River.
- To sample foliage used for gas exchange measurements for determination of carbon isotope discrimination values.
- To measure and select families based on their level of inbreeding depression occurring over seven years of shoot growth.
- To select five families with inbreeding depression values ranging from -1.5 to 30.2 for height growth, and –9.4 to 47.1 for diameter growth.

Results or End Product:

Gas exchange response of western redcedar families varied in their performance. For example, family 198, which had a low level of inbreeding depression (i.e. -1.5 and –7.2 for height and diameter growth, respectively), had similar or higher levels of seasonal water use efficiency patterns (Figures 3a & 3b). In contrast, family 408, which had a high level of inbreeding depression (i.e. 30.2 and 47.1 for height and diameter growth, respectively), had similar, or lower, levels of intrinsic water use efficiency. Further data analysis is currently underway to develop detailed gas exchange models, and relate this information to carbon isotope discrimination values. [OTIP 394]



Figures 3a & 3b . Gas Exchange Response of Two Cw families

Figures 3a & 3b show intrinsic water use efficiency (WUE_i) response to VPD for western redcedar from different families with low (198) and high (408) inbreeding depression values. Measurements of WUE_i were taken at photosynthetically active radiation (PAR) levels >800 mol m^{-2} s^{-1}.

6.1.5 Douglas-Fir Second-Generation Progeny Testing (Maritime SPZ)

Jack Woods, Norm Pomeroy and Keith Bird

Progress:

In the spring of 1999, the first series of second-generation coastal Douglas-fir progeny tests were established. In the second year (1999/2000) of this project, funding was provided to maintain the six test sites and to complete field marking and mapping. To date, all sites have been brushed and weeded, and trees are free-growing. Two sites were sprayed to control grass competition. All sites are mapped, and establishment reports are complete. Additional work to be done in this fiscal year includes completing the establishment of permanent location markers, and the fencing of one site which is at a high risk of being browsed by deer following spring flush. [OTIP 395]

6.1.6 Monitoring Second-Generation Coastal Douglas-fir Selections at Age 20+ to Reduce Risk Associated with Juvenile Selection Ages

Greg O'Neill, Jack Woods, Keith Bird and Norm Pomeroy

Background:

To increase average genetic gain per year, trees are generally selected at ages younger than full rotation. Monitoring the growth and form development of selections made in progeny tests, allows corrective action should any selected trees develop undesirable traits after the time of selection. Monitoring also assists in the development of selection strategies that maximize long-term gains.

Objectives:

This project consists of two parts:

- Form assessment methodology: a form investigation, previously done at ages six and nine on three test sites in the EP708 diallel program, is being redone at age 25. Growth data are also being collected, and trait correlations calculated. The objective is to refine stem-form assessment techniques.
- Re-assessment of second-generation selections: forward (offspring) selections from two series of the EP708 diallel program are being re-assessed at age 25 for both growth and form traits. The objective is to determine the reliability of age 13 selection methodology, and what changes, if any, are required.

Progress/Results:

In part one of the project, correlations among all growth traits are generally high, both within and between measurement ages. Family differences, investigated for both growth and form traits, were observed at all ages. Correlations between growth and form traits were moderate (about 0.40) and positive (unfavourable), indicating that selection for increased growth must consider form, to avoid negative impacts on form potential. These findings are consistent with investigations of Douglas-fir growth and form done in Oregon, where form defects are more prevalent than in coastal BC.

In part two of this project, test sites used for forward selections are being re-assessed for growth and form traits at ages 25 (EP708 Series 1) and 23 (Series 2). Selections made at age 13 will be compared with selections that would be made using age 25 (or 23) data, to determine the reliability of age 13 selections. Recommendations will be made concerning selection methodology on young trees for both growth and form. [OTIP 397]

6.1.7 Maintenance of High Elevation Douglas Fir Progeny Test Sites

Patti Brown

Progress:

The two high elevation Douglas-fir progeny sites, outplanted in 1997 on TFL 37 (Nimpkish), were checked for survival, and encroaching slash/brush was removed. Progeny are doing well except for a small area on one site that was subject to animal damage in the early spring. Survival is still greater than 95% on both sites. The heavy snowfalls of the 1998/99 winter caused a slight lean on many of the seedlings and some slash movement, but there was no permanent damage. [OTIP 384]

6.1.8 Planting, Brushing, Maintenance and Measurement of Interior Spruce Genetic Tests

Barry Jaquish

Objectives:

- To brush, maintain, prune and, if necessary, irrigate 33 Interior spruce progeny tests and demonstration plantations throughout the Interior.
- Measure tree height and condition on 14 sites.
- Plant three second-generation full-sib progeny tests in the Bulkley Valley (BV) seed planning zone.
- Plant four first-generation open-pollinated (OP) progeny tests in the Peace River (PR) seed planning zone.

Results and Deliverables:

Routine site maintenance was completed, as planned, by contract crews on the 33 sites. Three and ten-year tree height and condition were recorded for the Prince George/East Kootenay second- generation tests (3-year) and the Series 1 Thompson Okanagan polycross tests (10-year), respectively. Data analysis is complete for the Thompson Okanagan series and new parental breeding values have been estimated by Best Linear Prediction (BLP). The existing Thompson Okanagan seed orchard will be redesigned, based on these results.

Seven new test plantations were established for the BV and PR zones. The BV second-generation test series was established on three sites using an alpha incomplete-block design, with eight replications of 14 blocks of 10 full-sib families from the old EP670 Prince Rupert Selection Unit. Experimental units consisted of two five-tree row plots with trees planted at 2 x 2m spacing.

The Peace River OP test was established on four sites using the same alpha incomplete-block design with eight replications of 15 blocks of 14 families. The test population included 102 Ft. Nelson OP families, 21 previously tested Hudson Hope OP families, 40 select OP families from Peace River, Alberta, 20 select OP families from Quebec, and 16 operational control seedlots from the Peace River region of BC and Alberta. Experimental units consisted of four-tree row plots with trees planted at 2 x 2m spacing. The Alberta test material was included as part of the Tree Improvement Research Memorandum of Understanding between BC and Alberta. Two of the new PR sites were also manually brushed in late summer to remove competing vegetation. [OTIP 340]

6.1.9 Brushing, Maintenance and Measurement of Interior Douglas-Fir Genetic Tests

Barry Jaquish

Objectives:

To brush, maintain, measure tree height and record tree condition on eight Interior Douglas-fir progeny tests in the Prince George (PG) and Quesnel Lake (QL) seed planning zones, and three research plantations.

Results and Deliverables:

Brushing and site maintenance on 11 sites was completed as planned by contract crews. Ten and 15 year tree height and condition were recorded for sites in the QL and PG seed planning zones, respectively. Data analyses are in progress. Results will be used to estimate new parental breeding values and to rogue seed orchards. Site maintenance was also completed, and six-year tree height was recorded for three sites in the Interior Douglas-fir elevational transect study. This study explores growth and adaptational differences among populations separated by 50m of elevation, along three elevational transects in the Nelson (formerly Shuswap Adams) SPU. Data analyses are in progress. Results from the study will be used to refine Interior Douglas-fir seed transfer guidelines and SPUs. [OTIP 342]

6.1.10 Screening High Breeding Value Interior Douglas-Fir Parents for Resistance to Armillaria Ostoyae

Barry Jaquish and Mike Cruikshank

Background:

Armillaria ostoyae is a root disease that has serious ecological and economic impacts in the Interior Cedar-Hemlock (ICH) zone of the southern Interior. In many ICH forest stands and plantations, Armillaria infection results in high mortality and significant loss of tree growth. Current expenditures on Armillaria control and stand management in heavily infected areas are enormous. Over the last decade, the planting of Douglas-fir, a desirable high-valued species in which tree breeding programs are in place, has declined considerably, primarily because of its high susceptibility to Armillaria.

Since 1985, knowledge about Armillaria biology has increased dramatically; however, the development of efficient, cost-effective control methods are lacking. Current control measures include using more resistant species, inoculum removal, avoiding hazardous areas, cultural manipulation and integrated biological methods. Unfortunately, in many areas, the efficacy of these measures is low and unpredictable.

To date, no effort has been directed towards studying genetic resistance of Armillaria in Interior Douglas-fir, and developing resistant breeds for planting. Although breeding for genetic resistance is a complex science involving genes in the host species, the pathogen, their interaction with environments, and any progress in developing Armillaria resistant Douglas-fir breeds, would be valuable.

Objective:

The objective of this joint, multi-year project is to screen a number of families derived from high breeding value Interior Douglas-fir parents from the ICH zone for resistance to Armillaria ostoyae. It will use the method of inoculating young trees in containers, a technique that has been relatively successful in recent investigations of root disease in other forest and fruit tree species.

Progress:

This year's effort consisted largely of growing seedlings and preparing Armillaria inoculum blocks. About 50 seedlings from each of 133 open-pollinated family seedlots were grown in Styroblock 415B containers at the Kalamalka Forestry Centre. The 133 families originated from high breeding value parents from the old Shuswap Adams, West Kootenay Low, West Kootenay High, and Mica seed planning zones. About 3,500 birch inoculum blocks were also prepared at Forestry Canada Pacific Forestry Centre. In spring 2000, about 25 seedlings per family will be repotted with a single blank inserted in each pot, and grown for one year. In spring 2001, inoculum blocks will be inserted in the hole left by the blank in each pot. The test trees will then be monitored, for several years, for mortality. [OTIP 344]

6.1.11 The Genetic Improvement of Western Hemlock

Charlie Cartwright

Background:

Hemlock tree improvement in British Columbia commenced with selection of parent trees and provenance testing (seed transfer trials) in the 1960's. This was followed by progeny testing to select best parents for growth traits to include in seed orchards, which continued into the early 1990's. It became apparent that for orchard seed to be used, it had to offer sufficient gain to offset the cost advantages of natural regeneration. Considerable progress could be achieved with the 300 hemlock families then in test, but diversity requirements, selecting for traits other than growth (wood quality), and inbreeding concerns, meant a broader genetic base was required. For this reason, MofF staff acted to bring about the formation of the Hemlock Tree Improvement Co-op, (HEMTIC), providing access to 1200 progeny tested first-generation parents from U.S. Pacific Northwest programs.

From starting materials provided by HEMTIC, an advanced generation breeding plan was devised. A broader based trial series, utilizing 30 parents from each of the five testing regions: BC, North Washington Coast, South Washington Coast, North Oregon Coast and Mid Oregon Coast, was designed. This series, designated F-1, tests the level of adaptation of materials from across the co-op on all members' lands, and provides materials for recurrent selection. A second set of trials, the "elite" tests, uses only the best six parents from each program to permit construction of a very high gain seed orchard in the near future. To date, there are seven F-1 tests and four elites outplanted in BC.

The F-1 and elite trials will provide for selection of best parent tree, but several satellite trials at the margins of the seed zone are needed to develop appropriate seed transfer guidelines for tested materials. As well, continued maintenance and measurement of older trials will provide more reliable estimates of genetic worths of first-generation parents still used in seed production.

Objectives:

- Maintenance of F-1 trials established in the two previous years.
- Establishment of four elite trials.
- Establishment of two seed transfer trials.
- Measurement and maintenance of older first generation installations.

Progress to Date (January 29, 2000):

Early in 1999, elite trials 2.9 ha (4000 seedlings) in size were established in the Klanawa Valley near Bamfield, on Stove Creek main near Sayward, at the mouth of the Tlupana River north of Gold River, and near Michelsen Point, in Holberg Inlet. Survival and map checks, plus maintenance (conifer release) of the tests, continued this year. Since few seedlings have died, it was possible to postpone replacement planting until spring 2000.

The F-1 installations have been more problematic. A considerable maintenance effort was expended, particularly for the 1997 and 1998 Jordan River trials, and the 1998 Kettle Valley site. In the fall, a large replant was undertaken for the Kettle F-1, and also fence repair was necessary. Because of these stocking problems, there were not enough replacement seedlings to fill out the 1998 test at Raft Cove.

Other activities include update measurements for realized-gain trials, and first generation tests established in 1979 (20 year height, DBH) and 1989 (10 year height, DBH). Program information was presented to the summer 1999 meetings of the Coastal Silviculture Committee, and the Stand Management Co-op, as well as for an extension meeting at Campbell River in December. Results of a nursery study of the effects of cultural treatments on A class seed, particularly best seed orchard families, was presented at the Forest Nursery Association of BC annual meeting in Vancouver, September, 1999.

Looking at current products may sum up progress in hemlock tree improvement. Several seed lots with gain in excess of 15% are listed at the provincial Seed Centre. Levels of improvement in growth traits are likely to increase as new data on the American families is obtained from measurement of F-1 trials next fall, and more reliable age 10 and 20 measurements are taken for earlier BC first generation series. [OTIP 390]

6.1.12 Genetic Variation of Adaptive Traits of Western Hemlock from the Hemlock Tree Improvement Co-operative

Raymund Folk, Steven Grossnickle, and Charlie Cartwright

Background:

Recent trials have shown that western hemlock sources from Washington and Oregon tree improvement programs have the potential for improved height and volume growth over local sources. Tested material from these sources became available to BC seed orchardists through the Hemlock Tree Improvement Co-operative (HEMTIC) which is organized into five programs: 1) British Columbia; 2) Forks, Washington; 3) Gray's Harbour, Washington; 4) Willamette, Oregon, and 5) Tilamook, Oregon. However, existing information is inadequate on the tolerance of the elite material to local climatic conditions to define and establish seed transfer guidelines. One of the objectives of this program is to determine the genetic variation in the freezing tolerance and gas exchange patterns of the elite material during fall/ winter acclimation, and spring deacclimation periods.

Activities:

Crosses to be measured were selected based on their representation of families from within a program or between two programs of HEMTIC. In most instances, five crosses from within and between the HEMTIC programs were selected for the experimental population. The only exception was for the within crosses for the Tilamook program, where only three crosses were available. In addition, seedlings from the BC standard and the Gray's Harbour standard populations were also included in the assessment program. Seedlings were set up in an outdoor experimental compound at the BC Research Inc. facility in late August. Collection of freezing tolerance data and seasonal gas exchange patterns, were initiated in mid-September on all of the crosses. Data collection is continuing on a biweekly basis.

Frost Tolerance and Fall Acclimation Pattern:

Figure 4 shows the index of injury (mean ± SE) at –10°C for three to five western hemlock families within each of the five HEMTIC programs during the fall of 1999. Data for crosses between programs are not shown.

Families from each of the five programs had similar fall acclimation patterns during the fall of 1999. All families commenced acclimation (index of injury at –10°C) in late September, and all attained maximum (< 10% index of injury) frost tolerance by late November. Frost tolerance levels were similar throughout the fall acclimation period, except for the mid-November

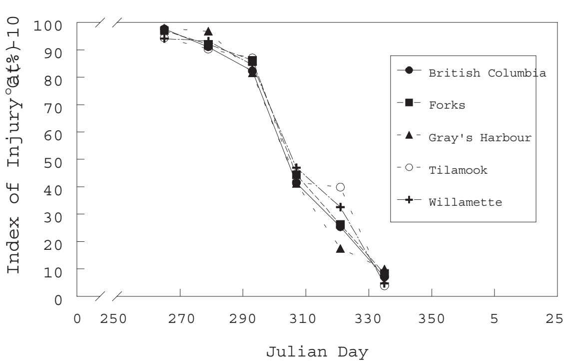


Figure 4. Index of Injury for Hw, Fall 1999.

(Julian day 321) measurement period, when families from the two Oregon programs had greater damage than families from the British Columbia and Washington programs. Index of injury at –10°C ranged from 17% to 39% during this measurement period, which is biologically significant. [OTIP 425]

6.1.13 Genetic Evaluation of Western Hemlock Breeding Population of British Columbia for Fiber Morphometric Traits

Mathew Koshy

Background:

This study will evaluate two series of families (Forks and MM79) in the BC breeding population for fiber morphometric traits. This evaluation is supplementary to a larger program in progress to evaluate wood quality traits in 100 other families, and will help rank the parental families and study the genetic effects and genetic correlations of the traits.

Activities:

The traits studied include:

- fiber length
- fibril angle
- relative density
- ring width (RW)
- number of cells per ring
- mean cell size (CS)
- mean double wall thickness (DW)
- mean DW/CS
- early wood percentage
- transition wood percentage
- late wood percentage
- Morks's index
- relative late wood percentage
- DW/CS ratio in early wood
- DW/CS ratio in transition wood
- DW/CS ratio in late wood

Measurements were carried out in 16-19 rings per tree, depending on the number of rings available for each tree at breast height.

Progress:

Ring measurements of 27 families and morphometric traits of 15 families were completed. Family means for morphometric traits have been calculated and analysis is underway. [OTIP 378]

6.1.14 Field Testing of Western Hemlock Cuttings with High Volume Gain
Patti Brown

Objectives:

The objective of this field trial is to compare the field growth and performance of hemlock cuttings and seedlings of the same stocktype and genetic makeup, to determine if cuttings are an acceptable alternative to seedlings for reforestation.

Activities:

The outplanting of this trial occurred in March of 1998 on five different coastal sites in each of the partners' operating areas, M&B, Western, Timberwest, Canfor, and Interfor. The average cutting and seedling heights were not significantly different at time of planting. Growth measurements two years after outplanting were taken in the 1999/00 fiscal period. The cuttings were shorter at all sites, and this was statistically significant at two of the sites. [OTIP 385]

6.1.15 Increasing Genetic Gain from the NST Pli (230) Seed Orchard through Progeny Testing.
Mike Carlson

Activities:

One hundred and nineteen orchard wind pollenated (WP) seedlots were grown representing parents in the Nass Skeena Transition (NST) Orchard (230) at Kalamalka Forestry Centre (KFC), as well as eight operational control seedlots from the NST, for outplanting on two prepared sites in the NST in spring 2000. This progeny trial will enable Orchard #230 to be rogued in order to increase genetic gains from future seedlots. [OTIP 402]

6.1.16 E. Kootenay Interior Lodgepole Pine Orchard Parent Breeding Values Estimation
Mike Carlson

Activities:

Thirty-four open pollenated (OP) families were grown, representing parents in the new East Kootenay (EK) Orchard, along with seven EK operational control seedlots for outplanting on three prepared sites in the EK in spring 2000. This progeny trial will enable the estimation of genetic gains in height and volume growth to be expected from the use of orchard seedlots in the future. [OTIP 345]

6.1.17 Realized Genetic Gain Trials to Quantify Productivity Increases from Genetic Selection in Lodgepole Pine
Michael Carlson, John Murphy, Lynette Ryrie and Vicky Berger

Background:

To date, productivity gains from selective breeding programs have been estimated from young open-grown trees in progeny test plantations. Accurate estimates of productivity gains on a per unit area basis for adjustment of growth models, and ultimately for timber supply area planning, are not available today. With increasing amounts of genetically improved planting stock being used each year, and the expectation that by 2007 approximately 75% of all reforestation will be with genetically improved seedlings, there is a need for per unit area productivity gain estimates for several commercial species.

Objectives:

For lodgepole pine in the a) central Interior and b) southern Interior, the objectives are:

- to develop generalized predictions of unit-area volume gains, for a range of genetic levels (three) from individual-tree progeny tests;
- to generate accurate growth and yield information from genetically improved stock, to calibrate growth models (TASS, etc.), including interactions among genetic gain, site index and stand density, and
- to demonstrate unit-area gains due to genetic selection.

Information pertaining to early realized genetic gain impact on green-up/adjacency issues, will be available by 2002, with the above objectives realized approximately by 2010 and beyond.

Activities:

- Permanent measurement plot boundaries were defined materially on the six Thompson – Okanagan sites during 1999.
- Six additional sites were selected, site prepared as required, and staked and readied for planting. The crop sown during the spring of 1999, will be planted in spring, 2000 in the Prince George Seed Planning Unit.
- The six sites chosen, followed the established protocols: two sites being of low growing potential, two medium and two high. [OTIP 347]

6.1.18 Screening Adaptive Traits of Lodgepole Pine Progeny from Elevational Crosses

Sylvia L'Hirondelle and Wolfgang Binder

Project Description/Overview:

This project supported the lodgepole pine operational breeding program. Seed orchards of lodgepole pine in the southern interior of BC include parents from an 800m elevational range. Progeny from intercrossing between different elevational sources may vary considerably in growth and adaptive traits. We screened adaptive traits to estimate genetic differences in growth potential and stress resistance (frost, drought, heat) of progeny in a nursery environment, and on field sites. Estimation of this variation will improve deployment decisions for sources from a wide range of elevations, and will help increase growth and decrease the risk of damage from environmental stresses.

Objectives:

- To determine how seedlings from different seed sources (elevational crosses) of lodgepole pine vary genetically in adaptive traits such as frost hardiness, drought tolerance, phenology, and growth patterns. This was done with nursery and field tests over two growing and fall acclimation seasons.
- To relate seed source genetic variation with geographical and site factors, and to estimate genotype by environment interactions. This information can be used to describe the climatic and microclimatic limits of seed sources from different elevations and elevational crosses.
- To make recommendations for possible changes to existing seed transfer and seed orchard seed-use guidelines, to increase potential growth and decrease potential damage from maladaptation.

Activities:

One-year-old seedlings of lodgepole pine were used for each of 16 elevational crosses (two each of high by high, low by low, high by low, and low by high, for each of two SPUs). Seedlings were transplanted into six sandbeds at Glyn Road Research Station in June 1999. They were watered and fertilized until late August, then half of the beds were given a four-week drought. Photosynthesis (CO_2 uptake) and quantum yield (chlorophyll fluorescence, an indication of photosynthetic potential) were measured during the drought. Beginning in October, needles were sampled from sandbed seedlings for frost hardiness testing on three dates. Needles were held at 4°C or frozen to three sub-zero temperatures in a programmable freezer. After thawing and pre-conditioning under bright light, then dark-adapting, we assessed freezing damage with quantum yield in the dark (QYD). Higher QYD indicates less damage (higher frost hardiness).

Freezing damage was also assessed on three dates in the fall for seven-year-old seedlings from three field sites (low, mid, and high elevation) near Salmon Arm. Needle samples from current growth were collected in the field and shipped to Glyn Road for freezing and subsequent QYD measurements.

Results:

Measurements of one-year-old seedling height in May showed that the low by low (LL) elevation crosses averaged 6 cm taller than high by high (HH) crosses, and seedlings from the Nelson sources averaged 5cm to 6 cm taller than Thompson Okanagan seedlings (Figure 5). Crosses between low and high (LH, HL) elevation parents were intermediate in height. Points shown are means of two replicate crosses for each type (LL, LH, HL, HH) ± 1 standard error.

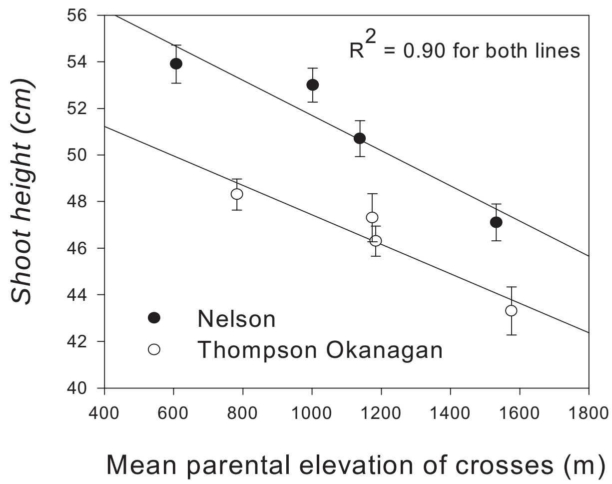


Figure 5. Seedling height versus elevation

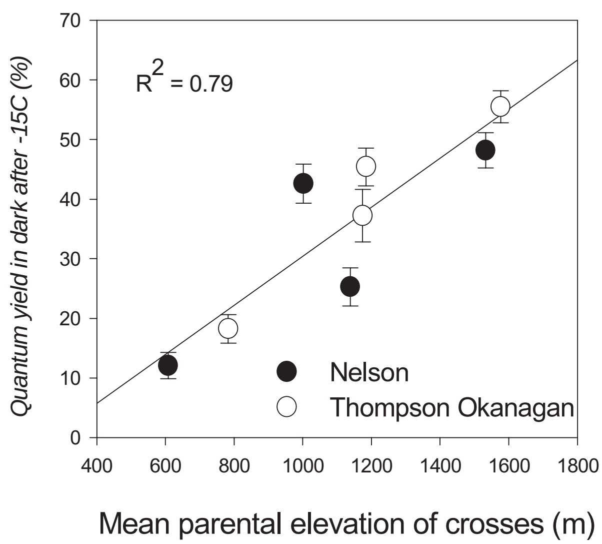


Figure 6. Seedling frost hardiness versus elevation

Before and during drought, QYD increased with source elevation with little difference between zones. Again, LH and HL crosses were intermediate between HH and LL crosses in QYD. After three weeks of drought, there was little difference in QYD between wet and dry treatments, although dry seedlings showed lower QYD after heat stress than wet seedlings. After two weeks of drought, photosynthetic rates measured by CO_2 uptake, decreased 30% to 40% for most crosses in the dry treatment, except for one LH cross from each zone that continued to fix CO_2 at 95% the rate of the wet treatment. As for QYD, photosynthesis increased with elevation and was similar for both seed zones.

Frost hardiness of seedlings at Glyn Road in early October increased sharply with increasing elevation of the seed source (Figure 6), with the LH and HL crosses intermediate in hardiness. There was more variation within and among these crosses than for HH and LL crosses. Frost hardiness was similar for both seed zones. As fall acclimation progressed, the effect of elevation decreased considerably. Seedlings from the wet treatment had greater frost hardiness than those from the dry treatment, especially in late October.

For needle samples from the three field sites, frost hardiness varied among sites and crosses within sites. Needles from the low elevation site were usually hardier than those from the mid and high elevation sites. In late September, needle frost hardiness increased with increasing elevation of the parent sources, particularly at the high elevation site (Figure 7). Again, the LH and HL crosses were intermediate in frost hardiness and usually showed the most variation

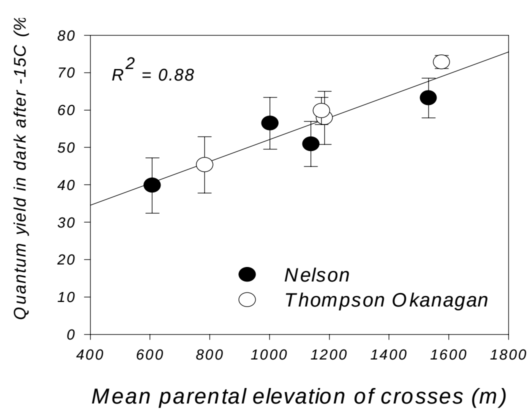


Figure 7. Frost hardiness versus elevation for needles from high elevation field site in late September

These results (more data analyses will be completed) show that adaptive traits in these crosses vary considerably with elevation of the parents, and also vary with environment on the field sites. Crosses between low and high elevation parents yield progeny intermediate in frost hardiness, photosynthetic traits, and height growth. [OTIP 351]

6.1.19 White Pine Blister Rust Resistance - Screening and Breeding of Populations

John King

Outline of Project:

Blister rust has devastated our native five needle pines since its exotic introduction at the turn of this century. Genetic resistance has been indicated by the improvement of populations in Idaho and Oregon, after phenotypic selection (often choosing the few trees surviving from intense attacks). A major gene resistance (MGR) has been found both in sugar pine and some Oregon populations of white pine (although rust races have evolved with a virulence response). In BC, there has been now nearly 15 years of effort mainly conducted by the CFS. Populations have undergone early screening under artificial inoculation. The Idaho material has augmented Interior populations. This project is concerned with integrating the effort that has been made in BC with the resistance found in the Oregon populations, particularly for Coastal white pine improvement. It seeks to construct pedigreed breeding populations for long-term field screening. Hybridizing of Eurasian five needle pines as a way of infusing durable resistance will be investigated.

Progress to date (January 31, 2000):

This year, material gathered from Doreena, (the Doreena diallels made in the 1980's) was sown along with some crosses made from the CFS material. Seed was sown at Green Timbers for outplanting to trials, and at CLRS for artificial inoculation. Outplanting sites for this material will located and laid out. Gary Jensen and Rich Hunt provided a ranking of the best available material from the CFS screening program for Coastal parents and plans are being made for a major scion collection program. In May of 2000, it is hoped that the F-1 breeding program will continue. Rich Hunt and John King will attend a field tour in May with Bro Kinloch, to look at the Happy Camp trials in Northern California. This will give some idea of how successful the deployment of MGR might be in Coastal populations of white pine. Happy Camp has been used as a monitoring site, looking at the spread of a virulence rust race to MGR. Evidence to date indicates virulence spreads very slowly, which suggests that MGR could be successfully deployed as a short-term strategy. [OTIP466]

6.1.20 Deployment of Major Gene Resistance into White Pine (Pinus Monticola) Seed Orchards

Abul Ekramoddoullah

Objectives:

- To inoculate white pine seedlings for MGR to blister rust.
- To evaluate inoculated seedlings for resistance.
- To clone resistant seedlings.
- To pollinate Coastal and Interior selected white pine trees with pollen from Dorena trees carrying MGR.
- To bag cones (June and July 1999).
- To collect seeds from these control crosses.

Progress:

A total of 150 resistant seedlings (free from canker following inoculation with the rust in two subsequent years) representing two families (carrying MGR) are now available for seed orchards.

Seven seedlings representing two families (five-year old now) inoculated in 1994 and 1995 are now free from cankers. Forty-nine scions were made from these seven seedlings. Four hundred and forty seedlings inoculated in 1997and 1998 are free from cankers. Seven hundred sixty seedlings inoculated in 1998 and 1999 will be examined for cankers in August 2000.

Seven families of slow-canker growth trees from the Coast Seed Orchards (located at Puckle Road) were pollinated using pollen lot 119-1504-845 (carrying MGR) from Oregon in 1998. A total of 48 cones were bagged in July1998 and unbagged in July 1999. Forty cones were picked. Family 2336 showed high abortion, both before and after pollination. Two trees aborted completely and only four of 29 strobili isolated produced mature cones. Conversely, family 2384 showed high fecundity, maturing 30 of 36 strobili isolated. Overall, 42 of 112 strobili matured, giving a survival of 37.5%.

Some 4025 seeds were extracted from these control crosses. Of these seeds, 3,217 seeds were filled. Seeds (300) for each of three seedlots of control crosses (MGR x slow-canker growth) have been stratified for growing seedlings. These seedlings will be screened for MGR and slow-canker growth resistance in 2000-2002.

Seedlings (259) of previous crosses (with susceptible western white of Idaho origin located at PFC ground) were inoculated in August, 1999. As of January 2000, all seedlings showed infection spots. These seedlings will be re-inoculated in August, 2000. They will be evaluated in November 2000 and 2001 for resistance reaction. [OTIP 458]

6.1.21 Realized Genetic Gain Trial to Quantify White Pine Blister Rust Tolerance Increases from Genetic Selection

Michael Carlson, Lynette Ryrie, Vicky Berger and John Murphy

Background:

Western white pine produces the highest value wood of any BC Interior species. Supplies of available white pine timber are rapidly decreasing in the southern Interior, and little reforestation with the species is taking place due to a lack of blister rust tolerant planting stock. Until recently, a similar situation existed in the Pacific Northwest of the U.S. Today, western white pine is again being planted in parts of the Pacific Northwest. The U.S. Forest Service's long term breeding effort (1960 to present) has produced seed orchard seedlots with an estimated 60% plus tolerance to white pine blister rust.

A breeding program in BC began in 1980, a cooperative effort of the MoF and the Canadian Forest Service. This program has successfully identified several dozen partially resistant white pine trees. In 1995, a six hectare grafted white pine seed orchard was planted by the MoF in Vernon: 80% of the trees in this orchard are from the U.S. program with the remainder coming from BC selection and screening efforts. Full production, of approximately two million seed per year, is expected by 2006.

Estimates of blister rust tolerance are needed for seedling crops from the MoF, Kalamalka Seed Orchard. Also needed, are demonstration plantings of rust-susceptible and rust-tolerant seedlots, to show field foresters and forest managers the benefits of using genetically improved seed in future reforestation efforts in the southern Interior. The "realized genetic gain" trial proposed will accomplish these objectives. This project will facilitate the process of restoring this valuable species to the future forested landscapes.

Objectives:

- To establish field plantings of western white pine seed sources of different levels of blister rust tolerance, in areas of high rust hazard, in order to estimate actual inherent tolerance levels.
- To develop estimates of the levels of tolerance to be expected from future seed orchard seedlots.
- To demonstrate, to field foresters, the benefits of using disease-tolerant seed orchard seedlots versus highly susceptible wild collected seedlots.

Activities:

During 1999, all trees planted on the four field sites were condition-assessed. Three sites exhibited an excellent survival rate. [OTIP 346]

6.1.22 Maintenance and Measurement of Interior Spruce Somatic Embryogenesis Clonal Candidacy Tests.

Barry Jaquish

Background:

Since 1992, BC Research Inc., the BC MoF, BC forest companies, and Forest Renewal BC have co-operated in establishing a number of Interior spruce somatic embryogenesis (SE) clonal field tests. The objectives of these tests are:

- To study and demonstrate variation among clonal lines.
- To identify clones with superior growth, tolerance to terminal weevil, and SE induction ability.

These plantings have been classified as clonal candidacy tests (CT) and clonal block (CB) tests. The plan for the CT tests was to establish about 1,200 clones in field tests, and monitor and assess their performance for 5-15 years before selecting clones for widespread deployment. Since 1994, over 1,600 clones have been planted on 33 sites. Many of these clones were derived from high breeding value parents, or parents with some degree of weevil resistance.

Objectives:

To inspect, brush, maintain, and measure sites in the SE candidacy test series.

Results and Deliverables:

Sixteen sites were inspected for brush competition, labeling and mapping, and damage. Tree height and condition were recorded for one six-year-old site (Hungary Ck), three four-year-old sites (Aleza Lk, Indian Point and Tumuch) and five three-year-old sites (Aleza Lk, Arctic, Fort St. James, Hungary Ck. and Quesnel). The two Hungary Ck sites were treated with Vision to remove competing vegetation, while the Tumuch site was hand weeded. The TFL-5 site was fenced to keep out cattle. Most test sites remain in good shape and are beginning to yield good growth data. To date, very little weevil damage has been detected on any of the sites. Analyses of data collected this year are in progress. [OTIP 341]

6.1.23 Spruce - Weevil Resistance Improvement -Screening and Breeding of Populations

John King

Outline of Project:

Genetic resistance to white pine weevil damage in spruce has been noted now for several years. This resistance can be quite marked with resistant families having only one tenth the level of attack, and indeed some Sitka clones have shown themselves to be immune under natural conditions. Work has been carried out identifying putative mechanisms of this resistance. This project seeks to determine the inheritance behind these resistant mechanisms, by continuing the screening of populations and accelerating the construction of pedigreed breeding populations.

Progress to Date (January 31, 2000):

Weevil infestations were made by the CFS at Camp 4 and Snowdon near Campbell River this year. These trials will complete the current round of family trials: only the series 4 trials that were established last year remain to be screened. CFS help will switch over the next few years from the screening of trials to helping us understand the mechanisms of resistance. The weevil infestation data have now culminated with the first two series of OP screenings and three series of clonal trials (EP 702.06). With this data, the establishment of breeding and seed orchards is being planned. A major part of this spring's work will be scion collections for these establishments. Crossing at the Saanich Forestry Centre and in the provenance trials (EP 702 trial at Sayward) will continue. Picea arboretums at Kalamalka and at Chiliwack will be investigated to inventory the species collected to date. Notes of general species susceptibility, and plans to augment these and replicate them at the Cowichan Lake Research Station will be made. If the 2000 cone crop looks good, collections will be made from the dry Douglas-fir zone. Trial maintenance and upkeep will be ongoing. The weevil resistance paper was submitted to Forest Science. Development of the breeding plan will be a major activity this year. [OTIP 468]

6.1.24 Screening for Levels of Resistance to Weevil Attack by Artificial Wounding in Spruce Hybrids from the Nass/Skeena Transition Zone

Greg O'Neill, Sally Aitken, Rene Alfaro, and John King

Background:

Identification of weevil resistance in spruce can take 10-15 years in the field. Early (i.e. age 3) identification of weevil-resistance using traits related to weevil resistance would enable early selection for resistance, and help advance the Sitka spruce breeding program. Investigations at the Pacific Forestry Centre and Simon Fraser University have shown phenotypic associations between weevil resistance and resin canal traits in Interior and Sitka spruce. The objectives of this project, therefore, are to examine genetic variation and control of resin canal traits in Sitka spruce, white spruce and their naturally occurring hybrids from the Nass/Skeena introgression zone. Resin canal traits will be evaluated in comparison to hybrid index values (1 = pure white; 0 = pure Sitka) based on molecular markers developed in another study.

Activities:

Sixty-two open-pollinated Sitka spruce, white spruce, and Sitka x white hybrid families from across the Nass/Skeena transition zone were used in the study. Weevil attack was simulated with an electric drill in the spring of 1999 (beginning of third growing season) on eight individuals in each family; while eight unwounded individuals were used as controls. Microscope slides of cross sections of the wounded portion of the leader were made in the fall of 1999. Measurement of resin canal traits (number and speed of formation of traumatic xylem resin canals; and number, size and proportional area of constitutive cortical resin canals) using an image analysis system, is nearing completion and the quantitative genetic basis of these traits will be analyzed. Third year height, bud burst timing and bud set timing were also recorded, and genetic relationships between these traits and resin canals will be determined. A report will present the results of these analyses and discuss implications for seed transfer and tree improvement in the Nass-Skeena area. It will discuss the use of resin canal traits in early selection, and methodology for resin canal analysis. [OTIP 416]

6.1.25 Yellow-Cedar Genetic Tests for Identifying Elite Populations

John Russell

Background:

Currently, up to two million yellow-cedar seedlings and rooted cuttings are planted annually in coastal BC. Seed for this valuable resource originates from wild-stand collections and from untested parent trees in MacMillan Bloedel's and TimberWest's seed orchards. Cuttings originate from mostly untested cutting-donors in various government and industrial hedge orchards. Selection of the top parents in the seed orchards based on progeny testing, will result in a one year reduction to reach free growing minimum heights (TIC Progress Report to 1996) and a 10% to 15% volume gain at rotation. Selection of the top clones, based on cloned progeny testing and their incorporation in hedge orchards, will result in even greater gains for reaching free growing and up to 20% volume gain at rotation.

Objectives:

The objective of this project is to provide up to 100% of the yellow-cedar seed and cutting needs with genetically-improved material, which will deliver 10%-20% volume gain and reduced time until free growing, by the year 2007 through:

- clonal progeny testing of parent-trees in existing seed orchards and gene archives;
- roguing of existing, or developing new second-generation seed orchards, and
- development of new seed and hedge orchards based on seven year clonal values.

Procedures:

For each of three annual series of field trials, the procedure involved establishing yellow-cedar clones from pedigreed material. One-year-old seedlings grown from seed from six 8-clone partial diallels were used as donor-stock for producing 1+0 rooted cuttings. Included in the cloned progeny tests were: 1) 1,800 clones from 96 full-sib families for progeny and clonal testing; and 2) one group of wild-stand seedlots (containing three to four seedlots) from representative biogeoclimatic sub-zones for checks across sites and series, and comparisons to select clones and families. The rooted cuttings are established in randomised incomplete block field trials.

Activities:

This year's activities included the planting of the final series. Three sites were established at:

- Jordan River (850 m).
- Pt. McNeil (250 m.
- Powell River (400 m).

Sites from Series 1 and 2 have very high survival and are growing well. Sites have been brushed for weed competition. It is anticipated that five to seven year height data will be taken for each series, and that seed or hedge orchards will be upgraded or established, based on either breeding or clonal values. [OTIP 391]

6.1.26 Planting Brushing, Maintenance and Grafting at the Barnes Ck. Clone Bank

Barry Jaquish

Background:

The Barnes Creek Clone Bank was established by the MoF in 1977 to serve as a long-term gene archive for important tree breeding materials. The 35 ha reserve is located on Crown land east of Enderby. It contains grafted trees from most of the parents in the provincial Sx, Fdi and Lw tree breeding programs and several important tree improvement and growth and yield research installations. The reserve was established with three goals: long-term preservation of important breeding material, ex situ gene conservation, and a source of male and female flowers for advanced-generation breeding and scionwood to establish seed orchards. For many clones, Barnes Creek represents the only site where they will be held in perpetuity. Recently, most activity on the site has been directed toward routine site maintenance and establishing a transplant bed for Douglas-fir and western larch grafting. Presently, the western larch clone bank is about 30 % complete.

Objectives:

- Transplant about 100 Douglas-fir grafts from the Kalamalka Forestry Centre.
- Graft and maintain about 700 trees for the expanded Nelson low elevation seed orchard being developed by Pacific Regeneration Technologies (PRT) at Armstrong.
- Maintain and protect the site by mowing the grass cover crop, spraying Vision along tree rows, irrigating young grafts and controlling pests as necessary.
- Maintain the grafting bed, prune rootstocks and winterize young grafts.

Progress:

All of the proposed work was completed as planned by contract crews. In addition, approximately 250 new grafts were moved from Barnes Ck. to the PRT seed orchard site. [OTIP 343]

6.1.27 Site Preparation for Future Second-Generation Breeding Arboreta Establishment at Kalamalka Research Station

Gary Clarke

Progress:

This project was successfully completed before the fall of 1999. The target trees were removed from the breeding plantations and disposed of in an effective manner. Methods were developed, as the project unfolded, to effectively remove the trees from the plantations causing minimal impact on the site. Ministry regular and seasonal auxiliary staff felled the trees, and ministry machinery was used to facilitate the completion of this project. This completes the first phase of the long-term goal of completely removing all unwanted ramets in preparation for establishing second- generation breeding material for either Sx or Fdi. Phase two will be to completely remove all remaining trees, and commence site preparation (possible soil amendments, irrigation system renovations, etc.), if time permits, to receive second-generation material for future breeding work. [OTIP 306]

6.1.28 Enhancing Breeding Arboreta at Kalamalka Research Station

Gary Clarke

Progress:

Funding of this project provided the necessary manpower to enhance the level of support to the Interior Tree Improvement Program (ITIP). Staff was able to provide more technical assistance with the spring breeding activities, as well as maintain a high level of maintenance of plantations used in the current breeding programs. Young plantations, which will serve as future breeding material, or provide information for determining future breeding strategies, were also maintained and protected to ensure optimal vigour and health. Every precaution was taken to prevent any conditions (potential insect infestations, weed encroachment and competition, drought, etc.) that would adversely affect the well being of all the material on site. [OTIP 307]

6.1.29 Support for Operational Plantations at Skimikin

Keith Cox

Activities:

Work done in nine operational plantations included herbicide spraying, insect monitoring, spraying for mites, mowing, hand weeding, rototilling, and mulching thinning debris.

The lodgepole pine realized gain demonstration plantation was handweeded, rototilled, and sprayed as needed. It was also rock picked. The differences between the natural stand seed source and the improved seed source are starting to show.

A site was prepared for a birch trial to be planted in the spring, by rototilling the rows and leaving grass strips in between the rows to prevent soil erosion.

A small area was prepared for the outplanting of rust inoculated white pine seedlings to screen for resistance.

Other plantations were mowed and/or herbicide sprayed as necessary, pocket gophers were controlled, and thinning debris was mulched. [OTIP 303]

6.1.30 Controlled Pollination Bag Purchase
Mike Carlson

Progress:

Negotiations are ongoing with a contractor for production of control pollination bags. [OTIP 470]

6.2 Operational Production

Projects that are funded under this section are designed to enhance seed and vegetative production, and the production capacity for seed orchards and vegetative facilities. It also involves the study of genetic processes and the development of techniques to improve production capabilities.

6.2.1 Pollen Collection and Supplemental Mass Pollination (SMP)
Tim Lee

Project Description/Overview:

At the Vernon Seed Orchard Co.(VSOC) orchards, pollen management is carried out. Collection, storage and re-application of pollen (SMP) has the potential to increase seed quantity and genetic quality.

Pollination bags at VSOC

Activities/Objectives:

Pollen surveys were done to ensure all desired ramets with pollen were included in the pollen mixes. Pollen was picked and vacuum dried when required, processed and reapplied or stored for future use. The objective is to enhance, and sometimes create a pollen cloud for the fertilization of flowering ramets.

Final Results or End Product:

Potential for over 30 million genetically improved seeds will be produced in orchards. Some genetically improved spruce is available, but little or no lodgepole pine or Douglas-fir seed is available. Pollen management plays a vital role in seed orchards. [OTIP 311]

6.2.2 An Elevated Truck Platform for Seed Orchard Management
Tim Lee

Objectives:

- To construct an elevated truck platform that would provide cost effective, efficient, and safe transportation and access throughout the orchard.
- To allow crews to SMP and bag flowers for the induction of SMP, and to complete these procedures more efficiently through repetitive operations.
- To increase the breeding chances and viable seed yield.
- To enhance cone harvest operations

Final Results or End Product:

The truck platform allowed us to apply bags and pollen, and harvest a specialty seedlot safely and efficiently. This resulted in providing both the MofF and VSOC parent companies with a weevil-resistant seedlot.

Elevated Truck Platform

Weevil problems throughout the Central Interior have increased substantially. The ability to efficiently produce pest resistant seed will help aid in the future of tree improvement. [OTIP 321]

6.2.3 Incremental Orchard Management Activities at Kalamalka Seed Orchards

Chris Walsh

Outline of Project:

The project involved a number of activities that increased the quantity and genetic quality of seed produced at Kalamalka. Kalamalka Seed Orchards produce seed for all five major species in the Interior: lodgepole pine, Interior spruce, western larch, Interior Douglas-fir and western white pine.

Activities Completed:

- Stem girdling in two larch orchards to induce flowering.
- survey for, and manual removal of, various pine pitch moths (Petrova spp. and Synanthedon spp.).
- Application of insecticidal soap to reduce adelgid populations and the resultant negative effect on cone production.
- Manual removal of weevil infested leaders to reduce weevil damage and sustain productivity of orchard trees.
- Application of insecticidal sprays to control the seed bug (Leptoglossus spp.) in 15 ha of Pli orchards to increase seed yields.
- Basal pruning of trees in all orchards to reduce pest populations.
- Crown management activities such as pruning, shaping and topping to allow greater efficacy of SMP treatments and improved access to crops.
- More complete rodent control.
- Foliar analysis within all orchards, used to adjust fertilizer application rates.

Product:

Improved orchard health and efficiency, resulting in sustainable delivery of improved seed of Interior spruce, Interior lodgepole pine, western larch, western white pine and Interior Douglas-fir. [OTIP 322]

6.2.4 Supplemental Mass Pollination to Increase Genetic Worth of Seedlots Produced at Kalamalka Seed Orchards

Chris Walsh

Outline of Project:

High breeding value pollen can be collected from clone banks and applied to various seed orchards at Kalamalka, improving overall fertilization efficiency, reducing pollination by undesirable parents, and increasing seedlot genetic worth. The result is an increase in both the quantity and genetic quality of seed produced.

Work completed:

- This proposal was only partially funded. Approximately 1,500mls of dry high breeding value pollen was collected from the larch-breeding orchard. Some of this was stored and some reapplied to the larch production orchards 332 and 333.
- Approximately 1.5 litres of Pw pollen from rust-tolerant sources were purchased from the Inland Empire Tree Improvement Cooperative. Stored Pw pollen was applied to the Pw Orchard 335.

Product:

Greater quantities of higher genetic worth Lw seed was produced in 1999, and greater quantities of higher genetic worth Pw seed will be produced in 2000. [OTIP 324]

6.2.5 Collection of SMP Enhanced Crops at Kalamalka Seed Orchards

Chris Walsh

Outline of Project:

SMP can significantly enhance the quantity and/or genetic quality of seed produced. The proposal estimated the crop volumes for orchards that were eligible for SMP enhancement and the costs of cone collection.

Work completed:

- Funding was approved only for Orchards 307, 332 and 333, and only to 25% of the requested amounts.
- 25.5 hl of cones were collected from Pli Orchard 307, yielding 4.9 kg of seed.

- 56.0 hl of cones were collected from Lw Orchard 332, yielding 45.1 kg of seed.
- 58.8 hl of cones were collected from Lw Orchard 333, yielding 44.1 kg of seed.

Product:

- Improved Pli seed for the Nelson SPU.
- Improved larch seed for the Nelson and East Kootenay SPUs. [OTIP 326]

6.2.6 Harvesting of Crops Enhanced through SMP Treatments in 1998

Tim Lee

Project Description/Overview:

There is very little A class (Pli) seed available for the Bulkley Valley and Prince George planning units for which the seed from Orchards #219 and #222 is intended. All female flowers were given three applications of SMP pollen in May 1998 and the harvest of cones is expected to yield two to three million seeds. The orchards are only beginning production, and the need for seed is far greater than the supply.

Receptive female flowers

Objectives:

The target production for the orchards at maturity is greater than 30 million seeds/year. The production of genetically improved seed begins earlier in the orchards, providing pollen is managed with the use of SMP applications. Our objective is to supply a larger quantity of improved seed for the planning units.

Final Results or End Product:

Approxamently 30 hectolitres of cones were picked in both orchards, yeilding 3.6 kg of seed. The supply of genetically improved seed for the planning unit above is less than the demand. Intensive management of cone crops is necessary to help orchards produce more seed in the early years of an orchard's life. [OTIP 329]

6.2.7 Harvest of Cone Crop Enhanced through SMP Treatments and Natural Pollen Cloud

Tim Lee

Project Description/Overview:

Trees in the Bowron Lake Sx Orchard (#214) have been top pruned to a height of three meters, which is a manageable height for pollination and picking using ladders. The main leader and all but two lateral branches on the top whorl are pruned. One of the two remaining branches will turn up and become the next dominant leader.

Objectives:

- To produce seed with a genetic gain of over 18%.
- To meet the annual target production for the orchard of 17.3 million seeds per year.
- To improve access to the cone crop for easier picking and a safer work environment.

Final Results or End Product:

More than 25 million seeds will be produced for the Prince George SPU. Pruning of the ramets will aid in the collection of future seedlots and also ensure that the irrigation pattern is not interrupted. [OTIP 330]

6.2.8 Collection of SMP Enhanced Crops at PGTIS

Carole Fleetham

Activities/Result:

In 1999, 19.7hl of cones were collected from two lodgepole pine orchards (#223 and #228) previously enhanced with pollen. This collection represented approximately two million seedlings for reforestation in the Central Plateau and Bulkley Valley low planning units.

The pollen applied increased the quantity of seed and improved the genetic quality of the seedlot. [OTIP 335]

6.2.9 Pli Pollination: Pollen Collection, Extraction and Re-application (SMP) - Orchard 311

Hilary Graham

Background:

In the Thompson-Okanagan low Pli seed unit, approximately 1.4 million seedlings are being produced annually from improved seed. Because the current need is for 6.7 million seedlings in this unit, there is a need to increase seed set and production in the orchard, as soon as possible. In order to increase seed set in this young orchard, the proposal is for SMP using pollen from the highest ranked clones in the holding area, and from the orchard itself.

Activities:

During the pollen flight period in 1999, pollen was collected by hand from the holding area and from Orchard 311. Whole pollen buds were collected by clone by a crew of experienced seed orchard workers.

Once collected, the pollen buds were brought into the laboratory for drying and processing.

Pollen was tested for moisture content, and put into freezer storage when it reached 6-8% moisture content. During the storage phase and just prior to reapplication, the pollen will be tested for germination.

Reapplication of this pollen did not occur in 1999. Another project with SMP was being conducted in this orchard, and further SMP would have confounded the results. Also, the intention of this project was to create an inventory of pollen for SMP activities in the spring of 2000. [OTIP 361]

6.2.10 Pollination: Pollen Collection, Extraction, and Re-application (SMP) - Orchard 313

Hilary Graham

Background:

In the Nelson (NE) low Pli SPU, little A class seed has been produced. The current need is for 6 million seedlings for this unit. Effective pollen management has the potential to increase seed set and enhance early seed production in this orchard. Young pine orchards typically suffer from a lack of pollen in the first few years of production. This lack of pollen leads to a low level of seed set. Significant seed set increases can be realized through SMP in years prior to full production. Therefore, enough pollen from the seed orchard holding area will be collected for SMP activities in 2000.

Activities:

During the pollen flight period in 1999, pollen was collected by hand from the holding area on site. The pollen was processed, tested for moisture content, and put into freezer storage when it reached 6-8% moisture content. During the storage phase, and just prior to reapplication, the pollen will be tested for germination.

In the spring of 2000, this pollen will be available for SMP activities in this orchard. [OTIP 362]

6.2.11 Enhancement of Genetic Worth of Orchard Seed through Control Crossing in an Interior Spruce Meadow Orchard

Clare Hewson

Outline of Project:

Interior spruce is a major component of the forest composition in the Bulkley Valley SPU, consisting of an average planting program of 5.5 million seedlings. At present, one developing and two producing orchards are fulfilling only part of this demand. The majority of the seed produced has an estimated genetic worth of eight.

Orchard 620 is a “meadow” orchard consisting of 600 closely spaced ramets arranged in clonal rows. The clones in this orchard have very high breeding values. The objective of this program in 1999 was to produce, by control pollination, a quarter of a million seeds with a genetic worth of 19 from 350 ramets from the best 12 clones in the orchard.

Progress to Date:

Due to the excellent flower crop in this orchard, over 750 crosses were possible. The pollen used had been collected in past years and had a weighted breeding value of 20.6. Pollen was applied using a small hand held pneumatic PVC sprayer with an attached hypodermic needle. This unit was developed by Research Branch several years ago, and proved to be extremely efficient for this type of work. The unit was connected to a portable nitrogen tank.

Pollination bags were removed approximately one week after the conelets became pendant. Although attempts were made to protect these conelets with insect bags, the procedure was abandoned when it became clear that many of the conelets were being knocked off by this procedure.

All cones were collected in August and are currently waiting extraction. It is anticipated that the genetic worth of this seedlot will be close to 19. [OTIP 373]

6.2.12 Genetic Enhancement of Seed Production in Orchards 303 and 310

Greg Pieper

Objective:

To achieve genetic improvement and increased seed production in Orchards 303 (Sx) and 310 (Pli) in the Thompson Okanagan SPU, by using controlled pollination, cone induction, and SMP.

Progress and Activities

A controlled cross program was carried out in the spruce orchard, and Seedlot 60150 was produced with a genetic worth (GW) of 15. Using SMP, and collecting from only higher breeding value (BV) clones, two seedlots with GW of 8.4 and 8.6 were produced. This represented 61 hl of cones or 13,000,000 filled seeds. The lodgepole pine orchard produced more seed than ever before, 9.6 hl of cones and 541,000 filled seeds. [OTIP 374]

6.2.13 Redcedar Orchard Improvements and Seed Production with Reduced Selfing

Patti Brown

Progress:

- 1 kg of seed was produced from ramets with pollen cones removed, or from cones covered with pollination bags.
- This has maintained the health and vigour of 1,000 two-year-old ramets, and 50 three-year-old ramets.
- A holding area for potential redcedar orchard clones was created from the breeding program. Up to 10 ramets from each of 291 clones, totalling 2,700 ramets, were transplanted into the holding beds. [OTIP 380]

6.2.14 Delivering High Gain Western Hemlock Reforestation Material for 0 - 800 Metre Sites

Patti Brown

Activities /Results:

- 2.68 kg of seed were obtained from the 1999 controlled crosses (with a GW of 16). This will produce approximately 600,000 seedlings for operational usage. Pollen from the higher value, higher elevation clones was not available from CLRS in time for the pollination period, so a limited amount of the higher elevation seed was produced and will be combined with last year's seedlot.
- 60 ramets from Forks,OR selections and high gain BC selections were added to Orchard #179 in August 1999, to increase the value and replace the 1998 mortality. [OTIP 386]

6.2.15 Enhancing Seed Production from Rust Resistant White Pine Seed Orchard #175

David Reid

Outline of Project:

There is insufficient production of blister rust resistant western white pine seed for coastal reforestation needs. Weather conditions in 1998 were considered to be ideal induction conditions so that large amounts of flowers were expected in Spring 1999. Pollen production may be limiting the amount of filled seed that can be obtained. This project involved using SMP to enhance the production of filled seed from this orchard to help meet Coastal needs.

Work Completed:

The objective of this project was to increase orchard seed set by ensuring that female reproductive buds received adequate amounts of pollen at peak periods of receptivity. In order to accomplish this, it was necessary to do several things:

- Monitor female phenology to determine the time of peak receptivity.
- Monitor male phenology to determine the time of optimum pollen maturity.

- Collect pollen buds at the appropriate stages of development.
- Extract the pollen, ensuring that moisture contents were suitable for freezer storage for those pollen lots needed for future use.
- Re-apply pollen at times of maximum female receptivity. Due to the variability of receptivity on any given ramet, this meant multiple applications.
- Harvest the ensuing crop at maturity in late Summer 2000.

Final Results or End Product:

All activities, except the cone harvest, have been completed. [OTIP387]

6.2.16 Reduction of White Pine Pollen Contamination Sources near Rust Resistant Orchard #175

David Reid

Outline of Project:

A Canadian Forest Service white pine rust traces trial plantation of about 5,000 seedlings was outplanted at the Saanich Seed Orchard site in 1988. In 1995, approximately 350 rust-resistant trees were transplanted to constitute a seed-producing orchard, which has produced three cone crops to date. The orchard now comprises 750 trees. Most of the remaining 2,500 plantation seedlings, which are now three to four metres tall, constituted a source of pollen contamination to the orchard trees and needed to be removed prior to 1999's anticipated bumper crop pollination season. There were still some rust-resistant trees within the original plantation. It was decided to leave these trees, after appropriate spacing, for future operational flower induction projects.

Work Completed:

About 2,000 trees from Interior provenances were cut down and chipped on-site. Several hundred trees from Coastal provenances, including some putatively rust resistant sources from Washington and Oregon, were retained, and a further 200 remaining trees were spaced for future trials. Stumps were removed and burned and the site was restored to orchard standards.

Final Results or End Product:

The contamination risk to Orchard #175 has been removed. The Coastal U.S. provenances remaining will provide a possible source for breeding material as well as a possible pollen source for the orchard. The trees intended for trial purposes have already been used in a study of GA induction rates in OTIP project #372. [OTIP388]

6.2.17 Production of an Enhanced Gain Seedlot from Orchard #149

Gord Morrow

Project Description:

The objective of the project was to increase the 1999 crop volume potential of Orchard #149, at Bowser Seed Orchards, by the application of circumferential stem girdling and gibberrellic acid treatments to approximately one half of the orchard ramets.

An annual need for 110 kilograms of enhanced gain Coastal Douglas-fir seed has been identified for the Maritime Seed Planning Zone. Orchard #149 is designed to produce 36.7 kilograms toward this need. The project will increase the number of cone and pollen bearing ramets in the orchard above that which would naturally occur, and thereby increase the volume and effective population size of the 1999 crop.

Results:

46.8 kilograms of seed were produced and registered in Seedlot #60580. The estimated genetic worth of the seedlot is +6.8% for stem volume, -0.8% for wood density, with an effective population size of 21. This crop marks the first year this orchard has reached and exceeded its designed production target of 36.7 kilograms of seed for the Maritime zone.

Intensive SMP was employed to maximize the potential quantity and quality of seed produced, and to minimize the effect of heavy regional pollen contamination. 7.3 litres of pollen were extracted from 216 litres of pollen cones collected. This pollen, together with pollen stored from the previous year, was used to make two SMP treatments to 486 ramets bearing female flowers.

DNA analysis of seed samples from the seedlot is currently being conducted. This analysis is expected to shed light on the efficacy of the SMP program, and the levels of regional pollen contamination. Values registered with the seedlot for genetic worth will be amended with the results of the DNA analysis. [OTIP 419]

6.2.18 Genetic Upgrading of Saanich Fdc Orchard #120
David Reid

Outline of Project:

In order to raise the genetic gain of the Douglas-fir sub-maritime zone seed Orchard #120 to meet the goals of the FGC, several operations were necessary. In the short term, the present seedling material in the orchard needed to be rogued to reflect the current lower elevation seed needs for this zone. All families, originating from parent trees above 900 metres elevation, would be removed. In the long term, higher gain clonal material from lower elevations would be required to replace the old orchard. The replacement material has been propagated and is being maintained in holding beds at the Saanich seed orchard site (OTIP project #421). Until the new stock begins production, the lower elevation trees in one half of the orchard, which remained after roguing, were to be retained. This would allow the other half of the orchard site to be cleared and prepared for the new orchard stock. The trees were to be felled and limbed, the logs decked off-site for disposal and the stumps and slash, ground on-site, for incorporation into the soil. As this was intended to be a two-year project, it was expected that work in the second year would involve further site restoration, including the replacement of drainlines and irrigation, and the marking of planting locations for the replacement material.

Work Completed:

Approximately 1,000 trees have been removed from Orchard #120. The eastern half of the orchard site (four hectares) has been completely cleared, while about 300 trees remain in the western half of the orchard.

Final Results or End Product:

The removal of the higher elevation component of Orchard #120 has removed a potential contamination source for the remaining lower elevation orchard trees. The 300 remaining trees will provide lower elevation seedlots for the sub-maritime zone until the replacement orchard stock enters production. The four hectare cleared orchard site can now be prepared for outplanting of this replacement stock in 2001. [OTIP422]

6.2.19 Alternate Host Removal at Skimikin Seed Orchards
Keith Cox

Background:

The alternate host for Inland Spruce Cone Rust (Chrysomyxa pirolata) is the One-Sided Wintergreen (Pyrola asarafolia). Removal of the alternate host plants closest to the spruce seed orchards reduces the concentration of rust spores available to infect the spruce cones. This plant prefers a moist, partially shaded location. Most of the Skimikin site is too dry or well drained for the plant to grow. Although the areas where the conditions favour the plant are relatively small, the perimeters of the Central Plateau spruce seed orchards are in this area.

The disease is spread from the alternate host plants to the spruce cones by spores released during periods of high humidity, usually during the night. The spores are small and fragile, usually only infecting cones a short distance away. This makes removing the plants a feasible control measure.

Activities:

The area west of the Central Plateau High seed orchard was worked on in 1999. This completes the removal of the alternate host from the strip of the perimeter closest to the two orchards. The areas previously covered will need checking for regrowth, but plant densities have been substantially reduced.

Herbicide spraying was tried again, with the addition of a surfactant to penetrate the waxy leaves. There was no mortality in the sprayed plots. The cone crop was sprayed with Ferbam to protect it from the rust, as the weather was cool and moist when the cones were receptive - conditions that favour the rust spore survival. [OTIP 305]

6.2.20 Production of a Weevil-Resistant Spruce Seedlot at Kalamalka Seed Orchards
Chris Walsh

Outline of Project:

A weevil resistant spruce seedlot for the Prince George SPU was produced through controlled pollination.

Work completed:

Clones within Orchard 209 of the Kalamalka Seed

Orchards have been ranked for weevil-resistance, as have clones within the Research Branch breed arboretum. Pollen was collected from these clones in 1998 and stored for use in 1999. Pollen isolation bags were installed on selected trees within the orchard, and the arboretum and weevil-resistant pollen was applied. The target of approximately 1,000 bags was met, and the target of 10 cones per bag was exceeded. Pollen was collected (2,750 mls dry) from the same trees, for use in this project and/or for use in future years. Pollen mix composition and selection of trees was designed to maximize weevil-resistance and genetic worth, while maintaining an effective population size minimum of 10. At the time of writing, seed is being extracted clonally and bulked to create the seedlot. Predicted seedlot size is approximately 400,000 seeds.

Product:

Improved weevil-resistant Sx seed for the Prince George SPU. [OTIP 328]

6.2.21 Weevil Resistant – Control Cross Seed Production from the Bowron Lake Spruce Orchard #214

Tim Lee

Project Description/Overview:

Forest companies of British Columbia battle the white pine weevil (Pissodes Strobi) on spruce plantations. In some cases, the infestation is so great that most planted seedlings are affected, and the plantation requires re-planting. Pollen is picked from clones that show a resistance to weevil and is used to control pollinate selected clones. Isolation of the female cones within pollination bags prohibits foreign pollen contamination during receptivity.

Objectives:

To produce seed that has a natural resistance to white pine weevil.

Final Results or End Product:

The seedlings produced from this seed will have a greater natural resistance to white pine weevil attack. This will aid in reforestation of areas known to have weevil problems. 1,468 kilograms of seed were produced. [OTIP 331]

6.2.22 Pheromone-based Mass Trapping and Mating Disruption to Reduce Damage by the Douglas-fir Pitch Moth (*Synanthedon novaroensis*) at the Prince George Tree Improvement Station

Robb Bennett

Project Description/Overview:

Douglas-fir pitch moth (DFPM) damages stems of lodgepole pine trees in seed orchards at the Prince George Tree Improvement Station (PGTIS). Using DFPM sex pheromone, this project aims to control DFPM by mass trapping it in one infested orchard and disrupting its mating behaviour in another over a two-year period.

Objectives:

To purchase insect traps, pheromone lures, and other equipment, in collaboration with the University of Northern BC.

To use this equipment in the second year of this continuing project, to reduce populations DFPM to non-damaging levels in the two most severely affected lodgepole pine seed orchards at the Prince George Tree Improvement Station. Populations will be reduced through mass trapping in Orchard #201, and mating disruption in Orchard #202.

Activities:

In 1999, we conducted DFPM mating disruption and mass trapping programs in PGTIS Pli Orchards 201 and 202 respectively and monitored DFPM populations in Orchards 201, 202, 203 and 204. Traps (100) and disruption devices (one per tree) were hung in orchards and monitored from May until August 1999, covering the flight period of DFPM.

Results:

All orchards were assessed for incidence of new pitch moth attack in early September. At the site, DFPM populations appeared to be declining. Most pitch masses surveyed had no larvae in them (Figure 8 shows the numbers of DFPM larvae and pitch masses observed in four lodgepole pine seed orchards at the Prince George Tree Improvement Station in September1999).

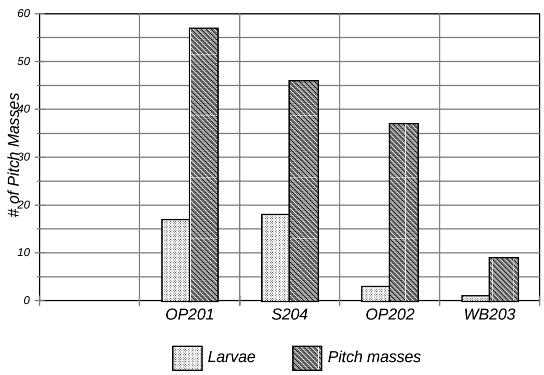


Figure 8. Proportion of Pitch Masses with Larvae

Very few first-year larvae were found (Figure 9 shows the numbers of DFPM larvae in each of three size classes observed in four lodgepole pine seed orchards at the Prince George Tree Improvement Station in September 1999).

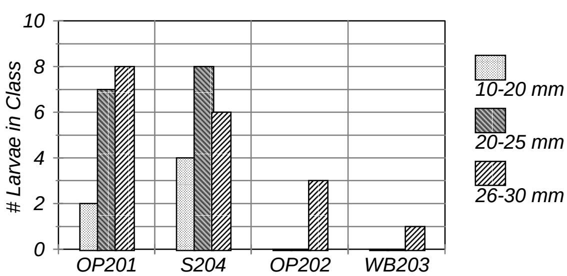


Figure 9. Frequencies of Larval Head Widths

Our finding of three size classes of larvae indicates that DFPM may have a three-year life cycle at PGTIS. The preponderance of the two larger size classes of larvae (i.e. second and possibly third year larvae) indicates that adult DFPM had little reproductive success in 1999, and supports our view that the population is declining. In light of the possibility that a three year life cycle is involved, and because larvae that likely will mature in spring 2000 are still present at PGTIS, funding has been requested to cover a third year of this operational insect management program. [OTIP 337]

6.2.23 Western White Pine Resistant Seed Production for Operational Usage

Patti Brown

Activities:

- Pollen was collected from all producing ramets in Orchard #174 and either redistributed or stored for future pollinations. 5000 cones were hand pollinated in June with orchard and/or MGR pollen from the Dorena program. Cool, wet weather in June caused a late pollination season. Despite the close monitoring for the timing of SMP application, many of these cones aborted soon after with less than 2,000 remaining at the end of the growing season.
- Ramets were heavily top and side pruned in June during shoot elongation, as it was observed that branches, previously pruned in this way, were still capable of producing female flowers the following year.
- Leptoglossus adults were monitored and removed by hand from cones. Leptoglossus were observed on the one-year as well as two-year cones and that may have been a factor in the high abortion rate but it is felt it was not the sole factor. 1,500 cones were collected in August of 1999 from 1998 pollinations and extracted by clone.
- Scions were collected in the spring of 1999 from five new parents identified with superior slow canker growth characteristics. Ramets from less resistant parents were removed from orchard #174 to make room for the new material. A total of 175 ramets were added in August of 1999, including replacement ramets. Additional scion material will be collected in the winter of 2000 for grafting that couldn't be done in 1999 due to heavy snow loads during the grafting period. Survival of the ramets planted in 1998 was very poor due to rooting problems in the original pots. These will be regrafted in 2001 when the surviving ramets are able to produce enough scion material.
- Maintenance was done on the two rust trials established in March 1999. [OTIP 382]

6.2.24 Management and Maintenance of Rust Resistant White Pine Orchard #403
Tim Crowder

Objectives:

- To manage Orchard #403 for vigorous vegetative growth and pruning to ensure as many cone sites as possible.
- To induce crops by G.A.4/7 stem injections and drought conditions.
- To manage any crops in such a way as to maximize seed set and yield.

Results:

- 533 trees in the orchard were maintained through irrigation, weed control, and fertilization.
- 320 mls of pollen were collected, extracted, and stored, and 225 mls were reapplied to all the trees with flowers.
- Insect control was carried out on all one- and two-year cones.
- Mature crops will be collected and the seed extracted. [OTIP 411]

6.2.25 Douglas-Fir Seed Production in Orchards #134, #154 & #183
Tim Crowder

Objectives:

To capitalize on a good, naturally occurring Fdc cone crop of approximately 250 hl, and maximize the quantity and genetic gain of seed produced from these orchards.

Results:

652 crop trees were managed to ensure the highest possible seed yield and genetic worth by:

- the collection and extraction of 3.5 litres of pollen. 2.5 litres of fresh pollen was mixed with two litres of stored pollen and re-applied to the crop trees. In addition, the orchard pollen was agitated eight times during the pollination period;
- the inducement of 220 non-crop trees for production next year, and
- the carrying out of flowering delay, frost protection & insect control.

Total production for these orchards was 365 Hl cones that yielded enough seed for 8.4 million plantable trees. [OTIP 412]

6.2.26 Inclusion of the Top Finlay Clones in the Central Plateau – Pli #218
Tim Lee

Project Description/Overview:

In order to upgrade a portion of the Central Plateau pine orchard to include additional high value clones, the orchard must be physically re-randomized and all records updated.

Objectives:

- To include top breeding value clones from the Finlay (Class 'B' SPZ) in the Central Plateau Orchard #218.
- To improve the genetic worth of seedlots produced.

Final Results or End Product:

The orchard will be fully planted. The seed produced will meet a specific need as no genetically improved seed of this quality is presently available for the Central Plateau SPU. [OTIP 310]

6.2.27 Improving Orchard Composition at Kalamalka Seed Orchards
Chris Walsh

Outline of Project:

The availability of new progeny test data creates new opportunities to improve the genetic worth of seedlots produced at Kalamalka. In consultation with tree breeders, trees of lower breeding values were removed from orchards for which there were new data. Concurrently, trees of high breeding value were added to orchards through grafting. Trees grafted under a similar project last year (funded as OTIP 108) were maintained.

Work completed:

- The largest grafting effort was within the Nelson Zone Lw Orchard 332. Clones were chosen for roguing/grafting based on newly available rankings from three-year data (series two progeny tests) and six-year data (series one progeny tests). Where grafting was done within the orchard, the lower ranked trees served as rootstock. Approximately 485 grafts were made in this way, 375 were alive in the fall.

- Approximately 280 grafts were made in the EK Zone Lw Orchard 333 to replace failed grafts from 1998. Of those 280 grafts, 228 of these survived.
- Smaller numbers of trees from lower breeding value clones were rogued from various Sx orchards while higher value replacements were grafted in a holding bed. Rootstock was established and maintained for future grafting.

Final Results or End Product:

Greater quantities of higher genetic worth Sx and Lw seed will be produced. [OTIP 323]

6.2.28 Operational Activities to Increase the Quality and Quantity of Genetically Improved Lodgepole Pine Seed at PGTIS for PG Low, CP Low and BV Low SPUs

Carol Fleetham

Background:

Three lodgepole pine seed orchards at the Prince George Tree Improvement Station, #220, #223, and #228, produce seedlings for the PG low, CP low and BV low planning units respectively. All three orchards are young and require various management activities to improve seed production and quality.

Activities:

Tree crowns in these orchards were pruned in June 1999, to increase the quantity of flowers. The result was an increase in the number of intra-fasicular buds and, therefore, the potential for more flowering branches the following year. GA 4/7 was also used on some clones to increase flower production. In addition, ammonium nitrate fertilizer was applied in May and July to promote flowering.

Mancozeb, a protectant fungicide, was sprayed on the tree crowns in all orchards to protect against lophodermella needle rust. Orchard trees were surveyed for root collar weevil attack and the larvae were eradicated. Vision herbicide was applied to tree rows to reduce the vegetation that is habitat to weevils. Foliage and soil sampling were conducted to monitor nutrient levels. [OTIP 334]

6.2.29 Willow Bowron #222 – Enhance Genetic Quality through Roguing

Tim Lee

Repositioning ramets with tree spade.

Objective:

- To remove 200 ramets from the Willow Bowron Pli Orchard #222 that were duplicated in the Bulkley Valley Orchard # 219.
- To add additional high value clones.

Activities:

- Ramets of the lower breeding value clones were removed from their orchard locations, and replaced with ramets from the 12 best clones.
- Re-randomization of the open positions for the inclusion of these 12 clones.
- Many of the trees were 9 to 12 feet tall and will require machines for removal. Four of the removed clones are common with the Bulkley Valley #219 orchard, and do better in that SPU.
- Ramets that can be tree spaded and moved were removed to a position in the Bulkley Valley Orchard.
- All records for the orchard changes will be changed to reflect the removal of some clones and the increased replication of others.

Final Results or End Product:

- Changes to the orchard were at an opportune time, as initial production was beginning.
- The improved clonal composition will improve the genetic quality of the seed produced

- No genetically improved seed is available for the Prince George SPU that this orchard is to supply. [OTIP 369]

6.2.30 Genetic Upgrading of Yellow Cypress Clonal Orchard

Cathy Cook

Background:

Stecklings (rooted cuttings) have been used by Western Forest Products Limited for yellow cypress regeneration since the mid-eighties. This system was selected to circumvent production problems with yellow cypress seed. Through an extensive testing program, higher gains in productivity can now be realized. Selection of the best clones from tests indicates an estimated volume gain at rotation of 18%.

Objectives:

Western Forest Products Limited has tested numerous yellow cypress clones from hedge orchards. Selection of the best performers in terms of growth and rootability has led to the selection of top performers. These selections, through this project, are being rejuvenated and replicated to replace less desirable hedges in the orchard.

Activities:

- Rejuvenation of 50 selected mature hedges continued with the establishment of the third round of rejuvenations.
- Generally, steckling form improved from the first round to the second round of rejuvenation.
- Decreased plagiotropism was observed.
- The third round of rejuvenation is underway, with the setting of 150 stecklings of each of the selected clones.
- Site preparation continues for the replacement hedges.
- Irrigation mainlines and spur lines are in place.
- A plan for the layout and planting is under development. [OTIP 406]

6.2.31 Redcedar Orchard #140 Pruning and Crop Enhancement

Tim Crowder

Objectives:

To produce 1.5 million plantable seedlings with a genetic worth above 4%

Activities:

One hundred and eight crop trees were managed to ensure the highest possible seed yield and genetic worth by:

- the pruning of existing trees to enhance pollen flow through the orchard, and encourage vigorous growth that will lend itself to female production;
- the induction of 108 non-crop trees to produce a crop for next year;
- pollen collection, extraction, re-application, agitation and monitoring, and
- the collection of 33.5 hl of cones, which yielded enough seed for 4.2 million plantable trees. [OTIP 413]

6.2.32 Incremental Orchard Management Activities at Skimikin Seed Orchards

Keith Cox

Background:

This project covered several activities aimed at increasing the quality and quantity of seed produced at Skimikin, including a cone induction trial, crop collections, roguing and re-labelling trees, and graft maintenance.

Harvest time at Skimikin

Activities:

- The timing of application of the flowering hormone gibberillic acid was tested by trial applications in May and September. The effects of this treatment will be evident from the resulting crop in 2000.
- All of the trees in the Bulkley Valley spruce orchards with a breeding value greater than three, were identified with yellow labels to facilitate crop induction work in the spring of 2000.
- Four orchards, that had been previously rogued, were levelled where the stumps had been removed.
- A total of 2,300 grafts were cared for in the holding area, in preparation for planting the Peace River spruce seed orchard in the spring of 2000. This unit has an annual requirement for seed to grow fifteen million seedlings.

Final Results or End Product:

Twenty-five percent of the following crop collections were funded by the project:

Orchard	hl (cones)	kg (seed)
206, Central Plateau High Spruce	13.8	17.6
301, West Kootenay Low Spruce	14.2	16.9
302, West Kootenay High Spruce	15.8	17
609, Southern Interior White Pine	57.2	29.7

This is enough seed to grow approximately ten million spruce and half a million white pine seedlings. [OTIP 304]

6.2.33 Graft Maintenance - VSOC Holding Area for 1999

Dan Gaudet

Objectives:

To provide cost effective, quality care for the development of new ramets prior to, and including, outplanting in the orchards. This care will ensure healthy, viable ramets and increase the production of genetically improved seed.

Final Results or End Product:

Grafts have grown to a good size and are suitable for establishment in the orchard. They will have a higher success rate once planted into their orchard locations. Healthy rootstock will be maintained and monitored for anticipated spring grafting.

Moving Grafts for outplanting

All grafts moved into orchard locations from the holding area will have an increased chance of survival due to the care and maintenance received. There is little improved seed available in the Interior for all species except spruce; the completion of orchards is a vital step towards meeting seed production targets. [OTIP 308]

6.2.34 Vernon Seed Orchard Company: Tree Nutrition Activities – Foliage Analysis

Dan Gaudet

Project Description/Overview:

The monitoring of ramet health in each orchard is common practice in managing orchards to ensure optimum seed production. Samples of foliage from each orchard are dried and the needles ground for analysis. Foliar analysis is done by a contract laboratory; results are used to determine the fertilizer requirements in the coming year. This practice is carried out annually, and is common management practice for most orchard sites.

Objectives:

Monitoring of nutrients will ensure optimum ramet development and seed production. By monitoring nutrient levels, an opportunity is provided to add nutrients if they are found to be deficient. The projected annual seed production for the VSOC site is 76 million. The seed produced is for the three main species harvested in the central Interior of British Columbia.

Final Results or End Product:

Healthy ramets are capable of carrying healthier cones and a greater quantity of them. This will enable VSOC to meet its target production level of 76 million seeds per year. As the demand increases yearly for improved seed, the management of orchards plays a vital role in meeting this demand. [OTIP 309]

6.2.35 Pest and Weed Management Activities

Dan Gaudet

Project Description/Overview:

The monitoring of ramet health for pests in each orchard is a common practice in managing the orchards' optimum seed production. Each orchard will be subject to periodic pest control evaluations by both VSOC staff and MoF pest management biologists. Spraying will occur only when undesired pests cannot be managed by other means.

Protecting orchard from pests

Objectives:

- To monitor pests throughout the growing season to ensure the timely application of pesticides.
- To control of pests as necessary for orchard health.

Final Results or End Product:

Through the control of insects, an increase in seed production will occur during cone production years, and orchards will have healthier ramets. Ramet health has a direct effect on seed production. [OTIP 313]

6.2.36 Inadequate Root Development and Crown Management of Lodgepole Pine Ramets: Bulkley Valley #219 and Willow Bowron #222

Tim Lee

Project Description/Overview:

Ramets with underdeveloped root systems require anchoring with tree ropes and stakes; this has been accomplished. The height of many orchards ranges from two to ten feet. As taller ramets reach eight to ten feet, the need for crown management becomes apparent. The cost for picking rises quickly as the height of trees increase, and so top pruning to shape and form the ramet is necessary. Each year a certain amount of pruning will be required.

Objectives:

- Thorough anchoring of ramets to establish a strong root system, which would enable the ramet to sustain wind without falling over.
- Pruning to manage ramet height, and cone and pollen production, and allow safe access.

Final Results or End Product:

- Anchoring the ramet has promoted better root growth and eliminated the possibility of losing the ramet
- The pruning of ramets has ensured subsequent cone crops can be picked for a reasonable cost.
- A small amount of genetically improved seed is available for the Bulkley Valley and Prince George SPUs, but much more is needed at this time. [OTIP 316]

6.2.37 Drainage System for Water Problem Areas Within Orchards - Willow Bowron Pine #222 & McGregor Spruce #211

Tim Lee

Project Description/Overview:

Poor drainage in Orchard #222 and #211 necessitates the installation of a permanent drainage system to remove unwanted seepage and/or surface water from entering the orchards.

Objectives:

- The installation of a permanent and easily maintained drainage system to provide adequate drainage for problem areas, by collecting surface and seepage water before it can affect the orchard ramets.
- To take all possible preventative measures to improve seed production.

Activities:

- The drainpipe was installed two to three feet deep and drainage rock will be used to help collect excess water.
- Drained water will be disposed of in a safe area outside the orchard boundaries.
- The system will be be easily maintained for years of service. This will aid in the orchards achieving their target production levels.

Final Results or End Product:

The drainage system will help ensure that the target production of genetically improved seed is met. [OTIP 320]

6.2.38 Orchard Establishment at the Bailey Site of Kalamalka Seed Orchards

Chris Walsh

Outline of Project:

The proposal consisted of the continued establishment of two ITAC approved seed orchards (Fdi Nelson High # 324 and the Pw Kootenay Quesnel # 335).

Work completed:

- Orchard 324: Establishment of this orchard commenced with approximately 150 trees that were grafted by Research Branch in 1998. Work included marking and preparation of planting locations, lifting of existing grafted stock at the Kalamalka Research Station, transportation to the Bailey Site, planting, fertilizing and maintenance.
- Approximately 400 ramets from the CFS rust tolerance screening program were planted and maintained in the existing Pw orchard 335 at Kalamalka's Bailey Site.

Final Results or End Product:

- Capacity for future production of improved Fdi seed (predicted genetic gain 15%) for the high elevation portion of the Nelson SPU.
- Increased capacity to produce rust tolerant western white pine seed. [OTIP 325]

6.2.39 Orchard Development: Layout, Drilling, Planting, Tagging and Final Inventory Confirmation

Tim Lee

Project Description/Overview:

To date, little or no genetically improved seed has been produced for the Prince George, Bulkley Valley, and Central Plateau SPUs. This year's planting projects will bring the seed production goals closer to being achieved.

Objective:

To complete orchard establishment.

Final Results or End Product:

Continued development of these four 1.5 generation orchards. The combined production of these Orchards (Pli 222, 219, 218, and Sx 211) will be greater than 50 million seeds per year, and will range in genetic worth from 7% to over 20%. [OTIP 332]

Preparing for outplanting

6.2.40 Reproductive Phenological Surveys for Pli 308 Seed Orchard

Hillary Graham

Background:

To achieve effective seed orchard pollen management, reproductive phenological surveys are necessary to determine the timing and order of seed-cone receptivity among the seed orchard's clones relative to the within orchard pollen cloud. The information generated will guide pollen management activities (including supplemental mass pollination) to increase seed set.

Activities:

Phenological data sheets were created to indicate both the presence of shedding pollen and the receptivity of seed-cones for each tree surveyed. Actual surveys commenced at the first sign of pollen flight and continued until pollen shed and seed-cone receptivity was complete (May 14 to June 14, 1999). During this period, orchard surveys were conducted daily.

In addition to the timing of pollen shed, the amount of pollen per tree was recorded. This data will be used to calculate genetic worth of seed produced in the orchard in 2000. Finally, the data collected from the surveys were condensed to provide a clone-by-clone summary of pollen flight and seed-cone receptivity. [OTIP 356]

6.2.41 Pli Pollen Monitoring in Orchards 311, 313, and 308

Hillary Graham

Background:

There are three lodgepole pine orchards and one holding area on the Armstrong site. The maladaptation risk due to pollen movement between the Nelson (NE) and Thompson-Okanagan (TO) low elevation orchards is moderate. However, the NE has high genetic potential and contaminating pollen would have a negative impact on the genetic worth of the seed. The holding area may also be contributing to the pollen contamination in the adjacent orchards. To determine the degree and amount of pollen movement both within orchards, and between orchards and the holding area, pollen monitoring was conducted.

Activities:

Just prior to pollen flight in 1999, one-day pollen monitors were installed in all three orchards, both at the orchard boundaries, and in the holding area. When pollen flight began, all monitors were equipped with a glass microscope slide covered with a film of Vaseline. These slides collected flying pollen. For the duration of the pollen flight, pollen slides were changed daily (at the same time of day), and the pollen-coated slides put into storage for counting. At the completion of pollen flight, the last slides were collected, and the monitors dismantled.

To assess pollen flight, actual counts of pollen grains were done on the slides collected. Using a simple stereo-microscope fitted with a counting grid, the amount of pollen collected was determined for each monitor. This data provided information of the amount of pollen within each orchard, going between the orchards, and from the holding area.

Final Results or End Product:

This information will be used in 2000 to develop an effective pollen management plan for the three lodgepole pine orchards. Also, monitoring year-to-year variation in pollen cloud density will help in the determination of an appropriate SMP management strategy for the seed orchards. [OTIP 357]

6.2.42 Ramet Maintenance and Pest Control in Orchards #303 and #310

Greg Pieper

Objectives:

- To improve seed production in these two orchards, by controlling pest that affect seed set and quality, as well as orchard health.
- To conduct crown management for height control in both orchards.
- To carry out roguing in spruce Orchard #303.

Progress and Activities:

In Orchard #303 (Sx) and Orchard #310(Pli), less money was spent on pest control than was applied for, because the populations of insects were down. Daconil was purchased for needlecast spray and SEVIN XLR for seedbugs. Sequoia pitch moth was bad in the lodgepole pine and was dug out by hand. Foliar and soil analysis was conducted in both orchards to prepare for next year's orchard maintenance. Top pruning in both the spruce and pine orchards was done to keep the height down. 23 ramets of poor genetic quality were rogued. 61 hectalitres of cones were collected in the Sx orchard, and 9.6 hectalitres in the Pli orchard. These crops were insect and disease free. [OTIP 375]

6.2.43 Douglas-fir Seed Production for 300m – 700m Elevation

Patti Brown

Result or End Product:

Orchard #116 produced 7.38kg of seed with a GW of four to be used by operations between 258m and 700m elevation. The extremely late pollination period and heavy crop production in the wild resulted in a contamination factor that lowered the GW by one. [OTIP 383]

6.2.44 Management and Harvesting of 1999 Western Redcedar Cone Crop – Improved by Cone Induction and Supplemental Mass Pollination

Cathy Cook

Background:

Western redcedar has the highest request numbers for regeneration in coastal British Columbia. Significant progress towards meeting the objectives of the FGC to increase the average gain in potential harvest volume, and to increase the use of improved material in regeneration, can be made through investment in the western redcedar tree improvement program.

Objectives:

Through intensive management of Cw Orchard #128 and Cw Orchard # 155, maximized seed production is anticipated.

Final Results or End Product:

- Supplemental mass pollination of the induced crop was completed under the previous year's funding. Spring surveys for western redcedar cone midge indicated low levels of infestation; no treatment was recommended.
- Frost protection by irrigation was continued to the end of April; however, significant frost damage was reported. Conelet abortion was estimated at 60% in Cw 128, and 10% in Cw 155. Damage was heavy in frost pockets within the orchards.
- Two custom seedlots were harvested from Cw Orchard #155, and one custom seedlot was harvested from Cw Orchard #128. Pending review and confirmation by the western redcedar breeder, gains in volume at age 60 of 10% and 5% are claimed for the custom seedlots, which provide seed for more than an estimated three million plantable seedlings. The general seedlots from these orchards will provide seed for an estimated additional eight million plantables.

A massive crop of western redcedar cones was harvestedin Cw 155 in the fall of 1999

- Though yield in these orchards was below the projected target due to the frost damage, high germination rates among the produced seedlots have been reported to date. Through co-operation and communication with the Tree Seed Centre personnel, the protocol for cone harvesting and processing was adjusted. Cones were shipped weekly to the Tree Seed Centre, where they were cured in a controlled environment and processed promptly. [OTIP 407]

6.2.45 Graft Maintenance of Saanich Fdc Holding Area

David Reid

Outline of Project:

Grafted material, that is to be the source of the genetic upgrading of Fdc Orchard #120, is established in a holding bed at the Saanich seed orchard site. Care and maintenance of new grafts is the most efficient method of promoting the growth of ramets to a plantable size, so that they will survive and grow in orchard locations. The objective is to provide proper maintenance to these grafts for the two years prior to outplanting.

Work Completed:

Over the course of this growing season all stock in the holding beds has been maintained by:

- pruning rootstock branches;
- fertilization;
- irrigation;
- graft maintenance;
- identity maintenance;
- mulching;
- providing protection from snow breakage,
- controlling grass and weed competition.

Final Results or End Product:

Over 3,000 ramets have been maintained through this growing season. The stock is healthy and vigorous and shows good growth and form. Mortality through the year, from all causes (mainly graft incompatibility), has been less than 5%. [OTIP 421]

6.2.46 Yellow-Cedar Seed Orchard Cone Induction and Seed Production

Don Pigott

Background:

In 1996, a part of MacMillan Bloedel's Seed Orchard #137 (yellow-cedar) was moved from Yellow Point to Reinhart Lake, in an attempt to remedy the absence of satisfactory seed production at the original site.

In April 1998, the Reinhart Lake seed orchard was assessed for presence of one-year-old and two-year-old cones, as well as pollen and female flowers for the current year.

Survival and vigor of the original plantings and the replacements was also recorded. Based on those assessments, the clones to be treated with GA3 in 1998 were also chosen. The 21 clones chosen were represented at Reinhart Lake, at the original orchard site at Yellow Point, and in the clone banks at Mesachie Lake.

Project Description/Overview:

This project involves the induction of cones using GA3 foliar spray applications for the purpose of producing more yellow-cedar seed for both end users and the breeding program.

Objectives:

- To increase seed production in MacMillan Bloedel's Seed Orchard #137, located at two sites, and the

MoF Cowichan Lake Research Station (CLRS) clone bank through GA3 cone induction.

- To increase seed production at two additional locations in the Port MacNeill area. One of these is a current genetics research trial, and the second is a phenotypically good, natural 20-30 year old stand.
- To determine the effects of orchard elevation and local climate on reproductive bud initiation and cone abortion rates, in order to enable increases in the production of viable seed.

Activities:

- Weather stations were set up to record temperature and rainfall at Yellow Point and at Reinhart Lake. Weather data was already being collected at Mesachie Lake.
- GA3 was applied as a foliar spray to two ramets of the 21 clones, at each of the three sites. The rate of application was approximately 0.2 grams of Activol per tree depending on tree size. Each site was treated three times, starting in late June and at approximately 10-day intervals. Twenty-four wildings (natural regeneration) were also treated at the Reinhart Lake site. Sixteen trees were treated three times, four were treated twice, and ten were treated once. In August, visual inspections indicated no phyto-toxicity and all trees appeared to be healthy.
- In June and July, the trees of the same 20 clones that were treated with GA3 at Rheinhart Lake, Yellow Point, and Mesachie Lake were assessed for numbers of cones. Numbers of cones were counted on three branches per tree. Cones initiated prior to the induction treatments were also tabulated.
- In early July of 1999, two new sites for GA3 induction trials were selected near Port McNeill. One was a genetics clonal research trial, while the other was a phenotypically good, natural 20-30 year old stand.
- In late September, all ramets treated were evaluated to estimate the approximate number of male and female strobili produced. In the spring, reproductive phenology and cone abortion rate will be assessed.
- In November, those cones, initiated prior to treatment, were collected at Yellow Point and Rheinhart Lake. There was an abundance of cones at Rheinhart Lake, probably induced by the stress of their relocation to the site from Yellow Point. There were not enough cones to collect at Mesachie Lake.
- In November, the seed from the collected cones was extracted and cleaned. Germination tests will be conducted shortly. However, preliminary observations indicate a much higher filled seed-per-cone content at Rheinhart Lake than at Yellow Point.
- At the genetics trial, two ramets of each of 20 clones were sprayed twice with GA3, at a rate of 0.2grams of Activol per tree. At the natural stand, 42 twenty to thirty-year-old naturals of various sizes were also treated with GA3.

Final Results or End Product:

- In general, a significant response to the GA3 applications was observed at both Mesachie Lake and Reinhart Lake. At Yellow Point, a heavy crop of both male and female flowers occurred on both the treated and untreated trees
- Perhaps the most interesting response was at Reinhart Lake on the wildings. All of the wildings treated developed reproductive buds while untreated trees had few or no male or female buds.
- In early November, a preliminary assessment indicated a very good response as compared to untreated controls at both sites near Pt. McNeil.
- Weather data, including hourly temperature and rainfall, have been recorded continuously at the three original sites, and are now also being collected at the two new sites near Port McNeill. [OTIP 423]

6.2.47 Purchase of $GA_{4/7}$ for Flower Induction in Seed Orchards and Breeding Programs

Joe Webber

Background:

The use of $GA_{4/7}$ as a flower induction technique is becoming more popular in seed orchard management, but it is also becoming increasingly difficult to obtain. Our previous supplier was Abbott Laboratories (Chicago), but they will no longer ship either crystalline $GA_{4/7}$ or their proprietary product ProCone to Canada. Dr. Richard Pharis, University of Calgary, has provided limited supplies of crystalline $GA_{4/7}$ in the past, and he was able to locate a new source .

Final Results or End Product:

$GA_{4/7}$ can now be obtained from Pharis through his sources in China. All ITAC and CTAC members were notified. A list of those needing $GA_{4/7}$ in the next two years, and the amount they needed, was compiled and an OTIP proposal submitted. In June, 1999, 1.7 kilograms of $GA_{4/7}$ was received and we are now allotting the amounts requested to the individuals participating in this project. [OTIP 477]

6.2.48 Accelerated Propagation
Keith Cox

Background:

Expansions are needed for several lodgepole pine seed orchards to meet the need for genetically improved seed. Extra rootstock was potted up in 1998 to produce more grafts in 1999.

Activities:

The rootstock was overwintered in the greenhouse, then grafted onto in early spring by Skimikin Nursery seasonal staff. The grafts were then misted and cooled to promote the formation of the graft union. The successful grafts were then pruned to promote good growth of the new shoots. An extra 2,600 grafts were made, and in May an extra 4,000 rootstock were potted up for grafting in 2000.

Most of the surviving grafts were shipped in August and September. A few remain to be shipped in the spring. The rootstock is being overwintered in preparation for grafting in the spring of 2000.

Final Results or End Product:

The average survival for the lodgepole pine grafts in 1999 was 85%. [OTIP 301]

6.2.49 Grafting of Rootstock Available for Expansion of the Bulkley Valley Pine Orchard #219 and Willow Bowron Pine Orchard #222
Tim Lee

Project Description/Overview:

The MoF will need to collect scion material to accommodate grafting of ramets required for the expansion of Orchards #219 & #222. Rootstock will need to be prepared and grafted onto in the holding area. Grafted ramets will be clonally tagged for future identification and pruned to promote proper growth.

Objectives:

- To graft 650 to 700 rootstock required for the expansion of Orchards #219 and #222.
- To ensure that VSOC produces as much improved seed as possible for the Bulkley Valley and Prince George SPUs. The shortfall in production is both internal and province-wide, so orchard expansion is for the benefit of all British Columbians.

Final Results or End Product:

Preparing scions for grafting

Seven hundred grafts needed for the expansion of the pine orchards, were completed. The demand for Class A seed for the SPUs is greater than the present orchards can supply. Expansion of the present orchards will contribute to the demand. [OTIP 319]

6.2.50 Propagation Activities and Maintenance of Grafted Orchard Stock at Kalamalka Seed Orchards
Chris Walsh

Background:

The timely production of good quality ramets to enable the development of new and expanded orchards is an essential first step to meeting improved seed production targets and seedling needs.

Activities:

- 1,500 graft-compatible Fdi rootstock were established in the Fdi propagation bed at the Bailey site of Kalamalka Seed Orchards.

- 1,485 grafts were made for the ITAC approved Nelson high Fdi orchard were made and maintained.
- Existing grafts for the Nelson low Fdi orchard, previously planted at Kalamalka, were lifted and shipped to PRT's Grandview site.
- 503 existing grafts for the EK Pli orchard, currently in holding beds at Kalamalka, were maintained.
- 1,802 new grafts were made at Skimikin in 1999 for the EK Pli orchard and were planted in the Kalamalka holding bed and maintained.

Final Results or End Product:

- Increased capacity for future production of improved Fdi seed for the Nelson Low seed planning unit and improved Pli seed for the EK unit.
- Rootstock for future grafting of Fdi stock for new and existing Fdi orchards. [OTIP 327]

6.2.51 Bulking up Tested Yellow-Cedar Donor Stock
Patti Brown

Final Results or End Product:

- Twenty four hundred one-year-old yellow-cedar cuttings from 64 of the best clones in the breeding program were outplanted in pots and in a field at Sechelt, and organically fertilized.
- Three thousand additional cuttings from the same clones were obtained from CLRS in an attempt to bulk up more juvenile material. These cuttings were set in two different rooting hormone treatments, Seradix#3 and IAA2ip, to observe differences in rootability.
- 40% of the clones were rogued from both collections in late summer, when the seven year test results became available. Only clones with a GW of nine or greater were kept. The cuttings remaining were pruned to promote side growth and juvenility. They will be used to supply future cutting material. [OTIP 379]

6.2.52 Bulking Up Clonal Material for Genetic Upgrading of Western Redcedar Seed Orchard
Cathy Cook

Background:

Western redcedar has recently been the focus of intensive breeding and tree improvement testing. By capturing the results of the tests as early as possible, Western Forest Products Limited will reduce the time to production of a second-generation orchard. This will increase the availability of high gain material for enhanced regeneration.

Objectives:

The aim of this project is to develop multiple replicates of more than 300 western redcedar parent trees currently in test, by grafting 25 ramets per clone. Upon analysis of the test results, beginning in 2003, roguing of this material will take place.

Activities:

The bulk of the work in this project is scheduled for the next quarter. To date, all required rootstock has been acquired. Scion collection is underway. [OTIP 408]

6.2.53 Crown Management of Orchard 308 (Pli – to Low)
Hillary Graham

Objectives:

The purpose of this project was to manage crown growth through pruning to increase operational efficiencies in seed and pollen production from Orchard 308. Prior to 1999, Orchard 308 was not adequately top pruned or managed for maximum flowering and pollen potential. By limiting height growth and opening up the crowns of ramets in the orchard, increased seed production and efficiency of cone harvest will be achieved. Thinning the crowns also allows for improved insect and disease management in the orchard.

Activities:

Pruning of Orchard 308 began once the trees had become dormant in the fall of 1999. Guidelines were prepared for the pruning crew, and training took place in the orchard. All of the employees working on this project were experienced cone pickers. Therefore, they all had a good understanding of cone site locations and the results to be achieved.

The main criteria were removal of non-productive branches in the centre of the crown to allow better light penetration, topping tall leaders to encourage branching, and pruning long spindly branches with long internodes and few cone sites. Also, the pruning crew was instructed to ensure that subsequent cone crops not be compromised by removing too many cone sites. Only those trees requiring branch or leader removal were pruned.

Orchard worker thins non-productive branches within the crown

Final Results or End Product:

The result of this project is an orchard that allows more light into the crowns, increasing the potential for pollen and cone production. It is expected that, within two years, increased seed production will be realized. [OTIP 360]

6.2.54 Management and Maintenance of Abies Amabalis Orchard #129

Tim Crowder

Objectives:

To manage and maintain of this orchard in a way that will promote consistent and copious production seed.

Final Results or End Product:

In the second year of a three year project:

- 2.230 orchard trees were maintained in a seed orchard setting by fertilizing, irrigating, pruning, and controlling insects, diseases, and vegetation.
- The orchard was surveyed for reproductive buds, insect and disease damage, cone production and maturity.
- Two litres of pollen was collected, extracted and stored for SMP.
- Two Hectolitres of cones were collected from 78 trees, and the seed extracted. [OTIP 410]

6.3 Technical Support

Projects that are funded under this section, support provincial-wide tree improvement needs, including seed pest management, and program planning and development.

6.3.1 Operational Crown Management in Two Interior Spruce 'High Density' Seed Orchards and Two Interior Western Larch Orchards

Clare Hewson

Outline of Project:

The management of 'high density' clonal row orchards, and conventional seed orchards consisting of rapidly growing species, pose major crop management problems to the orchard manager. This was the third year of a long term crown management program; the primary objective was to determine the most cost effective treatment for controlling height growth in these orchards, while, at the same time, maintaining optimal cone and seed production.

This program was initiated in 1997 under OTIP 69. In the last three years, six crown management treatments were applied to over 600 ramets in the 'high density' spruce orchards, and over 2,200 ramets in the western larch orchards. These treatments included various degrees of height control through leader pruning, and/ or various degrees of lateral branch pruning to obtain and maintain the desired hedge effect.

Although the orchards are still considered in a development stage, an exceptional cone crop was realized in the fall of 1999. Once this data is analyzed, some of the current techniques may be modified in order to ensure the most effective orchard and crop management practices (pesticide application, pollination, row access, cone collection, scion collection etc.) are applied. It is proposed that these operational treatments be continued to assess their effect on future orchard and crop management and crop enhancement programs. It is anticipated that recommendations for operational crown management of 'high density' clonal row orchards and conventional, rapidly-growing seed orchards could be available as early as 2001. [OTIP 370]

6.3.2 Operational Crown Management and Flower Induction in Two White Pine Seed Orchards

Clare Hewson

Outline of Project:

The management of seed orchards consisting of rapidly growing species, such as western white pine, poses major crop management problems to the orchard manager with regard to excessive height growth. This was the first year of a long term crown management program. The primary objective was to determine the most cost effective treatment for controlling height growth in these orchards, while, at the same time, maintaining optimal cone and seed production.

As the demand for rust tolerant seed exceeds supply, a second objective of this technical support project is to increase cone and seed production in western white pine by identifying procedures to induce flower initiation using Gibberellin$_{4/7}$ ($GA_{4/7}$).

Progress to Date:

In co-operation with the Research Branch and orchard managers at two ministry orchards (Kalamalka Seed Orchards in Vernon, and Saanich Seed Orchards in Saanich), three crown management treatments were initiated in 1999. These consisted of; 1) Crown removal at 2.5m at Kalamalka and 4.0m at Saanich, 2) Height control, combined with current primary leader and lateral removal in early spring, 3) Height control, combined with removal of bud primordia occurring on primary branches in the fall. It is anticipated that results of this support program will ensure the most effective crown management practices are applied to western white pine orchards. The results of this project will not be known for some time, but it is anticipated that this program will continue in 2000.

Cone induction using $GA_{4/7}$ was also initiated in two seed orchards (Skimikin Seed Orchards in Salmon Arm and Saanich Seed Orchards in Saanich). Treatments consisted of 40 and 80 g/l concentrations applied either in spring or early fall. Next spring, flower counts will be conducted to determine the efficacy of these treatments. [OTIP 372]

6.3.3 Cone and Seed Pest Management – Interior Operations

Robb Bennett

Project Description/Overview:

To provide cone and seed pest management services to Interior conifer seed production industry, including government and private seed orchards, and natural stand cone and seed collectors and dealers.

Objectives:

To provide operational funding to support the activities of one pest management biologist, including travel to orchard sites and related field work and extension activities, such as vehicle and facility maintenance, and laboratory and office supplies.

Activities:

During the period 1 April – 31 December 1999, the pest management biologist (Dr. Ward Strong) provided the following services to the Interior cone and seed production community:

- 106 pest surveys and identifications, damage predictions, and assessments.
- 26 written reports to orchard managers and other personnel.
- 63 other pest identification services to forestry personnel and others.
- 17 extension education presentations to students.
- Five professional presentations to various groups.
- Numerous "tail-gate" type extension presentations to operational personnel. [OTIP 338]

6.3.4 Control of Cone Beetles in a Coastal Seed Production Area of Blister-Resistant Western White Pine

Robb Bennett

Project Description/Overview:

Cone beetles (Conophthorus ponderosae) are causing significant losses of cones and seeds in a seed production area on Texada Island used for controlled breeding of blister-resistant western white pine. An integrated program of pheromone-based mass-trapping of beetles within this isolated stand, ground collections of beetle infested cones, and cone bagging will significantly reduce levels of damage.

Objectives:

To conduct a mass-trapping program against the white pine cone beetle (Conophthorus ponderosae), in an isolated stand of blister-resisant western white pine used for seed production from controlled breeding trials.

Sex pheromone-baited insect trap placed in crown of cone-bearing rust resistant western white pine tree

Activities:

In the second year of cone beetle management in the rust-resistant western white pine seed production area on Texada Island, insect traps were baited with cone beetle sex pheromones and placed in the crowns of mature trees. Trap catches were dramatically reduced from the previous year (508 in 1999, 2,630 in 1998), an apparent indication that the beetle population was collapsing. Eleven trees in each of two sites within the stand were climbed and the cones on them assessed for level of beetle attack. This survey showed no difference in level of attack between sites, suggesting that the population decline was occurring across the stand. It is hoped to continue beetle trapping at the site in 2000. [OTIP 465]

6.3.5 Operational Testing of Pheromone-Based Monitoring and "Attract-and-Kill" Control of Douglas-Fir Cone Gall Midge, (*Contarinia Oregonensis*) in Douglas-Fir Seed Orchards

Robb Bennett

Project Description/Overview:

The following have been successfully completed:

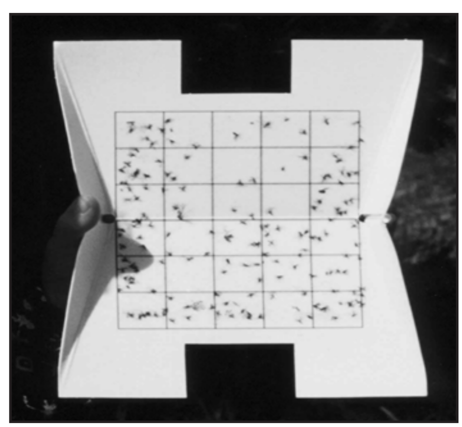
- Isolation, identification, and field-testing of the Douglas-fir cone gall midge (DFCGM) sex pheromone.
- Demonstration of a correlation between pheromone-baited trap catches and DFCGM egg infested cone scales.
- Demonstration that the pheromone is more attractive to male DFCGM than are virgin female DFCGM.
- Development of the basis for a simple operational DFCGM monitoring program using this pheromone.

This project provided a first year of funding for operational field testing of pheromone-based monitoring, and "attract-&-kill" (a mixture of synthetic pyrethroids and DFCGM sex pheromone) techniques for damage prediction and control of DFCGM.

Objectives:

In collaboration with Simon Fraser University, the following objectives were established:

- To field test pheromone-based monitoring of DFCGM to predict crop damage caused by it, in commercial Douglas-fir seed orchards.
- To field test pheromone-based "attract-&-kill" of DFCGM as a control option.



Cone gall midges caught in sex pheromone-baited insect trap

Activities:

Early spring weather initiated maturation and flight of DFCGM before funding for this project was approved. Thus it was not possible to run an effective large-scale monitoring and control program in 1999. However, it was possible to successfully field-test the "attract-&-kill" control technique in BC seed orchards: traps baited with complete formulation (base + pyrethroid + DFCGM pheromone) or base + pheromone were successful and equally effective, but somewhat less so than traps baited with pheromone alone. Control traps (unbaited), traps with base only (no insecticide or pheromone), and traps with base and insecticide, captured none to extremely few DFCGM. A complete set of DFCGM monitoring and control field tests will be run in early spring of 2000 in Douglas-fir seed orchards in Oregon, Washington, and BC. [OTIP 389]

6.3.6 Systemic Insecticide Drenches
Ward Strong

Background:

The objective of this project is to reduce seed loss due to insect activity in all Pli, Sx, and Pw programs, by providing information to improve pest management practices. This trial will determine whether insecticides can be applied by soil drenches rather than by broadcast sprays, which are hazardous to the applicator and the environment. Systemic insecticides may be taken up by the roots and move throughout the tree, thus protecting foliage and cones from insect damage.

Leptoglossus, a target for systemic insecticides

Drenches could reduce costs and applicator exposure, as well as increase the level of pest control, as compared to broadcast sprays. The immediate objectives are cost evaluation, ease of use, phytotoxicity, and efficacy of soil-applied systemic insecticides.

Planned Activities:

Four orchards (Interior Pl, Lw, and Sx and one Coastal Sx) were to be used. On each, 10 or 11 treatments were to be applied, composed of one or two rates of five pesticides and a pure water control. Replicates were blocked by clone. Applications were two weeks before budburst, except the Coastal Sx, which was to be in August. Interior applications were against general seed orchard pests, including stem, twig, foliage, and cone insects. Coastal applications were against the spruce aphid. Pesticides were applied by pouring the solution around the drip emitter(s) at the base of each experimental tree. Success would be assessed through periodic tree examinations and determination of seedset in the resulting cones.

Progress to Date:

All activities went as planned except that the Interior Sx orchard was dropped from the trial, due to very low cone counts. Applications were fast, simple, and of low hazard to personnel. Surveys in Interior orchards showed no patterns of phytotoxicity, except possibly very slight damage with Furadan and Lagon. Foliar pests were generally so spotty that no conclusions could be reached as to efficacy, except with the pine needle sheath miner, which was reduced with three of the insecticides. Cones are currently being extracted to determine seedset. The Coastal Sx orchard will be assessed in late February or early March for efficacy against the spruce aphid. [OTIP 463]

6.3.7 Spruce - Weevil Resistance Improvement - Marker Investigation
John King

Outline of Project:

Genetic resistance to the white pine weevil damage in spruce has been noted now for several years. This resistance can be quite marked (heritability has been estimated as 1.00) and one clone (898) so far has shown an immune response. Full-sib families have been made between this immune clone 898 and three highly susceptible Queen Charlotte Island parents. Understanding the mechanisms of this resistance and how it is inherited will be vital to building a durable resistance for deployment to the forest. Part of the understanding of the inheritance can be found through marker association with this resistance. It is proposed in this project to investigate and develop DNA markers that can be used to identify the resistance found in 898.

Pw clone 898

Microsatellite markers were selected as the target genomic sequences for development of DNA markers in spruce. Microsatellites are discrete regions in eucaryote genomes that are composed on uninterrupted tracts of simple sequence repeats (SSR), varying in length from approximately 20 bp to more than 100 bp. These regions are useful as genetic markers because they frequently vary in size when identical sites are compared between any two random individuals, and therefore act as distinguishable landmarks that can readily be detected, using DNA amplification and gel electrophoresis assays. Such sites are extremely common in eucaryote genomes, and, on average, occur approximately every 20-50 kb along the linear sequence of each chromosome.

This project aims to generate, over several phases, sufficient numbers (approximately 250) of genetic markers to aid in characterization of weevil resistance in clone 898, and any other number of phenotypic traits in spruce that are readily scored. As a first goal, 100 microsatellite markers are to be isolated, characterized, and then evaluated as for use in the existing 898 pedigrees.

Progress to date (January 31st 2000):

The first stages of marker development were to isolate total genomic DNAs, (using 898 as a source) and develop enriched libraries for the microsatellite-containing region of the spruce genome. This work parallels similar projects done previously for white spruce (R. Hodgetts and B. Thomas, U of Alberta). Total genomic DNAs were prepared from vegetative branches of clone 898 in late November 1999. The DNA was then digested separately, with two restriction endonucleases (Hae III and Alu I) to generate genomic fragments suitable in size for cloning into plasmid vectors. To enrich for microsatellite regions, the digested fragments were modified by addition of synthetic adapters, and then hybridized with synthetic oligonucleotides, complementary to the ubiquitous microsatellite sequences dCA_n and dAG_n. The oligonucleotides were also labelled with biotin, so that hybridized genomic fragments containing dCA_n and dAG_n sequences could be captured with streptavidin on bound to solid supports (paramagnetic beads). These enriched fractions of spruce genomic DNA were then amplified using primers complementary to the synthetic adapters, and cloned into plasmid vectors using a restriction site also contained in the adapters (EcoRI). As of Jan 3, 2000, approximately 3000 colonies were being screened for CA_n and AG_n containing clones. The level of enrichment observed in preliminary tests was approximately 20%, meaning approximately 600 microsatellite clones are now available. These are currently being evaluated in order to identify clones that have different sized inserts, (i.e. unique) and have low copy number in the spruce genome.

Similar enriched libraries are being developed for other microsatellite SSR motifs in clone 898. Biotin labelled tetranucleotide repeats motifs $GATA_n$ and $GACA_n$ have been prepared, and are being processed similarly. This class of SSR has the advantage of giving larger polymorphic differences between alleles, and simplifies interpretation of banding pattern obtained after electrophoresis. In addition, this class potentially can be analyzed using simpler electrophoretic techniques, (e.g. agarose gels versus polyacrylamide gels) and offers several advantages over conventional dinucleotide SSRs. [OTIP 647]

6.3.8 Production of Rust Resistant Seed in Western White Pine Seed Orchards

John Owens and Jordan Bennett

Introduction:

This was the second year of the trials and experiments carried out in the Pw half-sib seed orchard at BCMF Saanich Seed Orchard (SSO), and the clonal BCMF seed orchard (KSO) at Bailey Road near Kalamalka. These represent wet coastal and dry interior sites.

Objectives:

The objectives were to:

- determine the time of seed-cone bud initiation;
- determine the phenology of pollen-cone and seed-cone development for a second year;
- determine the reproductive potential (RP) and reproductive success (RS) and the causes of cone and seed loss; and,
- develop methods for enhancing seed and cone production.

Progress and Results:

Some objectives have been completed, and for others, seed and cone development and loss are still being measured from pollinations done in 1999.

Cone Bud Initiation:

In Pw, as in other temperate pines, pollen-cone buds are initiated in the fall, and overwinter at the sporogenous cell stage before pollen forms. Lateral bud primordia are initiated at the tips of the long-shoot buds in the fall, but do not differentiate into branch buds or seed-cone buds until April, after winter dormancy. Cytochemical tests for succinic dehydrogenase (a respiratory enzyme) showed elevated levels in some of the bud primordia early in April at SSO in 1999. These bud primordia subsequently developed into seed cone buds. Less active bud primordia slowly developed into lateral branch buds over the course of the entire growing season. This information will be used for cone induction trials in seed orchards.

Phenology:

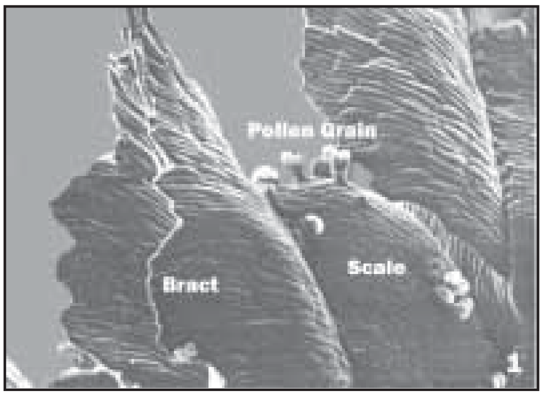
Phenology of pollen cones and seed cones was monitored every day, and the pollen flight was monitored continuously at SSO and KSO. Pollen flight at SSO began 15 days later in 1999 than in 1998. In both years, pollen release occurred over two weeks, with two peak periods occurring about six and nine days after release began. Seed-cone receptivity matched pollen release very closely. Pollen flight at KSO lasted only about one week with a single peak release period. Pollen release and receptivity began 20 days later in 1999 than in 1998. Maximum seed cone receptivity preceded maximum pollen flight by two to five days, indicating that protandry may be a problem as the trees in the orchard become more mature. At the present time, very few clones produce pollen. As more clones begin to produce pollen, there may be more variation in time of pollen release and the degree of protandry may decrease. This should be monitored every year. The adverse effect of protandry can be reduced by SMP.

Operational SMP:

Operational SMP was done at both seed orchards. SMP effects were monitored by measuring the pollination success (PS) (counts of the average number of pollen grains per ovule for 10 ovules per cone) and by measuring cone retention on SMP trees and control trees (no SMP). In both orchards, SMP was applied two to several times, determined primarily by staff availability. At SSO, there was an average of eight pollen grains per ovule with SMP and one per ovule with no SMP. However, cone retention was only about 50% in both treatments. At KSO, SMP had similar beneficial results on PS, but likewise, had low cone retention in August (~50%). By late spring there was an additional 25% decrease in the cone crop. Over-winter losses appeared to be similar at both sites, but complete data are not available, because the non-rust resistant trees used in the study at SSO, were inadvertently rogued during the winter months. The loss of at least 50% of the cone crop in both orchards warrants further study. KSO observations indicate that cone drop is a possible clonal trait.

Other Trials:

Several other trials were made at SSO and KSO. Briefly, the optimal stage for pollination of seed cones is Stage 4. Stage 5 is still quite receptive but Stage 3 is not. Therefore, SMP should not begin too early, but will be beneficial until cones become completely sealed at Stage 6. In control pollinations or breeding experiments, 0.4 ml of pollen per pollination bag is optimal, giving about 10 pollen grains per ovule. There is no benefit to using more pollen, and it may be detrimental by clumping in the cone and causing fungi to grow more abundantly. Pollen quantities of 0.3 ml or less, significantly reduced the pollen per ovule. Reduced PS effects ovule development, and may result in subsequent cone abortion. Pollen may enter the cone and attach to ovule tips, or it may adhere to hairs along the margins of bracts and scales in a golf tee fashion (See Figure 1). Water, as a fine spray, carries this pollen into the cone, increasing the PS and supplementing the pollination drop. Spray, as a fine mist, increased PS over controls at the dry KSO site, but did not at the wet SSO site.



Scanning electron micrograph, showing the scale margin at pollination with hair cells and pollen attached in golf tee fashion. Water spray causes pollen to be washed from the hairs down to the ovules, increasing pollination success.

Summary:

- Seed cone bud differentiation occurs in early April.
- SMP is essential in young seed orchards and greatly increases PS in young and older orchards.
- Seed cone receptivity and pollen release vary among years and last for about two weeks at SSO, and for about one week at KSO.
- KSO has some protandry but SSO does not.
- Cone drop is a major problem at both orchards and further studies must be done to determine the causes.
- PS is no doubt important but clonal effects may be important.
- In control crosses, and for SMP, the optimal time for pollination is Stage 4 of seed cones, and the optimal amount of pollen in breeding experiments is 0.4ml per pollination bag. [OTIP 473]

6.3.9 Open-Pollinated, Full-Sibling, Elite Seed Production is an Operational Reality for Douglas-Fir

Michael Stoehr and Joe Webber

Background:

This is the third year of testing open-pollinated efficacy for the production of elite seed crops in Douglas-fir. SMP efficacy for year one and two was 50% and 70%, respectively. This is substantially better than the current flat rate of 25% credited to orchard managers who use SMP for improving the genetic worth of production crops. These rates are encouraging, but they were also obtained under relatively light pollen load. Since competing pollen cloud density is one of the most important factors affecting SMP efficacy, it was necessary to test techniques under a heavy pollen load. The summer weather of 1998 was good for flower induction (hot and dry), so a good flowering year for the spring of 1999 was anticipated.

Activities:

In anticipation of the heavy pollen cloud, it was decided to include a more operational pollination device that applies greater volumes of pollen to a wider cluster of flowers. A bloom delay (over-head misting) and whole tree bagging was included. The latter involved tenting the entire tree with a porous, white, agricultural cloth. It was decided not to exclude pollen from sifting through the protection cloth, but rather to try to impede and trap it by misting the interior of the cloth. The cloth was relatively easy to erect (using the overhead wire already in place) and was not seriously damaged by the wind. The protection cloth was only used during the receptive period of the tree (seven to ten days).

Four pollination treatments were used. Open pollinated with no misting (O-D), cloth protected with no misting (C-D), open pollinated with misting (O-W), and cloth protected with misting (C-W). Unfortunately, the 1999 flowering crop was not heavy and abortion was high. Only five clones with a crop on each of the ramets were available.

Final Results or End Product:

Table 1 summarizes the filled seed per cone (FSPC) for the few cones that survived. The misting lowered seed yields for both the open-pollinated and cloth protected treatments. The best yields were obtained on ramets open-pollinated and not misted.

Clone	Trmt.	No. Cones	Tot. Seed	Filled Seed	FSPC
3212	C-D	10	212	30	3
3212	O-D	10	320	154	15.4
3212	C-W	0	0	0	0
3212	O-W	10	203	23	2.3
3204	O-W	0	0	0	0
3204	C-W	0	0	0	0
3204	O-D	2	114	71	35.5
3204	C-D	10	372	99	9.9
3235	O-W	0	0	0	0
3235	C-W	0	0	0	0
3235	O-D	0	0	0	0
3235	C-D	2	85	27	13.5
3261	C-D	10	306	109	10.9
3261	O-D	10	334	177	17.7
3261	C-W	10	151	31	3.1
3261	O-W	5	141	42	8.4
3265	C-D	0	0	0	0
3265	O-D	5	297	174	34.8
3265	C-W	0	0	0	0
3265	O-W	2	124	22	11

Summary of Means:

Treatment	O-D	C-D	O-W	C-W
Filled Seed/Cone	25.8	8.8	7.2	3.1

Table 1. Filled Seed per Cone by Treatment

The high abortion rate experienced may have been partially caused by the misting treatment. Higher abortion rates, on cones pollinating during wet conditions, have been noted. Since so few cones matured on misted ramets, it was impossible to say that misting significantly reduced yields, but the trend is there. What effect misting (dry and wet) and cloth protection (open and closed) had on SMP efficacy is currently being determined from paternity analyses. [OTIP 403]

6.3.10 SMP with Unique DNA Markers to Improve Seed Production and Confirm SMP Efficiency

Clare Hewson

Outline of Project:

SMP is a recognized orchard operational tool, used to improve genetic worth of seedlots and to increase seed production, particularly in developing orchards. This program was initiated in 1998, with the primary purpose of increasing seed production in one Private and two Ministry seed orchards. In addition, the pollen collected in 1998 originated from clones with unique DNA markers. This year, the pollen was applied operationally to ramets in the three seed orchards. The second phase of the program will provide seed to determine the contribution made by the supplemental application of pollen

This is a co-operative project involving seed orchards at the Prince George Tree Improvement Station, PRT Armstrong - Grandview Seed Orchards, and Kalamalka Seed Orchard, Vernon, with collaborators from the M of F Research Branch and BC Research Inc.

Progress to Date:

In 1999, the pollen collected from clones with unique DNA attributes in 1998 was applied to over 900 ramets in developing seed orchard #228 at the Prince George Tree Improvement Station, developing orchard #313 at PRT Armstrong's Grandview Seed Orchard, and mature orchard #307 at Kalamalka Seed Orchard. These cones will be harvested in the fall, 2000.

In addition to the operational program, pollination bags were applied to several branches and removed only during the application of pollen. They were then immediately replaced. Seed that will be collected from these branches in 2000 will represent the effect of applied pollen only. Other branches were bagged during only the period of pollen application. These will represent the effect of wind pollination only. A third set of branches were flagged only, and received both natural and applied pollen. Seed collected from this third set will represent the combined effect of natural and applied pollen. The crop will be harvested in the fall, 2000, and filled seed and seed efficiency will be determined for each treatment. This information will be used to assess the efficiency of SMP.

DNA analysis will also be conducted on seed samples from each of the three treatments from each orchard, to determine the contribution of applied pollen to the seedlot. This information will provide data to confirm and/or modify the current protocols for rating the effectiveness of SMP in lodgepole pine seed orchards. [OTIP 371]

6.3.11 Cone Induction in a Young Lodgepole Pine Orchard

Michael Stoehr

Background:

Seed production, in lodgepole pine seed orchards in the Okanagan Valley, is traditionally low, due to the low number of filled seed per cone. One way to offset these shortages in seed supply is to increase the number of seed and pollen cones per ramet. Various cultural and hormonal treatments have been successfully used to stimulate the coning response in conifers.

Objectives:

- To apply stem injections of the plant hormone GA (gibberillic acid) in the form of $GA_{4/7}$ and stem girdling, in a factorial fashion to a young, operational clonal seed orchard of lodgepole pine.
- To assess the efficacy of these treatments in inducing seed and pollen cones.
- To evaluate the phytotoxicity, occasionally associated with $GA_{4/7}$ treatments.

Activity:

In the summer of 1998, a 2x3 factorial experiment was conducted with two levels of girdling (yes vs. no) and three levels of $GA_{4/7}$ (0, ½ and full dosage) applied over six clones. The trial was conducted at PRT Orchard #311 (Armstrong). The following treatments were applied to two ramets per clone:

- GA at half dosage
- GA at full dosage
- Girdle (double overlapping)
- GA at half dosage plus Girdle
- GA at full dosage plus Girdle
- Control (no GA and no Girdle)

The GA was applied as stem injections, at a concentration of 25 mg/ml for a half dose and at 50 mg/ml for a full dose. The actual dosage injected was dependent on stem diameter measurements just below the lowest live branch. Trees with stem diameters of less than 5cm diameters received 0.2ml, trees with diameters between 5.1 and 7.0cm received 0.4ml. Trees above 10cm received 0.6 ml of GA solution. Girdling was done as a double overlapping girdle. Treatments were applied in August of 1998, and the following traits assessed in the spring of 1999: new seed cones, new pollen bud clusters, foliar damage, and the number of aborted 1998 cones.

Final Results or End Product:

The results of GA and girdling treatments on six lodgepole pine clones growing in PRT Orchard #311 age presented in Table 2.

Variables	Control	‰ GA	Full GA	Girdle	Girdle + ‰ GA	Girdle + Full GA
# of first year seed cones	82	71	85	45	62	48
Increase[1] (98/99)	4	6	6	2	5	3
1999 Pollen	3.8	16.6	16.3	3.6	11.2	3.3
Foliar damage[2]	0	1.6	1.5	0.3	1.8	1.9
# of second year cones	0.5	3.8	2.8	2.3	3	5.2

[1] Ratio of the number of cones initiated in 1999 to cones harvested in 1999.

[2] Damage Codes; 0=no damage, 1=chlorotic needles, 2=< 20% of needles dead,

Table 2. Results of GA and Girdling Treatments

Analysis of variance (not shown) for the number of 1999 seed cones, revealed that significant effects were due to clone and treatment. Therefore, the most successful treatments with acceptable levels of phytotoxicity were identified. It was decided that the half and full GA treatments gave best results, based on the number of seed cones initiated, and the number of pollen clusters initiated and causing the largest increases compared to the previous year's crop on a treated ramet. These two treatments, plus a control, were then applied to 40 clones in Orchard 311 in August 1999. Efficiency of these treatments will be evaluated in the summer of 2000. [OTIP 349]

6.3.12 Improvements to Collection, Processing, and Handling of Western Redcedar Cones from Seed Orchards

Don Pigott

Project Description/Overview:

This is a preliminary examination of the problem associated with achieving satisfactory seed quality and purity of western redcedar cones, and seed harvested from seed orchards. Collection and processing of western redcedar cones, and seeds from seed orchards to meet current purity and quality standards, is much more difficult than from natural stands. All aspects of collection, handling, storage, and processing will be evaluated to look for opportunities to improve seed quality in a cost efficient manner.

Progress:

In September-October 1999 western redcedar cones were collected from Timberwest's Mt. Newton Seed Orchard # 152 for this project. Cones were also collected from one natural stand at Memekay River near Campbell River, as a control.

Cones were collected to two different purity standards, and at two different times. Pre-cleaning at the collection site was attempted. The cones were processed at two different intervals after collection, and at two different kiln temperatures. Final cleaning is to be completed shortly.

Costs of collection and processing have been tracked. Once processing is completed, seed quality and germination tests will be conducted. [OTIP 420]

6.3.13 Production of Quality Seed in Interior Seed Orchards

Kermit Ritland

Background:

The genetic efficiency of a seed orchard can be enhanced by practices that minimize self-fertilization, parental imbalance, and outside pollen contamination. A large variety of studies have been conducted with various facets of genetic efficiencies in coastal seed orchards, but not with Interior seed orchards, specifically spruce orchards. In the previous two years, the focus has been on two spruce orchards: the Vernon Seed Orchard Company (VSOC), spruce seed Orchard #214, and the M of F seed Orchard #620 at Kalamalka. Both studies utilized isozyme markers, a type of marker available to forest geneticists for over 20 years, but a type of marker which is not highly informative about these aspects of genetic efficiency.

Activities:

This year, part of the work has involved developing better nuclear molecular markers for Interior spruce. Microsatellites are a type of marker which exhibit high variability, and hence are highly informative, and are the marker of choice for individual identification and paternity determination. However, the large genome size of conifers makes their development more difficult than for other plants and animals. A total of 36 microsatellite primer-pairs were evaluated last year, whose sequences were provided by four different sources (these markers were not "optimized" for the polymerase chain reaction, and their variability was unknown). After intensive screening, a battery of five highly polymorphic microsatellites (PG9, UACPg1b, UACPg2, UAKPg1, UAKPg3) were derived. All loci had at least five alleles in initial screening, with just six individuals; PG9 is known from other work to contain ca. 20 alleles.

For the evaluation of seed orchard genetic quality this year, seeds were obtained from VSOC #304 (37 clones) and the VSOC #212 (42 clones) in fall 1999. Seed were germinated and DNA extracted from eight individuals for each clone (632 extractions total). As of January 20, 2000, the assay for PG9 and UACPg1b, the Li-Cor sequencers, has been finished, and PCR products for loci UACPg2 and UACPg1 are being amplified. It is expected that all five microsatellites loci will be finished by the first week in March. It will then be necessary to estimate the degree of inbreeding (selfing), the degree of pollen contamination from outside sources, and degree of parental imbalance, e.g., variability among male and female parents in their contributions to the seed crop. The application of this method will optimize the genetic gain of seed orchard material, and is particularly needed in more advanced generation orchards. This procedure will also be the first to utilize highly polymorphic, microsatellite loci to study spruce seed orchard genetics, placing British Columbia at the forefront of modern forest genetics.

Also, this year, the forest genetics laboratory at UBC (and its mandate) was expanded through a $968,000 grant from the Canadian Foundation for Innovation. The objective was to create a "Genetic Data Center", envisioned as a service lab for molecular genetic work in forest genetics, gene conservation, and evolutionary biology. It should be a valuable resource for future FGC activities. [OTIP 367]

6.3.14 Controlling Selfing Rates in Natural and Seed Orchard Populations of Western Redcedar

Kermit Ritland

Background:

In western redcedar, earlier studies have indicated that significant levels of seed may be accidentally produced via self-fertilization (up to 60% selfed seed). This inbreeding can cause a loss of productivity in second growth stands established with this seed. This project is attempting to reduce the level of this selfing via the institution orchard practices that reduce selfing (the application of SMP, and the blowing of pollen), and monitoring their effect by estimating selfing and parental imbalance with microsatellite markers. As a control, selfing is being measured in non-manipulated seed orchards and in natural populations (the latter through in-kind contributions from UBC).

Activities:

This year, progress has been made with evaluations of orchard practices in three western redcedar seed orchards. The Lost Lake seed orchard consists of about 100 clones with four ramets per clone. In an experiment successfully conducted in spring 1999, one quarter of the orchard was left as control, pollen was blown over one half of the orchard, and SMP was applied to the other quarter of the orchard. From each of 10 clones seed were collected from three positions in the treetop, bottom south, bottom north. Seed were collected from the same clones in each treatment, for a total of 30 combinations. After cleaning, seed arrived at the laboratory in December 1999. Currently, 10 seed progeny are being assayed from each combination for microsatellite markers. In 1999, John Russell and associates also collected cedar seed from the Mt. Newton seed orchard (16 clones; three crown positions - upper, lower inside, lower outside) and from the Sechelt seed orchard (six clones; SMP, control; two ramets/clone; two crown positions - upper/lower). There are plans to assay this material in the coming year for selfing rates and parental imbalance. As part of an in-kind study, seed from 10 natural populations have been collected this past year, often by crown position, and these natural collections will be assayed for the extent of inbreeding.

To increase operational efficiency, a "bulk" method for estimating selfing is being developed, which is based upon the bulk extraction and assay of several seeds at one time from a parent, resulting in perhaps a four to eightfold increase of assay efficiency. As in-kind support, a graduate student Lisa O'Connell has developed a battery of 13 western redcedar microsatellite markers at no cost to the Tree Improvement Program. Overall, these operations will guide policy on seed collections of Cwr and will contribute to the FGC business objectives of increasing gain. [OTIP 418]

6.3.15 Comparison of Methods to Determine Gamete Contribution in Interior Spruce Seed Orchard Seedlots

Michael Stoehr

Background:

Seedlots produced in seed orchards must be rated to assign a genetic worth (GW) to each lot. According to the rating protocol, female gamete contribution is determined based on an estimate of the total volume of cones harvested per clone in the orchard. The male gamete contribution is determined based on pollen bud surveys prior to pollen shed. The purpose of this project was to determine the relationship of cone volume at time of harvest, and the number of filled seed (the actual female gamete contribution) per cone. Based on the strength of this relationship, the seedlot rating protocol may have to be adjusted.

Activity:

Six randomly selected cones from five ramets of each clone growing in Kalamalka Orchard #304 and Vernon Seed Orchard #214 were harvested in mid-August 1999. The total volume and weight of cones for each 30-cone sample was determined at that time. Five cones were then selected and seed extracted to be analyzed by K. Ritland to determine male gamete contribution based on molecular paternal analysis (OTIP 367). All seeds were extracted from the remaining 25 cones per clone. The filled seed content was determined by X-ray analysis of all extracted seed. Means, co-efficient of variation (CV) and R^2 values were calculated for a combined sample of 50 clones (clones from Kalamalka and VSO).

Results:

The correlation coefficients among the measured seed and cone traits, and their descriptive statistics of 50 Interior spruce clones growing in two orchards in Vernon, BC, are given in Table 3.

Trait	Cone Volume (ml)	Cone Weight (g)	# Seed per Cone	Filled Seed per Cone
Cone Volume		0.87	0.49	0.46
Cone Weight			0.26	0.28
# Seed/Cone				0.69
Mean:	14.5	7	103.7	46.7
CV (%):	25.6	27.6	24	48.3

Table 3. Correlation coefficients of seed and cone traits.

The correlation between cone volume and filled seed per cone is not strong, as only roughly 25% of the variation in filled seed content per cone is accounted for by cone volume in this sample of spruce clones. Furthermore, filled seed per cone as a trait is very variable among clones (Coeff. of Variation = 48%). This is also reflected in the raw data, as the filled seed percentages among clones range from 6% to 78%. Thus, several factors contribute to this trait, presumably during the periods of pollination, fertilization and seed development and, possibly, resistance to the western seed bug. However, levels of Leptoglossus during 1999 were low. X-ray work to determine the filled seed content is still in progress for 30 clones. [OTIP 348]

6.3.16 Comparison of Seedlot Genetic Worth (GW) Calculations Using Standard Protocol and Gamete Contribution Provided by Molecular Analysis

Michael Stoehr

Background:

Seedlot rating requires, as one of the input variables, the expected maternal gamete contribution, estimated as the volume of seed cones produced by each clone. Pollen contribution is usually based on pollen surveys. As expected, these two input variables may be subject to error and may cause the GW of a seedlot to be either over or underestimated. Techniques are now in place for lodgepole pine that can be used to estimate clonal gamete contributions to a seedlot much more precisely. Open-pollinated seedlots can be analyzed with a set of chloroplast (cp) DNA markers to determine not only male and female gamete contribution, but also outside orchard pollen contamination and possibly, SMP efficacy. Finally, this type of analysis may also shed some light on the problem of low seed set in lodgepole pine orchards; especially, if low seed set is caused by selfing.

Activity:

To estimate the amount of pollen flow, seven-day pollen monitors were set up prior to pollen shed in Riverside's lodgepole pine Orchard #310 (Figure10).

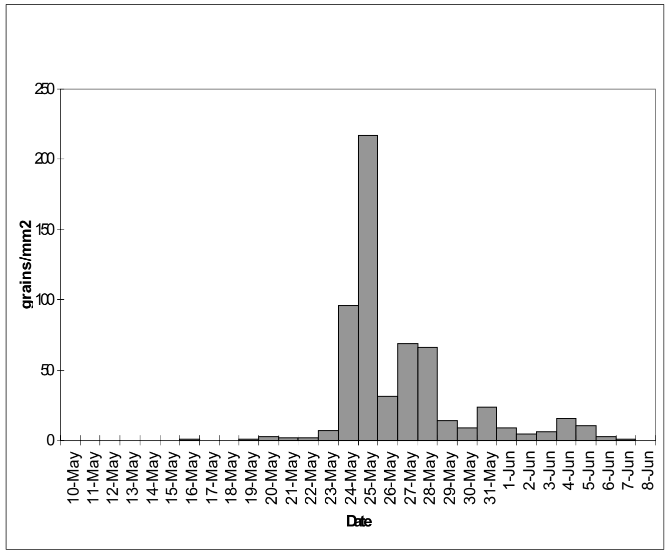


Figure 10. Pollen Monitoring at Riverside Lodgepole Pine Orchard #310 (Spring 1999)

At the same time, vegetative buds from each clone represented in the orchard were collected. Total DNA was extracted from the samples. Work on fingerprinting the orchard is in progress. In the fall 2000, 50 open-pollinated seed from each clone will be assayed to determine their male parent. [OTIP 350]

6.3.17 Enhancing Seed Production and Genetic Worth in Western Hemlock Seed Orchards

Joe Webber

Objectives:

The objective for this project is to develop the necessary diagnostic tools for rating the paternal contribution to western hemlock seed lots. This work will lay the foundation for fairly assessing SMP efficacy and its actual effect on the genetic worth of seed crops. The approach successfully used for Douglas-fir, lodgepole pine and Interior spruce is being followed. In co-operation with BC Research and CanFor Seed Orchards (Orchard #179 Sechelt), it is intended to identify specific DNA markers which can discriminate all contributing pollen parents within any particular seedlot. These markers will then be used to answer questions about orchard design (i.e., selfing), SMP efficacy and genetic worth.

The specific objectives for 1999/00 were to test six markers and their ability to discriminate between range wide parents of western hemlock. Six markers were identified. However, these markers could only distinguish about 50% of all seed orchard clones in the CanFor Orchard 179 (Sechelt). Apparently the diversity of the Hw chloroplast DNA was not sufficient to discriminate between all Hw clones tested. Year two objectives will concentrate on developing two to three more markers. These markers will then be used to determine SMP efficacy (paternal contribution) and selfing rates in 10 operational SMP seed lots. The actual lift in genetic worth can then be compared to the current lift, using the flat rate of 25% for SMP efficacy. [OTIP 401]

6.3.18 Seedlot Rating Comparisons Using Standard Protocol and Molecular Techniques in Douglas-Fir

Michael Stoehr

Background:

The Bowser seed orchards are located in an area with a potential for pollen contamination from surrounding Douglas-fir stands. Pollen monitoring to evaluate contamination is often not effective, as pollen shed within the orchard coincides with local pollen shed, even if orchard cooling is used. Therefore, seedlot rating, according to the protocol, may not be accurate. As contamination may be overestimated. A more accurate estimate of pollen contamination and SMP efficacy is obtained by paternal analysis of a seedlot using molecular techniques.

Activities:

Orchard #149 at Bowser has been genotyped with a variable chloroplast DNA marker. Total DNA has been extracted from vegetative bud tissue from each clone in the orchard.. More markers are needed to increase separation ability. Work is underway to evaluate a seedlot that has been subjected to SMP, and that is not subjected to SMP to estimate SMP efficacy. An estimate of pollen contamination will also be determined. [OTIP404]

6.3.19 Long-term Effects of Inbreeding on Coastal Douglas-Fir Growth and Yield in Operational Plantations

Tongli Wang, Sally Aitken, Jack Woods, Ken Mitchell, Ken Polsson, and Steen Magnussen

Background:

The effect of inbreeding on potential genetic gains has become one of the major concerns in advanced generations of tree breeding programs and seed orchards. Decisions will need to be made on tradeoffs between additional genetic gain that can be obtained by selecting related individuals, and potential losses in growth due to inbreeding.

Objectives:

- To simulate the effects of inbreeding on the merchantable volume of stands at harvest, using a growth and yield model.
- To make recommendations on allowable proportions of related parents in seed orchards.

Activities:

To determine the performance of inbred individuals compared to outcrossed individuals, the survival and growth of coastal Douglas-fir families, with different levels of inbreeding created through controlled crosses was analyzed using data obtained from two 10-year-old field tests. These analyses showed that inbreeding depression (percent reduction in growth due to inbreeding) has increased considerably from age five to age ten.

A meeting of the geneticists and growth and yield modelers collaborating on this project was held to discuss approaches for reaching the objectives of this project using the TASS model. It was decided to develop frequency tables for analysis based on the distribution of 10-year height for different inbreeding levels as input data for TASS. The simulations were run for three site indices (20, 28 and 35m) and three planting densities (625, 1111 and 1890 trees/ha). Potential proportions of trees in initial field plantations for three inbreeding levels ($F = 0.125$ (half-sib matings), 0.25 (full-sib matings) and 0.5 (self-pollination)) were estimated by considering the probability of related individuals mating, and seed production, nursery survival and culling rates for outcrossed and inbred seedlots. In total, 23 scenarios, comprising different combinations of various inbreeding levels, were constructed. TASS simulations were repeated 30 times for each scenario at each site index and density, for a total of 6,210 runs.

Final Results or End Product:

Preliminary results indicate that there are significant differences ($P < 0.0001$) in merchantable volume (MV) and survival among the scenarios, with significant interactions between scenarios and both site index and planting density. The differences in MV among scenarios, increased with stand age, site index, and planting density. Greater proportions of inbred trees were purged from modelled stands through competition at better sites, higher planting densities, and older harvesting ages. With realistically low proportions of inbreds in seedlots, particularly on productive sites planted at high densities, inbreeding will have little effect on merchantable volume at rotation, despite the high inbreeding depression exhibited by Douglas-fir. [OTIP 376]

6.3.20 Interior Spruce Genecology and Class A Seed Zones in Southeastern BC

Sally Aitken and Barry Jaquish

Background:

The new interior Class A SPZs for Interior spruce in southeastern BC are being evaluated in a seedling common-garden experiment, as existing field tests have not provided direct comparison of materials from all areas. There is a need for additional genecological information to support the deployment of seed within this area. Eighty families originating from across the new East Kootenay and Nelson SPZs, as well as the zone of overlap (Class B seed planning zones East Kootenay (EK), Mica (MI), Shuswap Adams (SA) and West Kootenay (WK)) are being evaluated for growth rate, bud phenology, cold hardiness and response to drought over a two-year period.

Final Results or End Product :

Seedlings were grown in 1999 at both the University of British Columbia (UBC) and at the Kalamalka Research Station. First-year height growth, timing of bud set, and occurrence of second flushing were recorded for the seedlings at UBC. Preliminary analyses indicate that families from the EK, MI, SA and WK Class B SPZ’s do not differ significantly for first-year height growth, but differ significantly ($p < 0.01$) for timing of bud set. Families from the EK and MI zones set bud earlier, on average, than families from the WK and SA zones.

A seedling common garden experiment, with different temperature and moisture treatments, will be established with these seedlings in May, 2000. Seedlings will be planted in raised nursery beds designed for a common rooting environment, but with control of soil moisture and temperature. Growth rate, phenology, response to temperature and moisture, and cold hardiness will be evaluated for all families. A field experiment with the same families will also be established on a high-elevation site near Nakusp. The results will be evaluated in terms of the implications for seed transfer in this area. [OTIP 365]

6.3.21 Refinement of Western Redcedar Seed Transfer Guidelines through Nursery Population Screening for Keithia Leaf Blight Resistance

Harry Kope, John Russell and Dave Trotter

Objectives:

- To establish a survey of a broad base of coastal populations of western redcedar seed and clones, representing different elevation and moisture transects, for Keithia resistance.
- To recommend refinement of existing seed transfer guidelines and breeding zones.

The materials used were seed from 28 populations with five open-pollinated families per population, representing various site associations within the coastal wet maritime and the sub-maritime subzones, for a total of 140 families. Also used, were clones from western redcedar cuttings from six elevational transects, (represented by six clones from each of three elevations per transect) and from nine populations of extreme wet and dry site associations (represented by six clones per population), for a total of 162 clones.

Progress to Date:

- Cuttings were set in PSB313B containers in February 1999 with three replicates of 16 cuttings per clone.
- Seed were sown in PSB313B containers in March 1999 as four replicates of 20 seed per family into 70, 313B styroblock containers.
- The seedlings/cuttings were grown under operational greenhouse conditions at Green Timbers reforestation nursery.
- Western redcedar seedlings, infected with Keithia leaf blight, were introduced into the greenhouse to allow for intentional infection seedlings and cuttings.
- In September 1999, four replicates of 11 seedlings per family were transplanted into PSB415D containers.
- In November/December 1999, cuttings were transplanted as three replicates of 11 cuttings per clone into PSB415D containers.
- During transplanting, a number of cuttings were culled from each clone and these were inspected for the presence of Keithia leaf blight. At this early date, the initial symptoms of Keithia leaf blight were seen on some cuttings. [OTIP 414]

6.3.22 Seed Transfer of Douglas-Fir in the Sub-Maritime Seed Zone

Raymund Folk, Steven Grossnickle, and Jack Woods

Background:

The Sub-Maritime (SM) seed planning zone occupies the area of climatic transition between the Coast and Interior. This zone contains highly complex patterns of climatic change due to the extreme topography of the Coast mountains, combined with the mix of coastal and continental influences. Douglas-fir genecology and seed transfer within this zone is being studied in a series of projects, including provenance tests established in the 1970's, genecology field trials planted in 1997, and screening for population differences in adaptive traits. The latter two projects utilize an extensive seed collection made from throughout the SM zone. This report summarizes progress on adaptive trait screening.

Drought Tolerance (Gas Exchange):

Gas exchange measurements were made on eight Douglas-fir populations growing on a farm field-site at the Cowichan Lake Research Station. Gas exchange responses to changes in vapour pressure deficit were assessed.

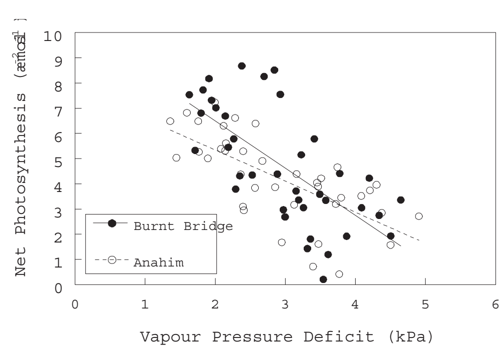


Figure 11. Net Photosynthesis vs Vapour Pressure Deficit for Two Fdc Populations

Response patterns were different among the eight populations. Most differences occurred at lower vapour pressure deficits (i.e., <2 kPa), indicating that populations were similar in their response to increasing evaporative demand, but different in their maximum levels under less limiting atmospheric conditions. Figure 11 shows the net photosynthesis of two Douglas-fir populations, from the Bella Coola River seed collection transect, under varying vapour pressure deficits during July and August 1999.

Frost Tolerance Patterns:

Thirteen populations of Douglas-fir seedlings were grown at Green Timbers Forest Nursery and planted at the Silvagen outdoor research compound. Samples were tested on a bi-weekly basis at –10°C and -20°C throughout the fall of 1999. Acclimation patterns differed among populations during most of the fall measurement period, but the greatest magnitude in differences in frost tolerance occurred October 25 at –10°C, and December 20 at –20°C. Fall acclimation patterns showed a better relationship to inland distance (i.e., straight-line distance from the coast) than to elevation of parent tree locations. Index of injury decreased with increasing distance inland. Seed transfer guidelines may be related more to maritime proximity than to elevation. Figure 12 shows the relationship between index of injury and inland distance for thirteen Douglas-fir populations on October 25 at –10°C and on December 20 at –20°C. [OTIP 396]

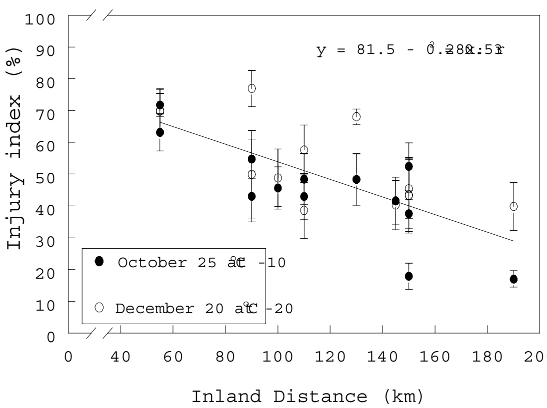


Figure 12. Index of injury vs. inland distance

6.3.23 A Computer Model to Forecast Sitka and Interior Spruce Growth and Yield, in Plantations with Weevil Resistant Stock

Rene Alfaro, John King, Ken Mitchell and Robert MacDonald

Background:

A computerized decision support system was developed at the Pacific Forestry Centre to estimate the impacts of spruce weevil *Pissodes strobi* Peck (=white pine weevil), in spruce (*Picea* spp) regeneration in BC. It was adapted to analyze the yield of plantations initiated with stock of varying resistance levels. The program, named Spruce Weevil Attack (SWAT), works with the Tree and Stand Simulator (TASS) model developed by the BC MoF to forecast growth and yield of the major tree species of BC. SWAT simulates the damage to individual trees, including destruction of the leader, crown recovery, and the formation of stem defects. The program reports tables representing stand development under different scenarios of weevil intensity and duration.

Activities/Methodology:

In this project, existing information on growth of spruce stock with different resistance levels, as well as data on weevil population dynamics in various weevil hazard zones, was consolidated. This subroutine will allow estimation of growth and yield of plantations of various resistance configurations. This information is crucial to make informed decisions regarding level of resistance to use (i.e. stock type) in different ecosystems.

Resistance rank was implemented at three levels for each mechanism, and is based on field measurements of resistance. The user can specify proportions of various genotypes, and the program handles planting bag mixing.

Product:

Users can specify the desired plantation through a Plantation design box. This box allows the user to specify the size of the plantation to simulate the hazard zone where the stock will be planted, and to specify the relative proportion of resistant stock to use. Another window allows the user to set the level of weevil resistance for up to three different genotypes per plantation.

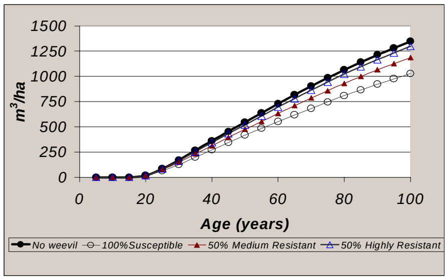


Figure 13. Simulated Yeild of Sitka Spruce planted in an area of high weevil hazard

After a run, the user can see the progress of an outbreak on plantations of different resistance make-up and can access yield information in TASS format. A variety of silvicultural decisions, such as planting densities, need to be established before a final database can be constructed. The program also produces the typical Typsy-like volume age curves (Figure 13), after taking into consideration the effects of weevil on productivity. Figure 13 shows the simulated merchantable volume (12.5+) vs age of Sitka spruce (Site index 27) planted in an area with high weevil hazard, assuming different stock mixtures which vary in level of resistance. [OTIP 456]

6.3.24 Deployment Schemes for Genetically Improved Forest Trees: Optimum Patterns Against Risks for Currently Known and Unknown Pests

Alvin Yanchuk, John Russell, Ken Polsson and John Bishir

Outline of Project:

Continuing on from the Science Council of BC project, there have been advances in the computer simulation model that will help to examine optimum patterns for deployment of selected clonal and non-clonal material within and among stands. Clonal mixtures, versus mosaics of clonal blocks, with varying numbers of clones (i.e. 2, 6, 18, 30), tend to show that random mixtures are better in the face of a currently known pest (i.e. terminal weevil). While this may be intuitive, the results are complex and many interactions are present with respect to the size of the mosaics (block size), numbers of clones, and the magnitude of resistance among the clones used. So far, it seems that clones, with any amounts of resistance, will dominate the final stand composition, which may have other implications (e.g., genetic diversity "available" through the life of the stand). The model is now being expanded to examine risks from an unknown pest (i.e. assuming the weevil model serves as a surrogate for some other biotic threat), differential heritabilities in growth and resistance, and deployment across the landscape. [OTIP 471]

6.3.25 Yellow-Cedar and Western Redcedar: Enhancing the Deployment of Genetic Gain through Developments in Vegetative Propagation

Bevin Wigmore and John Russell

Objectives:

This project has two main objectives:

- To screen elite yellow-cedar (Cy) clones for nursery performance prior to hedge orchard establishment.
- To develop protocols for vegetative propagation of western redcedar (Cwr).

Progress:

Yellow-Cedar:

The BC Ministry of Forests (MoF) and Western Forest Products(WFP) have identified elite clones of Cy. These clones are currently being established in hedge orchards. It is imperative that these selected clones perform well in the nursery, in terms of their rooting percentage, stem form (i.e. not plagiotropic), plug quality, and percentage of crop meeting target specifications for height and caliper.

In this project, 5000 one-year-old cuttings in the WFP program were selected as ramets for a further round of rejuvenation. The cuttings set from these ramets will be evaluated in the fall of 2000 for incorporation into a hedge orchard. The MoF elite clones, which are being established as hedge orchards at four sites, were too small to evaluate in 1999, so this part of the project was postponed until 2000.

Two additional experiments were initiated, with the objective of maximizing Cy hedge quality. One is evaluation of nursery performance of cuttings from existing serially-propagated stock plants at the Cowichan Lake Research Station. These stock plants are up to 17 years of age and have been through up to five propagation cycles. The other is a hedge orchard fertilization trial.

Western Redcedar:

Elite Cwr families have been identified in MoF trials and can be propagated by controlled crossing in seed orchards, which eliminates selfing. The seed produced could then be bulked up through rooted cuttings, if protocols were available.

In this project, 1,000 Cwr cuttings were set at Cairnpark Nursery in February 1999, and 400 stock plants were established. Seed for another 500 stock plants was sown in January 2000. The cuttings were successful: 95% rooted, and 85% were liftable in September.

The average number of cuttings obtained from a one-year-old Cwr stock plant was 18, and from a two-year-old, 32. Cultural trials are in place to try to increase these amounts. Also, a rooting trial with smaller-sized cuttings was established in January 2000. [OTIP 424]

6.3.26 G x E and Nursery Carryover Effects of Spruce Somatic Embryogenesis (SE) Clones on Six Central Interior Reforestation Sites.

Chris Hawkins

Activities:

Prince George Selection Unit full sib seedlings and selected somatic embryogenesis (SE) clones from the same spruce families, were grown at Pelton Reforestation and Green Timbers Test Nursery in 1994. They were planted, after cold storage, on six sites north and east of Prince George in the spring of 1995 (Table 4).

A young Spruce tree of SE origin

Two-year growth of full sib seedlings was better than that of SE clonal material. There was an interaction (GxE) between clone and site (classified by bigeoclimatic [BEC] sub-zones), and SE clonal growth was different between nurseries. Five-year measurements were conducted in the fall of 1999.

Final Results or End Product:

Fifth year height and survival was different among sites (Table 4) and clones (Table 5). The poorest growth was observed in the ESSF, and the best growth was observed in the SBSmk1. There was significant spruce leader weevil attack at the Bear site, reducing height growth, but survival was excellent. There was an interaction between clone and site. However for most clones, performance was stable across the sites (Table 4).

Site	BEC	Year 5 height (mm)	Survival (%)
Hambone Lake	SBSwk1	613	88
Davie Lake	SBSmk1	678	90
Aleza Lake	SBSwk1	655	89
Bear FSR	SBSwk1	534	96
Longworth FSR	SBSvk	579	78
Hungary Creek	ESSF	337	83

Table 4. Site, biogeoclimatic sub-zone, and year Five pooled mean height and survival

Interesting observations from the fifth year measurements were:

- Full sib seedlings performed better than clones of the same family.
- Mean family breeding values did not correlate well with family performance across the sites (e.g. T full sib, Table 5).
- Nursery effects were still significant after five years (not shown).
- Registered seed orchard seedlot (6863) and wild seedlot (29163) ranking was variable across sites.
- None of the material is suitable for the ESSF around Prince George.

Table 5 shows selected genetic entries (ID: registered seedlots, full sib seedlings, and SE clones), 15 year family mean breeding values (BV), and fifth year height rank out of 33 entries, and height as a percentage (%) of the tallest entry on each site.

ID	BV	Hambone Rank/33 - %	Davie Rank/33 - %	Aleza Rank/33 - %	Bear Rank/33 - %	Longworth Rank/33 - %	Hungary Rank/33 - %
6863	n/a	11 - 75	7 - 85	7 - 94	7 - 94	9 - 80	3 - 95
29163	n/a	12 - 74	9 - 85	4 - 95	12 - 84	10 - 80	8 - 85
G full sib	30.9	7 - 85	6 - 87	2 - 98	6 - 95	4 - 92	5 - 91
G441	30.9	27 - 51	25 - 56	31 - 50	25 - 66	31 - 40	30 - 56
G442	30.9	17 - 64	14 - 79	19 - 72	15 - 82	19 - 58	19 - 71
J full sib	20.3	5 - 85	2 - 99	3 - 95	3 - 98	2 - 99	1 - 100
J739	20.3	16 - 66	17 - 72	16 - 47	16 - 80	13 - 75	17 - 73
J1054	20.3	33 -37	33 - 37	33 - 44	33 - 41	33 - 36	32 - 55
M full sib	7.4	2 - 89	10 - 84	12 - 84	14 - 82	6 - 90	9 - 85
M612	7.4	30 - 47	32 - 46	32 - 48	30 - 54	32 - 40	29 - 58
T full sib	13.6	3 - 89	1 - 100	1 - 100	1 - 100	3 - 94	6 - 89
T716	13.6	14 - 71	19 - 70	21 - 71	18 - 77	27 - 52	15 - 74
T801	13.6	21 - 58	18 - 70	17 - 74	20 - 76	17 - 66	26 - 62
U full sib	17.0	10 - 77	8 - 85	8 - 89	10 - 91	7 - 89	4 - 94
U185	17.0	28 - 48	31 - 46	30 - 51	32 - 43	30 - 44	28 - 60
U284	17.0	9 - 77	12 - 79	9 - 89	13 - 83	11 - 79	13 - 79

Table 5. Breeding values and Fifth year height rankings of SE clones

The data present an important question that cannot be answered at this time. What is the reason for the poor performance by SE clones within a family? Hawkins (1999: Proc. W. For. Conservation Nur. Assoc. edited by T Landis) suggested it was related to stock quality at the time of planting; emblings were of lesser quality compared to seedlings. However, the culturing/planting of low gain (value) SE clones cannot be ruled out. The poor performance by clones, the interaction of clone with site, and the long-term effect of nursery on field performance will be pursued over the coming year in this and related studies. [OTIP 354]

6.3.27 Five Year Field Performance of Six Spruce Seed Orchard, and Wild Seedlots Grown at Seven Forest Seedling Nurseries

Chris Hawkins

Background:

This trial was initiated in 1994, as part of the larger seed orchard seed project begun in 1993 by Silviculture Branch of the BC Forest Service. An orchard and a natural stand seedlot, from each of the Prince George, Shuswap Adams and East Kootenay seed planning zones, were grown at seven nurseries in 1994. The nurseries were Surrey, Reid Collins, Mountain View, Skimikin, Woodmere, Northwood, and Red Rock Research. Stock was summer planted in 1994, and spring planted in 1995 at two sites, one in the ICH (Skimikin) and the other in the SBS (Prince George) (Table 6).

Final Results or End Product:

The data were analyzed in a fixed effect analysis of variance model. After two years growth there was a difference between sites and plant dates. Nursery explained more of the variation in two-year height than any other source of variation in the model. Nursery location did not account for any of the variation. Five year heights were measured in the fall of 1999 at both sites. The stocking at Skimikin was reduced from about 6,500 to 3,200 saplings after measurement.

Mean pooled height was still different after five years between sites. The greatest growth was seen at Skimikin, 90cm versus 74cm at Prince George. Table 6 shows the mean poled height at planting (0), and after five years (5), and fifth year survival (%) by site (SK, Skimikin; PG, Prince George) for each nursery (identity coded). There were 17cm and 16cm differences in mean pooled fifth year heights between the best and poorest nurseries at Skimikin and Prince George respectively. Fifth year survival was better at Prince George than at Skimikin, and it too was significantly affected by nursery origin.

Site	Nursery 1	Nursery 2	Nursery 3	Nursery 4	Nursery 5	Nursery 6	Nursery 7
	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)
SK	0 5	0 5	0 5	0 5	0 5	0 5	0 5
PG	19 99	15 87	15 88	19 82	21 87	17 91	16 92
	Survival %	Survival %	Survival %	Survival %	Survival %	Survival %	Survival %
SK	69	64	67	73	78	81	75
PG	85	80	76	77	81	85	84

Table 6. Spruce seedling height-growth and survival by nursery of origin.

The East Kootenay sources had the poorest growth at both sites. Table 7 shows the mean height (cm) at planting (0) and after five years (5), and fifth year survival (%) by seed planning zone (PG, Prince George; SA, Shuswap Adams; EK, East Kootenay), seed source, and time of planting (SU94, summer 94; SP95, spring 95).

	Site					
Variable	Skimikin			Prince George		
	Height 0	Height - 5	Survival %	Height - 0	Height - 5	Survival %
Zone						
PG	16	91	63	16	83	86
SA	18	92	80	18	71	74
EK	16	86	75	16	67	85
Source						
Orchard	18	91	74	18	74	80
Wild	16	88	71	16	74	73
Time						
SU94	14	91	65	14	75	85
SP95	19	89	79	19	73	79

Table 7. Spruce seedling height-growth and survival by SPZ, seed source and time of planting

Shuswap Adams wild stand trees after Five growing seasons at Skimikin.

Seed planning zone, seed source, and planting time significantly affected survival. However, for fifth year height, there was little or no difference between time of planting and seed source. At both sites after five years, nursery still accounted for about 20% of the explained variation in height. Survival was also significantly impacted by nursery origin. Therefore, nursery origin can have a significant positive or negative impact on early spruce seedling performance, whether it is seed orchard or wild stand in origin. Selection of nursery, therefore, may be as important a decision as selection of the seedlot for a reforestation site, as it can prolong the time to free-to-grow. [OTIP 355]

6.3.28 Development of a Species Plan Information Reporting Tool (SPIR)

Leslie McAuley

Background:

New business and information management requirements have recently been identified as part of the provincial Forest Genetics Council (FGC) strategic business plan. This includes an expanded role in seed planning and seed needs analyses, evaluation and audit, gene resource management, and the incorporation of Tree Improvement (TI) gains into the timber supply review and integrated silviculture planning process. Development of a SPIR is necessary to meet FGC program goals, address expanded TI client information needs, improve communications and extension opportunities, and, thereby, increase the delivery of genetic gain to the field. An information management tool is also needed to monitor and evaluate program success at the Species Plan level.

Project Description:

Development of a SPIR was undertaken to address FGC Business Plan objectives and program goals (seed production and genetic gain targets) within a Species Plan framework. Summary reports and charts were developed to assist clients with seed planning (available versus projected), seed needs analyses (supply versus demand) and timber supply reviews based on selected Seed Planning Units (Species/SPZ/Elevation combinations). The tool was developed with an MS Access front-end. Database design and programming was completed as a student work term requirement within the Computer Systems Technology Co-operative Education Program.

Final Results or End Product:

An SPIR was developed upon completion of the project. A number of changes were made to the existing SPIR data model as a result of the new Seed Planning Unit (SPU) /Species Plan framework, new SPAR management unit (TSA/TFL) links, and ISIS/MLSIS data extract links. The project outputs were as follows:

- SPIR Client (CLIENT) and Administrative (ADMIN) version (Version 4.1).
- An Archive function for storing SPAR data extracts.
- A new Seed Planning Unit (SPU) data model.
- An expanded Seed Use Reports menu (GW-SPAR, 5 Year Average).
- A new Species Plans menu (Timeline reports & charts).
- A new Timber Supply Reports (ISIS/MLSIS) menu.
- A timber supply TI Gain methodology (GW-TIPSY).

SPIR User Manual, CLIENT and ADMIN. [OTIP 451]

6.3.29 Effect of Using Genetically Improved Seedlings on Woodflow
Ivan Lister

Background:
The project models the effects of the current and planned genetic improvement program on woodflow in the Nelson Forest Region. It is believed genetically improved seedlings will have significant positive impacts that can improve site productivity, reduce minimum harvest ages and address regeneration green-up constraints. The project originally focused on four species (lodgepole pine, Douglas-fir, larch and spruce) and three Timber Supply Areas(TSAs), Arrow, Golden and Cranbrook, but due to the status of the databases, only Arrow, and one other TSA, will be completed. In the short term, the results of this project will allow a comparison between the effects of genetic gains and other silvicultural activities. In the long term, the results can be used provincially to determine the relative impact of different orchards to woodsupply.

Objectives:

The main objectives of the project are:

- to identify the genetic gains from the current and planned tree improvement programs;
- to adjust appropriate TIPSY stand level growth curves to reflect these gains;
- to apply these stand level gains into forest level analysis, and
- to identify the effects of these genetic gains on woodflow and other management objectives.

Planned Activities:

The TIPSY stand level and FSSIM forest level models will be used to examine
several scenarios:

- No genetic gain base case.
- Gains from existing orchards only.

- Gains from existing orchards, existing rogued orchards, plus new planned and expanded orchards as required.
- Using genetically improved seed strategically, only in highly constrained areas.

Progress:

- Appropriate yield and orchard production estimates have been developed for all the species.
- TIPSY growth curves to reflect the genetic improvement have been developed.
- The IFPA database for Arrow TSA has been updated to reflect the additional requirements of this project.
- A base case is currently being completed and the sensitivity tests will be conducted beginning the third week of February.
- If time and funding are still available, analysis will begin on the second TSA.
- The final report will still be submitted by March 31, outlining the methodology, results and recommendations. [OTIP 366]

6.4 Gene Conservation

Projects under this section are concerned with the development and operation of a province-wide gene conservation program, to catalogue and preserve the genetic diversity of native tree species.

6.4.1 Genecology and Clonal Testing of Native Black Cottonwood
Cheng Ying

Progress:

A stoolbed was re-established, accommodating about 860 clones, at Surrey Nursery, and a back-up stoolbed rected to the establishment of two short-term common garden tests at Surrey Nursery and Terrace. The Surrey test will use five ramets per clone in a randomised complete block experimental design with single-tree plots; the Terrace test will have two ramets per clone. The main interest is in growth, hardiness and pest tolerance. The two tests under contrasting environments will hopefully provide adequate screening for genetic differentiation, and identify genotype x environmental interaction in certain traits associated with drainages, stands within drainages, and clones within stands. [OTIP398]

6.4.2 Maintenance and Measurement of Red Alder Provenance Tests
Cheng Ying

Progress:

Three red alder tests located at Thunderbird (Terrace), and Bowser and Saanichton on Vancouver Island (about 7,500 seedlings) were measured for five-year height growth. Preliminary analyses of the growth data indicate strong regional differentiation of provenance performance. Fast growing provenances at Bowser and Saanichton were mostly from southern Vancouver Island and below 300m elevation. The better provenances at Terrace, however, were from along the lower Skeena River below 150m, and all southern provenances suffered severe winter killing.

Detailed analyses of early results by Andreas Hamann showed a clinal variation along the coast, and a transfer of 100km from provenance origin was associated with a decline of 2.5% in survival and about 5cm in two-year height. The analyses also identified the Georgia Depression as an area of potentially productive seed sources. A report to summarize the five-year testing results is being prepared. [OTIP399]

6.4.3 Initiation of *ex situ* Gene Conservation of Limber and Whitebark Pine
David Kolotelo

Background:

Extensive damage to whitebark pine caused by white pine blister rust

Whitebark pine and limber pine are considered the two conifer species in greatest need of gene conservation in BC. They are generally non-commercial species, but play important roles in their high elevation habitats as a food source for birds and mammals. Both species are highly susceptible to the white pine blister rust that poses a serious threat to these species.

Whitebark pine is additionally threatened by the mountain pine beetle and fire suppression which has caused the species to be outcompeted by sub-alpine fir and Engelmann spruce. Currently, only three seedlots of whitebark pine and two seedlots of limber pine are present in long-term storage at the Tree Seed Centre, totalling approximately 11Kg. The whitebark pine seedlots exhibit very poor germination (1%, 6% and 10%), which is partly due to seed immaturity, as cone collectors must compete with Clark's nutcracker for cones.

Clumped habit of whitebark pine caused by the seed caching behaviour of Clark's nutcracker

Objectives

To obtain individual tree collections of limber and whitebark pine for gene conservation, and increase knowledge and expertise of these species in the areas of cone caging, collection, post-collection handling and processing.

Final Results or End Product

Cones were caged and collected for whitebark pine from Terrace (six trees); Lime Mountain (nine trees); Apex (14 trees); Thynne Mountain (seven trees), and from Kicking Horse Pass (six trees) for limber pine. In general, it was a very poor year for cone production in both species, and many other sites were visited and determined to be unsuitable due to crop size or accessibility. On most sites large numbers of emerging pollen buds were observed for whitebark pine, but female stobili were too small to be detected. All cones were forwarded to the Tree Seed Centre and are currently being processed. The Tree Seed Centre is also independently investigating alternate pretreatment methods for whitebark pine with seed in storage or obtained from Alberta. [OTIP 453]

6.4.4 Interior Spruce Gene Conservation at PGTIS

Carol Fleetham

Activities:

The Prince George Tree Improvement Station's Interior spruce clone banks contain most of the province's Interior spruce parent tree selections. Many of the approximately 3,000 different clones can only be found in this gene archive.

Approximately 900 1997 grafts, including 300 from the Peace River seed planning zone, were transplanted from the holding beds into the clone banks in 1999. Furthermore, 600 new grafts were made ensuring that clones are replicated several times so that sufficient scion will be available when needed for development of new and genetically improved seed orchards.

An inventory of all Interior spruce clones has been completed. The location of each clone (seed orchards, clone banks and/or breed arboretums), number of ramets, age and scion availability is indicated in this data bank. This information will help develop a management plan for Interior spruce gene conservation. [OTIP 336]

6.5.1 Communications, Extension and Education

Projects under this section provide information on skills and knowledge, or direct/enhance communication between tree improvement and its clients and/or promote tree improvement in British Columbia.

6.5.1 Development of Spruce Somatic Seedling (SE) Demonstration Sites in the Central Interior of BC

Don Summers, Chris Hawkins, Bonnie Hooge, and Kendel Thomas

Activities:

Between 1995 and 1998, 33 sites were planted around the Prince George (Low) spruce seed zone to illustrate the performance of a number of different propagation types available for Interior spruce. This was carried out in association with a separate project (Hawkins OTIP 207) involving a series of candidacy tests for clones produced through somatic embryogenisis (SE). Candidacy tests were composed of random single tree plots.

Each site in this project has a series of individual blocks (<2000 m2), each planted to one of the following:

- different clones of SE propagules,
- cuttings from select seed,
- seedlings from select seed, or
- seedlings from wild seed.

As a descriptor, the project is referred to as clonal block because the majority of blocks on each site contain single clones of SE material. Each block has a sample plot in the approximate middle. These sample plots have been selected for growth assessments.

In 1999, heights of trees in sample plots for 24 of the 33 sites were measured under local contract. This completes measurements for at least one, three and five years in the field at all sites, depending on date of planting. Measurement data, maps and other information are being assessed, and selected sites will be developed as documented demonstration resources for the northern forestry community. A number of industrial partners are interested in cooperating with site maintenance.

SE Clone from Family 107 after Second Growing Season near Prince George

In following years, measurements will be taken to complete three and five- year data in the more recent plantings. Other than maintaining the block identities and plantation performance, most sites will be treated as operational plantations. Unfortunately, some may have to be abandoned for biotic (animal damage) or abiotic (frost, snow) reasons. [OTIP 352]

6.5.2 Genetic Gains Demonstration Plot Upgrade

Peter Richter

Activities:

A demonstration planting of progeny produced from the lodgepole pine Thompson-Okanagan (TO) low breeding program was established in a highly visible area of the PRT Armstrong Nursery Site in 1998. The demonstration plot allowed for a visible comparison of growth rates between the progeny of highest ranked clones, the progeny of low ranked clones, and a natural seed source. It was an appropriate location as the two operational TO orchards were located on this site.

In order to complete this project, it was necessary to replace dead and dying seedlings in the plot, and upgrade the area to a presentable state for public viewing and educational purposes. Also, for long term maintenance, groundcover was required to suppress weed growth around the young seedlings.

In the spring of 1999, this upgrade was completed. All dead or dying seedlings, for which there was a replacement, were removed and replaced. Permanent irrigation was set up in the plot, and weeds cleared from around the growing seedlings. After the weeding was completed, permanent groundcover was laid along the seedling panels to provide more permanent weed control. The rows between the seedling panels were mowed, as needed, throughout the growing season.

This upgrade to the plot has brought it to a state where the public can appreciate it, and be informed of the genetic gains that are possible in Interior lodgepole pine through the work of the Operational Tree Improvement Program in British Columbia. [OTIP 359]

6.5.3 Extension Workshops - Class A Improved Seed

Diane Gertzen

Workshop Introduction:

The forest tree genetic resources of British Columbia are likely to be richer, more varied and more complex than those of any other mid to northern latitudinal jurisdiction around the globe. Research into genecology, seed transfer, gene conservation and practical tree improvement, have been underway in British Columbia for four decades. The fraction of the total seed need for reforestation that is from genetically selected sources, is about 35% now, and is increasing rapidly each year.

An understanding of how these materials came to be, and their potential impact on forest productivity and forest health, are important for today's forest manager.

Activities:

A Forest Genetics/Tree Improvement Workshop entitled: Seed Planning, Policy and Programs in BC is planned for Wednesday, March 15, 2000 at the Prestige Inn, Nelson, BC.

This workshop will provide a brief history and current overview of forest genetics, seed transfer, seed supply and production and gene conservation in British Columbia generally, and the Nelson Forest Region specifically.

This workshop will be duplicated in other Forest Regions over the coming year. [OTIP 368]

6.5.4 "Seeds – The Next Generation" School Education Program

Patti Brown

Activities:

Four Vancouver schools and two local school Grade 5's participated in the "Seeds – The Next Generation" sessions. The seed they produced will be sent out in February along with the 2000 invitations. [OTIP 381]

6.5.5 Seed Orchards of BC (2nd Edition)

Ron Planden and Diane Gertzen

Outline:

The Orchard Directory was designed for audiences directly involved in the day-to-day activities of orchard management, as well as those less familiar with the orchard business. Since its publication in 1996, the Directory has proven to be an invaluable extension tool for tree improvement clients across the province. In order to maintain its usefulness, the Orchard Directory must be updated to reflect recent organizational, planning and policy changes. These changes must also be made to coincide with Tree Improvement Species Plans and the revision of the Interior Seed Planning Zones. The Orchard Directory will be formatted for the TIP web site to increase client access, and the timely delivery of information.

Objectives:

Client information and planning needs were to be met with the revision of the current publication, to reflect the organizational, policy and planning changes that have occurred in the past two years. Formatting the Directory for the web site was to increase administrative efficiencies, and client access to current information.

Procedure:

The Orchard Directory is an extension and communications tool. In order for this information to be of greatest use, it must be easily accessible and current. To achieve this, the first edition (1996) was sent to appropriate orchard managers to be reviewed and revised.

Project Development to Jan 28, 2000:

The project is still a work in progress. Information specific to individual orchards was sent to orchard managers for revision. Most of the managers have responded with only one or two still outstanding. Publishing the Directory on the web has been put on hold due to the acts of vandalism that occurred on October 31, 1999. Some managers are concerned about creating a web version of the Orchard Directory feeling that this may put orchard facilities at risk.

The information that is presented in the first edition has proved to be invaluable in the seed planning process. It is hoped that the information in the second edition will prove to be just as useful.

Once a final version is written, a secure manner in which to distribute the Directory will be found in consultation with all orchard managers. [OTIP 474]

Appendix 1

Tree Species Names and Abbreviations

CONIFERS		
western redcedar	Thuja plicata	Cw
yellow-cedar	Chamaecyparis nootkatensis	Yc
Douglas-fir	Pseudotsuga menziesii	Fd
Interior Douglas-fir	Pseudotsuga menziesii var. glauca	Fdi
amabilis fir	Abies amabilis	Ba
grand fir	Abies grandis	Bg
noble fir	Abies procera	Bp
subalpine fir	Abies lasiocarpa	Bl
mountain hemlock	Tsuga mertensiana	Hm
western hemlock	Tsuga heterophylla	Hw
Rocky Mtn. juniper	Juniperus scopulorum	Jr
alpine (subalpine) larch	Larix lyallii	La
western larch	Larix occidentalis	Lw
limber pine	Pinus flexilis	Pf
lodgepole pine	Pinus contorta	P1
lodgepole pine	Pinus contorta var. latifolia	Pli
ponderosa pine	Pinus ponderosa	Py
shore pine	Pinus contorta var. contorta	Plc
western white pine	Pinus monticola	Pw
whitebark pine	Pinus albicaulis	Pa
Engelmann spruce	Picea engelmannii	Se
Sitka spruce	Picea sitchensis	Ss
white spruce	Picea glauca	Sw
spruce hybrid (Interior spruce/s)	Picea cross (Se and Sw mixtures)	Sx
Sitka x unknown hybrid	Picea sitchensis x?	Sxs
western (Pacific) yew	Taxus brevifolia	Tw
HARDWOODS		
red alder	Alnus rubra	Dr
black cottonwood	Populus b. ssp. trichocarpa	Act
hybrid poplars	Populus spp.	Ax
trembling aspen	Populus tremuloides	At
paper birch	Betula papyrifera	Ep
Garry oak	Quercus garryana	Qg

Appendix 2

(FGC Species Planning Units)

Unit #	Species	Planning Unit and Elevation
1	Douglas-fir	Maritime Low (south) (<700m)
2	Redcedar	Maritime Low (0-600m)
3	Western hemlock	Maritime (0-600m)
4	Interior spruce	Nelson Low (<1300m)
5	Interior spruce	Nelson High (1300-1700m)
6	Sitka spruce	Maritime All (0-750m)
7	Lodgepole pine	Nelson Low (<1400m)
8	White pine	Coast (<1000m)
9	Amabilis fir	Maritime (<700m)
10	Lodgepole pine	Thompson Okanagan Low (<1400m)
11	Yellow-cedar	Maritime (<1200m)
12	Lodgepole pine	Prince George Low (<1100m)
13	Western larch	Nelson Low (<1300m)
14	Interior spruce	Prince George Low (<1200m)
15	White pine	Kootenay/Quesnel Low (<1400m)
16	Lodgepole pine	Thompson Okanagan High (>1400m)
17	Lodgepole pine	Bulkley Valley Low (<1100m)
18	Lodgepole pine	Central Plateau Low (<1000m)
19	Douglas-fir	Sub-Maritime Low (200-1000m)
20	Lodgepole pine	Nelson High (>1400m)
21	Douglas-fir	Nelson Low (<1000m)
22	Douglas-fir	Nelson High (>1000m)
23	Interior spruce/Sitka spruce	Sub-Maritime/Nass-Skeena Transition (All Elevations)
24	Western hemlock	Maritime High (>600m)
25	Interior spruce	East Kootenay Low (<1700m)
26	Lodgepole pine	Prince George High Elevation (>1100m)
27	Redcedar	Sub-Maritime (200-1000m)
28	Interior spruce	Thompson Okanagan High (1300-1850m)
29	Lodgepole pine	East Kootenay High (>1400m)
30	Interior spruce	Thompson Okanagan Low (<1300m)
31	Douglas-fir	Maritime High (700+m)
32	Lodgepole pine	East Kootenay Low (<1400m)
33	Redcedar	Maritime High (600+m)
34	Western larch	East Kootenay Low (800-1500m)
35	Interior spruce	Bulkley Valley Low (<1200m)
36	Grand fir	Maritime Low (0-700m)
37	Douglas-fir	Quesnel Lakes (All Elevations)
38	Western hemlock	Maritime Low North (Merged)
39	Douglas-fir	East Kootenay (All elevations)
40	Interior spruce	Peace River Low (<1200m)
41	Douglas-fir	Prince George (All Elevations)
42	Interior spruce	Prince George High (>1200m)
43	Douglas-fir	Cariboo Transition (All Elevations)

Appendix 3

Contact Phone List for Contributors

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Bird, Keith	MoF	250-749-6811
Bishir, John	NC State	919-515-2598
Brown, Patti	CFP	604-885-5905
Browne-Clayton, Shane	Riverside	250-762-3411
Carlson, Michael	MoF	250-260-4767
Cartwright, Charles	MoF	250-387-6477
Clarke, Garry	Mof	250-260-4763
Cook, Cathy	WFP	250-479-4911
Cox, Keith	MoF	250-835-4541
Crowder, Tim	TFL	250-652-4211
Cruikshank, Mike	CFS	250-363-0600
Draper, Dale	MoF	250-356-9276
Ekramoddoullah, Abul	CFS	250-363-0692
Fan, Shihe	Silvagen	604-224-4331
Fleetham, Carole	MoF	250-963-8416
Folk, Raymund	BCResearch	604-224-4331
Gaudet, Dan	VSOC	250-542-0833
Gertzen, Diane	MoF	604-930-3309
Graham, Hilary	PRT	250-546-6713
Grossnickle, Steve	BCResearch	604-224-4331
Hawkins, Chris	MoF	250-963-9651
Hewson, Clare	MoF	250-260-4776
Hooge, Bonnie	Mof.	250-963-9651
Jaquish, Barry	MoF	250-260-4766
King, John	MoF	250-387-6476
Kolotelo, David	MoF	604-541-1683
Kope, Harry	C. Biol.	250-727-0514
Koshy, Mathew	UBC	604-822-8737
L'Hirondelle, Sylvia	MoF	250-952-4128
Lee, Tim	VSOC	250-542-0833
Lister,Ivan	MoF	250-354-6624
Macdonald, Robert	Ramsoft Sys.	250-389-6221
Magnussen, Steen	CFS	250-360-0600
McAuley, Leslie	MoF	250-356-6208
Mitchell, Ken	Mof	250-387-6673
Morrow, Gordon	MoF	250-757-2015
Murphy, John	MoF	250-260-4754
Newton, Craig	BCResearch	604-224-4331

O"Neill, Greg	UBC	604-822-1845
Owens, John	Uvic	250-721-7113
Painter, Roger	MoF	250-356-9276
Pieper, Greg	Riverside	250-546-2293
Piggott, Don	YPP	250-245-5935
Planden, Ron	MoF	250-356-6207
Polsson, Ken	Mof	250-387-6948
Pomeroy, Norm	MoF	250-749-6811
Reid, David	Mof	250-652-5600
Ritland, Kermit	UBC	604-822-8101
Russell, John	MoF	250-749-6811
Ryrie, Lynette	MoF	250-260-4772
Stoehr, Michael	MoF	250-952-4120
Strong, Ward	Mof	250-549-5696
Summers, Don	MoF	604-930-3301
Thomas, Kendel	Woodmere Alt.	780-835-5292
Trotter, Dave	MoF	604-930-3302
Walsh, Chris	MoF	250-260-4777
Wang, Tongli	UBC	604-822-1845
Webber, Joe	MoF	250-952-4123
Wigmore, Bevin	Contractor	250-748-0357
Woods, Jack	MoF	250-356-0888
Yanchuk, Alvin	Mof	250-387-3338
Ying, Cheng	MoF	250-387-3976

Back Cover Interpretations

Pollen Management has developed greatly since the days when a paper bag in a warm room was the drying apparatus for pollen buds. The use of supplemental mass pollination (SMP) as an orchard management tool to enhance crops has required the development of specific technologies and information about each species. Large quantities of pollen are now routinely produced and it is important that the quality remains high.

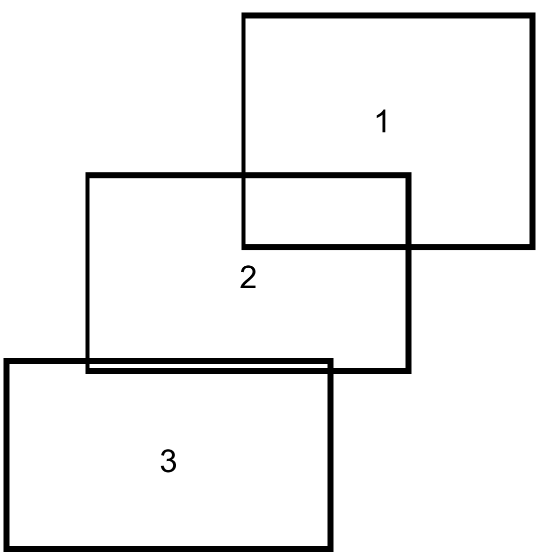

Plate 1. Pollen drying systems are now available that dry large quantities of pollen that are uniform and of high quality.

Plate 2. Pollen is routinely collected and stored in freezers from one year to the next. This helps ensure that there is sufficient pollen in year's when it is in short supply and to help improve the parental contribution of the overall crop.

Plate 3. Testing pollen lots, high in the crown of a tree. Quality control is critical part of pollen management and ensures crop success.

FOREST RENEWAL BC

BRITISH COLUMBIA

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