Forest Renewal BC Tree Improvement Program

FOREST RENEWAL BC

FGC Forest Genetics Council of British Columbia

Project Report
2000/2001

Front Cover Interpretations

Western redcedar is the newest addition to gene resource management programs in British Columbia. First generation breeding began in 1995 and over 750 polycross families have been bred to-date. Currently, 450 of these families have been planted in over 25 field trials with the rest scheduled to be planted over the next two years. Parents from around 250 of these families originated from coastal Washington and Oregon, and an additional 200 parents from American sources have been established in breeding orchards. Five-year measurements will be taken fall 2001 from the first series of progeny trials. It is anticipated that new backward selected orchards, established from ramets currently in holding areas, will start producing appreciable amounts of seed by the latter part of this decade. Establishing the top 20-40 breeding value parents out of approximately 1000 tested, should produce up to15% volume gain at rotation.

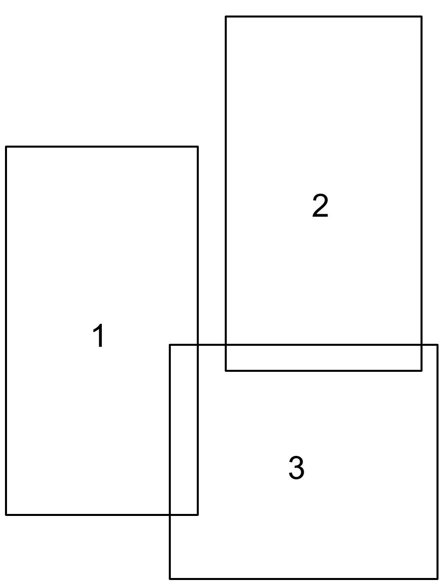


Plate 1. Breeding western redcedar. Two- to three-year-old ramets can be successfully induced using GA_3 to produce female flowers and bred the following year. The first generation of families were bred using a 20-clone polymix. This was to avoid differential inbreeding and subsequent growth depression in open-pollinated seed.

Plate 2. Western redcedar progeny trial. This four-year-old tree, growing on a productive site on southern Vancouver Island will be measured fall 2001. All progeny test sites have had good survival and are free from deer browse.

Plate 3. Screening trees for wood durability. Dr. Bob Daniels, Forintek, has been developing methods for detecting chemical compounds associated with wood durability using a HPLC. He is currently working on analysing parent trees from seed orchards and related 10-year-old progeny to determine the best method and genetic material to screen for wood durability.

Forest Renewal BC Tree Improvement Program

Project Report 2000/2001

Coordinated and compiled by:

Brian Crown, Island Eyes Images,
and Roger Painter,
Tree Improvement Branch

British Columbia Ministry of Forests

Acknowledgements

Four years ago the Operational Tree Improvement Program issued it's first Call for Proposals. Since then approximately 500 requests for funding have been received. The proposals have been evaluated and about 375 accepted for investment. Over that space of time the program has grown in complexity as the Forest Genetics Council (FGC) improved its planning process for identifying priorities for investment. The FGC and it's supporting Technical Advisory Committees (TAC's) have developed a broad based long-term strategic plan that takes into account all aspects of tree improvement while creating mechanisms to measure its progress. This has involved the voluntary help of a large portion of those in the tree improvement industry. Species committees, proposal review committees, TAC's, and special task-forces have all worked to ensure that our industry has the guidance and direction for meeting the overall goals set by the Forest Genetics Council. Tree Improvement is a long-term program that requires broad support and considerable stable investment.

This report would not be complete without recognizing the support of Janet Gagne and her staff at Forest Renewal BC for their hard work and continued support. My thanks go to the Project Leaders for completing their portions of this report. This publication is truly a global effort by the tree improvement community and provides a way of showcasing progress on the projects undertaken while reviewing the progress of the program as a whole. Congratulations to you all, I think you will be proud of the results of this the fourth annual report. I would also like to acknowledge the work of the editorial review team, Charlie Cartwright, Diane Gertzen, Hilary Graham, Ron Planden, and Chris Walsh for checking our presentations.

The front and back covers of this year's report focus on the work of Dr John Russell, the Ministry of Forests Breeder for Western redcedar and Yellow Cedar. John has provided an excellent visual presentation of his work and we are pleased to be able to use this publication to showcase his work. Although Western redcedar is the newest breeding program much progress has been made and it provides a perfect example of the progress and success of tree improvement in BC.

This year has seen a number of changes in program structure over last. Communications and Extension and Gene Conservation now have their own TAC's and sub-programs. This will provide greater depth in the future to the work in those fields. Select-Seed is now in operation and working towards starting the new orchards we have all been waiting to see. I would like to take the opportunity to thanks all those who have worked specifically with me in the Operational Tree Improvement and Breeding Programs. They have made the job of administering the program a relatively problem free process. We will continue to work on their behalf in providing Forest Renewal BC with good sound reporting and accountability while allowing the projects leaders to get on with the business at hand.

To all the Project Leaders I hope 2001/2002 is very successful.

Roger A. Painter

Tree Improvement Co-ordinator

Forest Genetics Council

Introduction

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

This report marks the fourth anniversary of the Forest Renewal BC-sponsored Operational Tree Improvement Program (OTIP) delivered by the Forest Genetics Council (FGC). Operational program goals include:

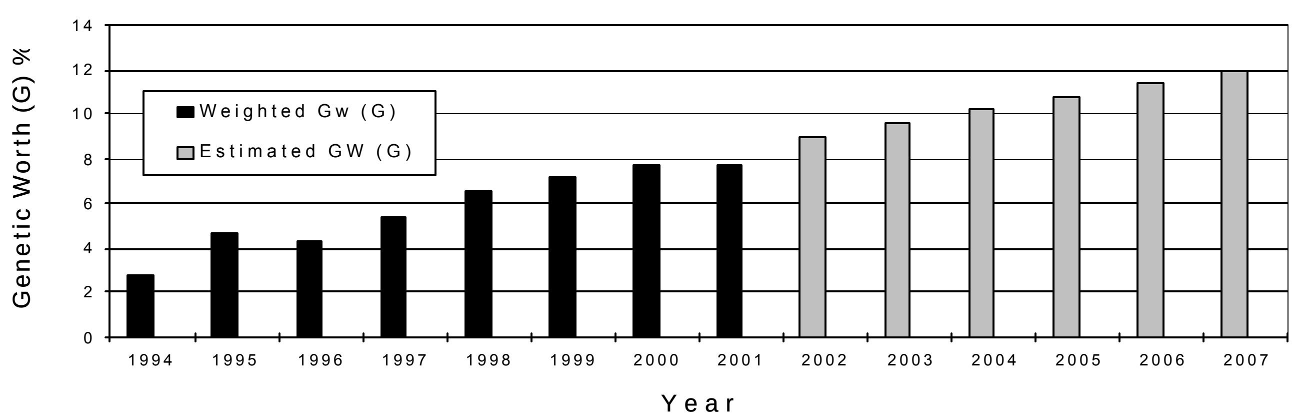
- doubling the genetic gain (genetic worth) of select materials planted from 6 to 12% by year 2007;
- increasing the use of select seed to 75% of total annual provincial sowing requests by year 2007;
- managing a gene conservation program to maintain genetic diversity in commercial tree species; and,
- supporting the long-term seed production capacity needed to meet the priorities of the FGC business plan.

This report marks the first year that the program has use formal performance indicators to target and measure performance to goals. Considerable planning has gone into establishing key performance indicators (kpi's) or brief overviews of performance in the 7 program areas.

The Ministry of Forests Seed Planning and Registry System (SPAR) is the broad performance measurement tool used to measure progress in goals 1 and 2. The genetic worth (GW) of material sown in a given reporting period is captured by SPAR and reported annually as a provincial average. Genetic worth is an expression of added volume growth expectation at rotation age – thus a GW 10 seedlot can be expected to produce 10% more volume than a GW 0 seedlot at time of harvest.

In 2000/01 the average genetic worth of material requested for reforestation in B.C. rose very slightly to 7.8%. This figure includes all select seed and cuttings, i.e. all material with a genetic worth of greater than zero, whether from superior provenance or seed orchard origin. Figure One shows the historic, current and projected genetic worth values.

Figure 1: Actual and Estimated Genetic Worth of Select Seed Requests (1994 - 2007)

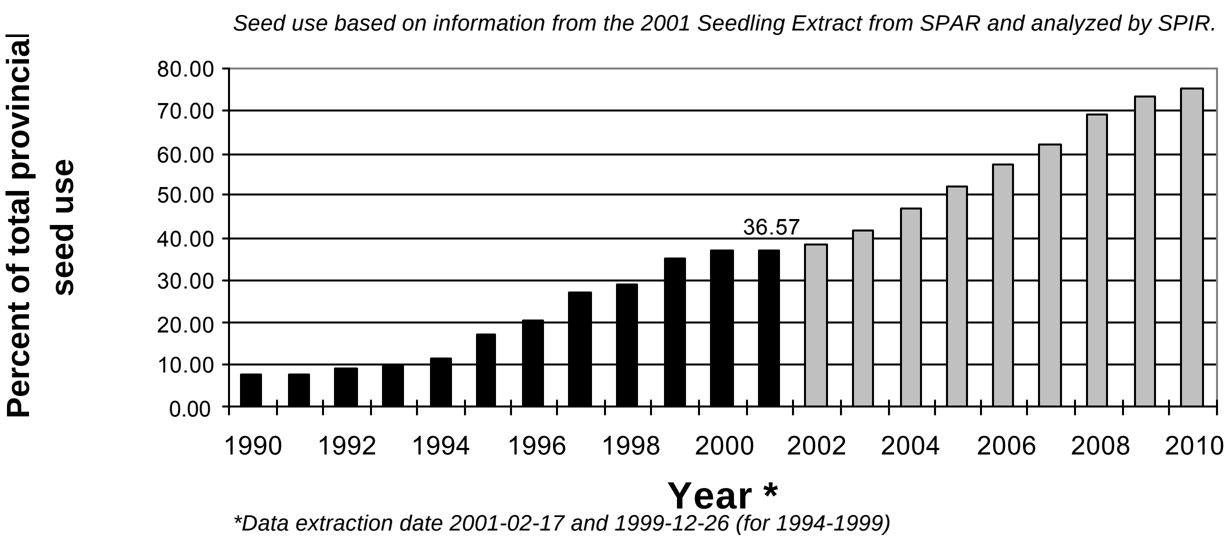


Introduction *(cont'd.)*

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

Select seed use (goal 2) is also captured in SPAR and averaged 37% of provincial seed requests in 2000/01. This is unchanged from the previous year (see Figure Two) and clearly the FGC will be challenged to meet its goal of 75% select seed use by 2007. Substantial and unforeseen shortages of lodgepole pine orchard seed are the main reason for this shortfall. However, the cyclic nature of seed production and increasing likelihood of substantial pine crops with maturing orchards offers reason for belief that this shortfall is temporary and will be rectified.

Figure 2: Actual and Projected Use of Select Seed (1990-2010)



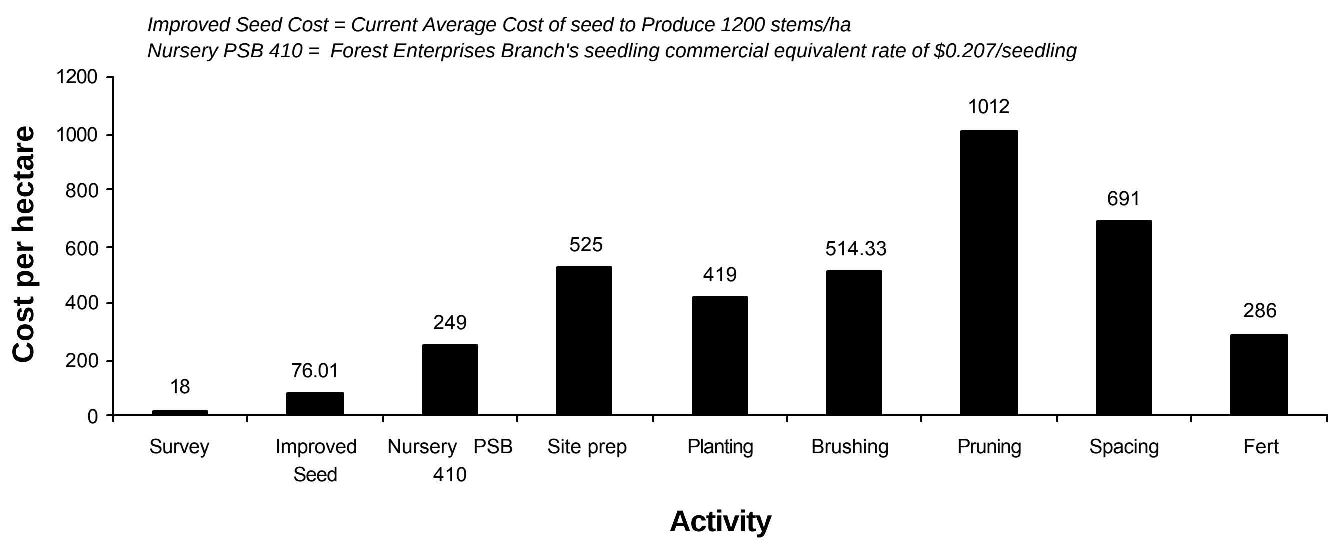
It is important to note that all materials used in British Columbia's operational reforestation program are derived from selections of wild native trees exhibiting good performance traits. These selected parents are tested in conventional breeding and testing programs and are not 'genetically engineered', 'genetically modified' or otherwise artificially produced through modern biotechnology.

The 3rd goal of the Forest Genetics Council – gene conservation – received a boost this year with the announcement of an FRBC-funded Gene Conservation Centre at the University of British Columbia. This centre of expertise will combine tree gene conservation topics with a broader range of gene conservation issues and ensure that proposed forest practices safeguard the forest genetic resource. The Forest Genetics Council looks forward to productive association with the Gene Conservation Centre for many years to come. Further information can be found within this report.

FRBC concluded their agreement with SelectSeed Co. Ltd. to resource the expansion of existing and establishment of new seed orchard capacity to meet FGC program priorities. This multi-year agreement provides funds to encourage the development of needed seed orchard capacity through out the province and allows accomplishment of provincial productivity goals. More information is found within this report.

Tree improvement remains one of the best silvicultural investments in British Columbia - in part because of its relatively low initial cost (Figure Three). Continued FRBC program support and guidance captures this biological and economic potential and realises it in terms of increased production and use of high quality reforestation materials. This production benefit is increasingly finding its way into Resource Management Plans, Incremental Silviculture Strategies, Innovative Forest Practices Agreements and Timber Supply Forecasting. The Chief Forester of British Columbia now routinely takes tree improvement benefits into account in the determination of allowable annual cuts.

Figure 3: Average Silviculture Activity Costs



The Forest Genetics Council of British Columbia only functions and meets its goals of genetic management of B.C. forests through the dedication of individuals and organisations. On behalf of the Chief Forester of British Columbia, the Council Co-Chairs wish to thank university, Ministry of Forests, forest industry, and private company staff working on Council and its' various committees and sub-programs.

Introduction *(cont'd.)*

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

The Council has long-enjoyed the support of the forest industry of British Columbia and this is critical to the well being of this program. In particular, the coastal forest industry members were early supporters and adopters of the tree improvement opportunity. Similarly, British Columbia's interior forest industry supports some of the most innovative co-operative seed orchards to be found world-wide.

The Forest Genetics Council Co-Chairs invite you to review the programs and projects described in this report and return any questions or comments to:

OTIP Program Administrator
Ministry of Forests
Tree Improvement Branch
PO Box 9518 Stn Prov Govt
Victoria BC, V8W 9C2

Further tree improvement information can be found at our Web sites:

Forest Genetics Council:	***http://www.fgcouncil.bc.ca/***
MoF, Tree Improvement Branch:	***http://www.for.gov.bc.ca/TIP/index.htm***
MoF, Research Branch:	***http://www.for.gov.bc.ca/research/***

Table of Contents

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Program Overview

1.0 Forest Renewal BC Tree Improvement Program

Forest gene resource management encompasses the conservation, controlled use, and enhancement of genetic resources of forest tree species, and related communication and extension activities. The Forest Genetics Council of British Columbia (FGC) coordinates a provincial forest gene resource management program that is implemented by stakeholders in the forest industry, Ministry of Forests (MOF), Canadian Forest Service, and universities.

Forest Renewal BC is a major funding agency for forest gene resource management in British Columbia. Through its Tree Improvement Program (TIP), Forest Renewal invests in forest gene resource management activities that support its objectives and are incremental to existing government and industry activities.

The Forest Renewal BC TIP is guided by strategic and annual business plans prepared by the FGC.

1.1 The Forest Genetics Council of B.C.

The Forest Genetics Council of British Columbia (FGC) is a multi-stakeholder group representing the forest industry, Forest Renewal BC, Ministry of Forests (MoF), and universities. Council's mandate is to champion forest gene resource management in British Columbia, to oversee strategic and business planning for a co-operative provincial forest gene resource management program, and to advise the province's Chief Forester on forest gene resource management policies. FGC members provide strategic direction to the provincial forest gene resource management program. FGC Technical Advisory Committees (TACs) provide technical and policy information to Council and contribute to the development of FGC plans and associated budgets.

Council's goal is to maximize the economic benefits from tree improvement gains in wood quality, quantity, and pest tolerance by: supporting a gene conservation program, developing long-term production capacity, doubling the average volume gain of select seed , and increasing the amount of select seed used. The FGC Business Plan defines the annual set of activities and associated budgets to achieve this goal.

- ***Forest gene resource management*** *is a co-operative effort. In broad terms, the MoF leads tree breeding activities and private industry leads operational production of reforestation materials. The Canadian Forest Service, MoF Research Branch, and universities undertake research supporting tree improvement, while private institutions focus on applied research related to operational production.*
- ***"Select"*** *refers to seed that comes from breeding programs that select from wild stands the trees with superior characteristics for growth, strength, or pest-resistance. "Seed" as used here refers to all selected reforestation materials, including vegetative propagules. The Forest Genetics Council does not support genetic engineering, and no genetically modified materials are used for Crown land reforestation in British Columbia.*

1.2 Forest Renewal TIP Subprograms

The Forest Renewal TIP is consistent with the provincial strategy for forest gene resource management developed by the FGC. The TIP goals are to increase the growth rate, wood quality, and pest resistance of seedlings, and to preserve the genetic diversity of tree species across the province. TIP activities are organized into seven subprograms (Figure 4).

- Gene Conservation
- Tree Breeding
- Operational Tree Improvement Program (OTIP)
- Expansion of Orchard Seed Supply (SelectSeed Ltd.)
- Extension and Communication
- Seed Planning and Information Tools
- Administration.

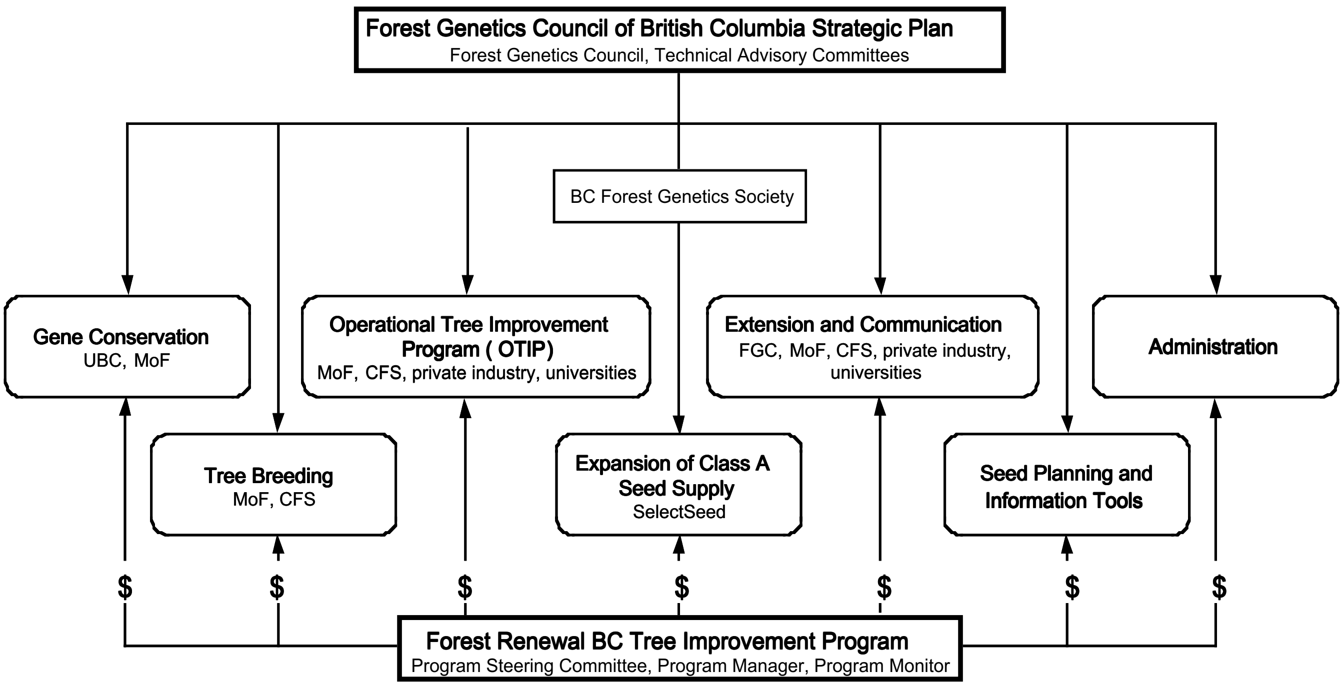


Figure 4. Relationship between FGC Strategic Plan, Forest Renewal BC TIP, and participants in various forest gene resource management areas

1.2.1 Gene Conservation Subprogram

Gene conservation activities protect the gene pool needed for species to adapt to future environmental conditions, and to ensure that genetic resources are maintained for future generations. Activities are developed by the Gene Conservation TAC and a newly established Forest Gene Conservation Centre at the University of British Columbia. Technical direction is reviewed through a Scientific Advisory Committee. The Centre receives funding through a Contribution Agreement with Forest Renewal BC, and will seek funding from other agencies or groups as opportunities arise.

1.2.2 Tree Breeding Subprogram

The Tree Breeding Subprogram focuses on the continued improvement of seed and vegetative materials for reforestation. Tree breeding activities include selecting parents in wild stands, propagation, testing offspring, mating, establishing/maintaining/ measuring trials, and technical support. The Subprogram also includes applied genecology to support the information needs of seed planning unit (SPU) programs as described in Species Plans. FGC Interior and Coastal TACs and their associated Species Committees carry out planning for the Tree Breeding Subprogram. The MoF Research Branch manages and carries out Tree Breeding Subprogram activities.

1.2.3 Operational Tree Improvement Program (OTIP)

The objective of the OTIP is to increase the quality and quantity of seed produced from existing forest company and MoF seed orchards. It also provides technical support for orchard production and management, including pest management. OTIP spending is based on Species Plans. Projects are developed through a call-for-proposals process that is based on Species Plans priorities. FGC Review Committees review and rank all proposals on need, technical merit, impact, value, and cost. The MoF Tree Improvement Branch administers the OTIP on behalf of Forest Renewal and the FGC.

1.2.4 Expansion of Orchard Seed Supply Subprogram (SelectSeed Ltd.)

Forest Renewal BC supports seed orchard expansions and the co-operative production of vegetative materials through Select Seed Company Ltd. (SelectSeed), a corporation wholly owned by the B.C. Forest Genetics Society (Figure 1). SelectSeed's primary mandate is to support seed orchard expansions needed to meet FGC objectives. As SelectSeed is controlled by stakeholders and not aligned with any single agency, it also provides program management services to the FGC.

SelectSeed's business plan and investments are based on the long-term and annual business plans prepared by FGC TACs and Species Committees. Management discretion for spending lies with the SelectSeed Board of Directors, and is guided by the terms of the SelectSeed-FRBC Multi-Year Agreement. Orchard development agreements take the form of long-term contracts that provide stability for investment and management. The SelectSeed Business Plan is reviewed and approved annually by the FGC.

1.2.5 Extension and Communication Subprogram

The Extension and Communication Subprogram supports FGC goals and objectives through extension, communication, and education activities. These activities are developed and guided by the FGC Extension Technical Advisory Committee (ETAC), which includes representative groups involved in research, extension, training, and communications. The ETAC prepares an annual activity plan to guide extension and communication activities. The plan forms the basis of an annual call for proposals in conjunction with the OTIP subprogram call. Extension and Communication contracts are administered by the MoF Tree Improvement Branch on behalf of Forest Renewal and the FGC.

1.2.6 Seed Planning and Information Tools Subprogram

The Seed Planning and Information Tools Subprogram supports the development of computer-based information systems that improve user access to information about the availability of select reforestation materials. Two information systems projects are in progress: SPAR Web Conversion, and development of the Species Plan Web Mapping System. These projects are jointly funded by the Ministry of Forests and the Forest Renewal BC TIP. Seed Planning and Information Tools activities and budgets are developed by the Seed Information Systems Steering Committee (SISSC), comprised of staff from the MoF Tree Improvement Branch (TIB), MoF systems staff, and the FGC Program Manager. Projects are identified by the Committee, developed by TIB staff and presented to the Forest Genetics Council for approval. This two-year subprogram, which ends in 2002, is administered by the TIB on behalf of Forest Renewal BC and the FGC.

1.2.7 Administration Subprogram

The Administration Subprogram has two components. The administrative infrastructure for the Tree Breeding, OTIP, Extension and Communication, and Seed Planning and Information Tools subprograms is provided by the MOF under the FRBC/Ministry of Forests Goals Agreement. Support for the Council's day-to-day business, meetings, communications, and planning activities are provided by the FGC Executive Secretariat, whose services are contracted out through a competitive bidding process.

1.3 TIP Budget

Subprogram budgets are listed in Table X, which includes only Forest Renewal BC's financial allocations. In-kind, staff and other contributions by industry, Ministry of Forests and university cooperators are not included, but are substantial and necessary inputs for program success. Actual spending may differ somewhat from the information presented here (see table below).

Subprogram	Budget	Expenditures
Gene Conservation	$183,700	$183,700
Tree Breeding	$2,350,000	$2,238,283
Operational Tree Improvement Program (OTIP)	$1,545,000	$1,426,892
Expansion of Orchard Seed Supply (SelectSeed Ltd.)	$4,766,300	$368,031
Extension and Communication	$170,000	$108,083
Seed Planning and Information Tools	$275,000	$274,966
Administration	$365,000	$363,849
Forest Renewal BC Tree Improvement Program Contribution	$9,655,000	$4,963,804
* Most of this budget was intended for a long-term fund that will support long-term orchard development contracts. Approximately $4 400 000 was place in the fund during the fiscal year.		

Table 1. Budget summary for Forest Renewal BC Tree Improvement Program

- ***Seed planning units-groupings*** *by species, seed zone, and elevation band-form the basis for tree breeding and seed production planning.*
- ***The Board*** *is comprised of representatives from the private sector and government, including the industry and government FGC Co-Chairs.*

2.0 The Fourth Year in Review

Roger Painter

The tree improvement industry continues to move forward towards its long-term objectives with the continued support of Forest Renewal BC. Tree Improvement offers the opportunity for the forest industry to increase both the quality and the quantity of the crops that are planted today and thus ensure that future generations will have healthy stronger forests. This will help meet the growing need for forest products in the future and provide a strong long-term economy. Our industry's goals are, by their very nature, long-term and require a constant commitment to ensure that they will lead to a stable source of economic benefit. This program has provided a steady source of resources to help move the tree improvement industry towards it overall objectives.

This year, the Tree Improvement Program has reorganized and refocused its operational program through to two key approaches. The Operational Tree Improvement Program (OTIP) has been divide up into sub-program to better provide direction for specific areas. Five sub-programs now exist on the operational side of tree improvement. They include Operational Production (OTIP), Tree Breeding, Extension and Communication, Gene Conservation, and Seed Planning and Information Tools. Further the Forest Genetics Council has formed new Technical Advisory Committees to better facilitate this, one for Extension and Communication (1999) and the other for Gene Conservation (2000). These Committees have been working to create goals and priorities specific to those areas. The second approach has been for the Council to develop a performance planning system to ensuring that the overall program goals are met. All projects now have a series of specific performance indicators to judge their effectiveness. Species committees have also taken on a stronger role in reviewing progress and providing priorities for investment. This will have the effect of ensuring that stronger investments are initiated and achieved. With this in mind, a total of 116 proposals in the operational program were received in 2000/2001 for funding. The technical review committees recommended that 98 proposals be accepted for funding. The total amount of proposals received was approximately $2.4 million. Just under $1.6 millions in proposals were finally approved.

This program is divided into Coastal, Interior and Provincial regions. Funding for each has been fairly evenly distributed between Coast and Interior. Although the Coast represents a smaller area overall, the tree improvement activities in this region are more advanced and diverse. A small number of provincial based projects were also received. The interior, however, did receive a greater portion of funding this year for work related to Lodgepole Pine. A sub-committee was formed in the Fall of 1999 to review and make recommendations on work to answer problems related to seed-set in Lodgepole Pine orchards in the Okanagan. Seed yields have not been at the level that was originally expected and a number of approaches have been suggested to improve production. This committee reviewed the various approaches, made a series of recommendations, and these were incorporated into the Call for Proposals issued this year. Initial results from projects begun this year are very promising. The breakdown of investment by region for OTIP is as follows:

Number of projects and funding by region		
Interior projects	55	$908,785
Coastal projects	43	$683,052
Overall Total	98	$1,591,838

As with the first three years, the support provided by Forest Renewal BC has been consistent with the investment necessary in the early phases of the Forest Genetics Council overall plan. Tree Breeding, as a Ministry of Forests responsibility is now not part of the original Operational Tree Improvement Program, Call for Proposals process. Priorities for the Tree Breeding sub-program are still developed through the Species-plan sub-committees but decisions on projects to be undertaken are reached through co-ordination with the Tree Improvement and Research Branches of the Ministry of Forests and the FGC Program Manager. Considerable support is needed in this sub-program and will continue to receive strong levels of funding in the early years to ensure that development of new production stock is achieved for the new orchards that are expected in the very near future. These new orchards will provide seed for the various Seed Planning Zones where production 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. Work in Tree Breeding has already provided much of the necessary genetic material to establish these new orchards. The development of a long-term investment program through SelectSeed has begun and over 13,000 grafts have already been made in 1999/2000 and 2000/2001 for new orchard establishment.

Although not a specific sub-program technical support is an integral part of tree improvement in general and continues to be a part of OTIP. This has shown its value particularly with the Lodgepole Pine seed-set issue. Tree improvement requires the ability to develop better methods for operational delivery of its product. The Operational Production program continues to expand and enhance existing orchard capacity. A project breakdown by areas of investment follows:

Number of projects in each area of investment	
Tree Breeding	36
Operational Production	61
Technical Support	37
Extension and Communication	8
Seed Planning and Information Tools	2

The tree improvement industry represents a broad base of partners. This includes forestry companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies and individuals. In 2000/2001 Tree Improvement Program involved 42 separate proponents from all parts of the industry. With the changes in structure that include sub-programs and the new focus driven TAC's, the Forest Genetics Council continues to provide the direction necessary for making sound investment and guidance for selecting acceptable proposals. The initiation of performance planning will also help to ensure that approved submissions reflect the direction that the Council has set for meeting it's goals. The Council, through its TAC's strives to review and update it's planning documents annual. Seed Planning Units (SPU) (see Appendix 2) have become a key element in the planning process and define the intensity of business planning required to successfully manage a diverse provincial program and be a strong partner with Forest Renewal BC.

2.1 Gene Conservation, UBC

Sally Aitken

Just as forest management and resource use requires balance through an active conservation program, tree improvement requires a gene conservation program to ensure the stewardship of genetic resources for future generations and provide raw material for the adaptation of species to future environmental conditions. Gene conservation is an integral part of the Forest Genetics Council (FGC) business plan. A mechanism was needed to allow for the objective evaluation of the current degree of protection of forest genetic resources in British Columbia, and to provide recommendations on necessary steps to further protect genetic diversity. During the past year, the Centre for Forest Gene Conservation (CFGC) was established at the University of British Columbia. The Centre is funded through a contribution agreement directly with Forest Renewal BC, but oversight and guidance is provided by the Forest Genetics Council through the Gene Conservation Technical Advisory Committee (GCTAC). The initial plan for the CFGC covers a seven-year time frame, with an initial funding agreement for two years (FY 2000/01-2001/02).

The plan was developed to address objectives developed by the GCTAC. To meet these objectives, several initial projects were identified. Three projects were initiated in 2000/01:

- ***Strategy for forest gene conservation in BC.***
  A strong gene conservation program requires a sound framework based on population genetics theory as well as integration with resource management and land use planning efforts. Dr. Gene Namkoong has played a key role in this initiative. The long-term maintenance of genetic diversity is strongly affected by the effective sizes of populations, the spatial structuring of genetic diversity, numbers and frequencies of rare alleles, and selection/mutation/drift balance. Breeding programs can be structured in a manner that conserves and even enhances genetic diversity. Strategies for the conservation and management of genetic diversity in the face of rapid climate change also need to be developed.

- ***Genecology and population genetic structure of whitebark pine,*** *Pinus albicaulis.*
  Whitebark pine is an important conifer for

ecological reasons, and is threatened by white pine blister rust. Little is known about the population genetic structure of BC populations of this species, and planning a gene conservation strategy requires additional information on genetic structure. M.Sc. student Jodie Krakowski is characterizing the amount and distribution of genetic diversity in whitebark pine to provide information on population variation for the development of a conservation strategy for this species. She has completed a project to estimate mating system parameters (degree of outcrossing versus inbreeding) for this species using isozymes. It appears there is considerably more self-pollination and inbreeding in whitebark pine than in most pines, with an effective selfing rate of approximately 40%, on average.

- ***Sampling strategies and geographic scale for capture of diversity and conservation of rare alleles.***

  Ex situ conservation, through collection and storage of seed or cryogenic preservation of tissue cultures, is a good complement to *in situ* conservation, and provides a back-up source of germplasm in the event of a major catastrophic event. It is also an efficient way to capture rare alleles, which represent the most vulnerable component of diversity. Strategies for collection of seed are much more flexible than the design of *in situ* reserves, and can be designed to maximize the capture of genetic diversity across the landscape, particularly rare alleles. PhD student Washington Gapare is looking at sampling strategies for conservation of rare alleles through a study of the distribution of rare alleles at different spatial scales, using Sitka spruce as a model species.

Four additional projects will be initiated in 2001/02:

- ***Genetic issues in forest certification.***

  Obtaining certification for wood products based on sustainable forest management is becoming increasingly important to the economic health of BC's forest industry. Genetic aspects of sustainable forest management need to be addressed in the forest certification process. We will develop a discussion paper on the scientific basis for genetic criteria for certification, review the current standards for genetic management of certifying organizations, and assist with evaluating the degree to which criteria are being met in British Columbia.

- ***Cataloguing in situ protection of genetic resources for trees.***

  In order to assess the need for additional gene conservation activities, good census information is needed on the sizes of populations for species of concern in currently protected in in situ reserves, and evaluation of genetic resource management practices in reserves and in other conservation programs. Since the completion of D. Lester and A. Yanchuk's survey of the protected status of conifers in 1996, additional areas have been conserved under the Protected Areas Strategy. Hardwood species have not yet been assessed. In addition, both public and private databases with inventories of species distributions have continued to grow and improve, and GIS technologies have developed. Alvin Yanchuk will guide this program.

- ***Develop marker-based methods of monitoring and managing coancestry in breeding populations.***

  Multi-generational breeding programs require tools to monitor levels of genetic diversity over time in breeding and deployment populations. Tools for monitoring can be theoretical, requiring input of population size and relatedness; or empirical, using genetic markers. The availability of molecular markers and analytical tools for tracking genetic diversity and managing coancestry will improve the ability to maintain genetic diversity in breeding programs while obtaining genetic gain. The objective of this project is to determine the natural pedigree structure among clones of high breeding value, and use this information to optimize the preservation of genetic diversity in breeding programs. Kermit Ritland and Yousry El-Kassaby will lead this effort.

- ***Genecology and population structure of minor tree species.***

  To determine if the current degree of *in situ* protection of species is adequate, information on the amount and distribution of genetic variation is needed. While our understanding of population genetic structure of economically-important, widespread conifers is quite good, we know relatively little about species of small tree stature, narrow distribution or little economic importance.

The objective of this project is to determine the genetic structure and degree of population differentiation for minor angiosperm and conifer tree species not previously investigated, and to develop seed transfer recommendations for these species. The first challenge will be to prioritize species for study. Once species are prioritized, seed collections will begin.

2.2 Tree Breeding

2.2.1 True Fir

Cheng C. Ying

Four short-term provenance tests were established last year, two for amabilis fir and two for subalpine fir. The northern site is located at Woodmere Nursery near Telkwa and the southern site at Sylvan Vale Nursery on Vancouver Island. These tests are intended for intensive observation of growth, hardiness and phenology for about 5 years. The objective is to establish a geographic pattern of adaptive variation in growth and tolerance of climate stress as a framework for seed transfer and genetic resource management.

The amabilis fir involves 32 provenances and 254 wind-pollinated families, and the subalpine fir 111 provenances and 515 families. After the first growing season, survival was near 100 percent except for the subalpine fir test at Sylvan Vale Nursery where we lost about 30% of the seedlings because of poor drainage of the site. First-year height varied significantly among provenances and families. At Woodmere, provenance mean height of amabilis fir ranged from 15 to 29 cm and family mean height from 13 to 32 cm, and subalpine fir provenance mean from 10 to 24 cm, and family from 9 to 29 cm. At Sylvan Vale, provenance mean height ranged from 17 to 21 cm, and family from 13 to 24 cm. We did not measure the subalpine fir at Sylvan Vale because of the high mortality.

We did also a small scale germination study of 20 amabilis fir provenances with different combinations of stratification and chemical treatment. The "best" treatment improved the germination rate of the poor germination provenances from 14 to 76%. A similar study with subalpine fir is on-going. Details will be reported after the completion of the latter. Screening for Balsam Woolly Adelgid is being conducted in the greenhouse. In addition to growth, plans are to assess both spring and fall phenology and winter injury.

With this intensive monitoring of the tests, a broad database can be built. It will be possible to deliver a biologically sound seed transfer guideline and identify superior provenances for plantation forests within the next five years.

2.2.2 Western Hemlock Tree Improvement - 2000 / 01

Charlie Cartwright

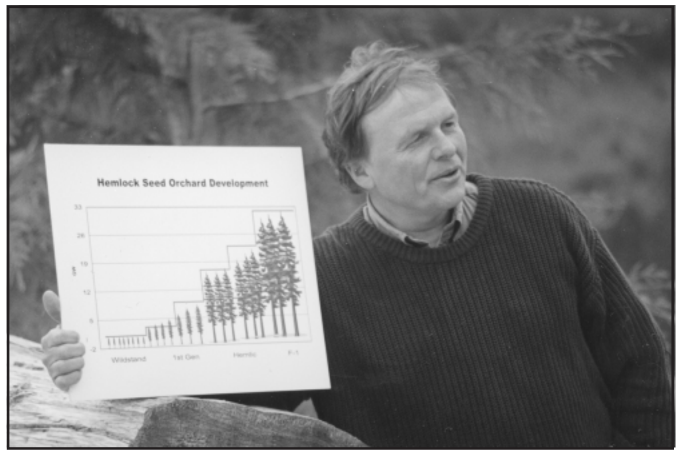


Figure 5. Charlie Cartwright Illustrating Hw gain

Low elevation hemlock tree improvement efforts this year produced substantial advances, but not without some unfortunate mishaps. Breeding efforts were hampered by poorer than usual response to flower induction, but were offset by extraordinary success with controlled pollinations. Fewer isolations than planned were made, yet the number of crosses completed exceeded expectation. In addition, a pollen storage failure during the winter will limit the ability to capitalise on an ambitious year of flower induction that has resulted in good prospects for next year's breeding.

In the field programs, first results from advanced generation testing were obtained in the fall and were promising. The trials compare height growth (age five years) of the best 150 parents from 1500 in the Hemlock Tree Improvement Co-operative (HEMTIC) which includes programs from BC, Washington and Oregon. Although there was a latitudinal cline in survival, favouring local sources; families from all regions figured in the top ranks. Results from on-going first generation trials, which are still important to estimation of breeding values, were less encouraging with some sites becoming less reliable over time. Broad future gains of the program will not be impacted, but the ability of seed producers to put together higher gain lots in the next few years will be limited.

Tree improvement for high elevation hemlock (above 600m) was more clearly on track. Crossing for future testing had good returns and new trials sown in 2000 did well in the nursery. These will be out-planted in the first weeks of the new fiscal year. Prospects for production of seedlots with greater than orchard mean genetic worths is now good, with release of rankings for 82 more parents last year and a reasonably promising cone crop.

Supporting research to the hemlock program has also been encouraging. An ecophysiology study investigating cold hardiness of parents from HEMTIC supports the results of the advanced generation trials, with more variability accounted for by family differences than by region. This suggests that tested materials from the south may be of greater interest to us than originally thought. Similarly, transfer north of volume gains achieved for the BC southern maritime is being investigated through deployment of tested and natural populations to the Queen Charlotte Islands and adjacent mainland coast. Seven small trials were established last spring . Wood studies have progressed with further investigation of density, morphometric and attributes of interest to the fibre industry being studied for selected families. Lastly, field testing of the shade tolerance of high gain parents versus woods' run populations has commenced to confirm results of nursery bed trials.

2.2.3 Pine and Broadleaved Genetics Team Millennium Report

Mike Carlson, John Murphy, Vicky Berger and Lynette Ryrie

Lodgepole Pine

Increasing quantity while maintaining quality of second generation pine tree stemwood are the objectives of the current controlled pollination efforts at KFC and RRRS. The second generation breeding for each of five seed planning zones consists of two breeding subpopulations: one emphasizing volume growth rate and one wood relative density (specific gravity). The best first generation progeny tested parent trees for each trait are grouped and intercrossed in factorial sets to produce 65 second generation test families for each breeding objective. Spring 2000 was the fourth season of second generation breeding. At present: the PG breeding set is finished, the BV set is nearly finished, NE is about one-half complete, and the TO crossing is beginning. The CP crossing has not started.

Year 2001 will see the PG second generation family set (~130 families) sown, grown and cold stored for year 2002 planting on three or four wild sites in the PG seed planning zone. Regular industry co-operators, (Canfor, The Pas, Lakeland, Riverside, West Fraser etc.), will again be asked for help in locating good test sites.

The PG zone "realized genetic gain" (RGG) trial was planted spring 2000. The same type trial was established in the TO zone in 1999. The objective of the RGG trial series is to quantify the gains in wood volume production that can be expected in future plantations using Class A seed. These are area-based plantings of 'elite' seed orchard seedlots, 'orchard run' or average seed orchard seedlots and 'wild' seedlots. Other factors tested include site index (low, mid, high SI's) and inter-tree spacing (1.5m, 2.5m, 3.5m). Data from these plantings will allow area-based yield improvement estimates and calibration of growth and yield models used in timber supply analyses.

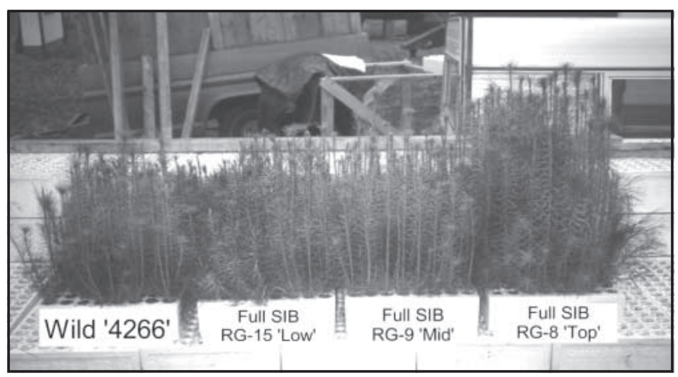


Figure 6. 410 seedling genetic entries in 1999 Thompson-Okanagan Pli realized genetic gain trial. L-R: Wild seedlot 4266, Orchard Run (RGs15,9), and Elites (RG8).

Other Pli trial planting in 2000 included 2 progeny test sites in the NST zone. Data from these sites will allow roguing and genetic gain increase of our NST orchard (#230). Three progeny test sites were planted in the new EK low zone in an effort to quantify gains from the soon-to-be EK seed orcard and to test the general adaptedness of the parent set chosen for this orchard.

Figure 7. 1999 Nass Skeena transition (NST) progeny test seedling crop grown at KFC. Note the unusual array of fall foliar pigments. Parent trees from a wide range of elevation and distance from the ocean.

The first "forward" selected seed orchard parents (34) were grafted for the EK low orchard in 1998. Forward selecting of orchard and/or breeding trees refers to the practice of looking at family and individual offspring (within family) performances in our progeny tests and selecting trees based on an "index" score combining family and individual tree trait values. This year another 80 trees were selected from our PG and BV 1985/86 progeny test series for use in orchard expansions for these zones. Approximately 6,000 scions will be collected in March and grafted at the Skimikin nursery site in April.

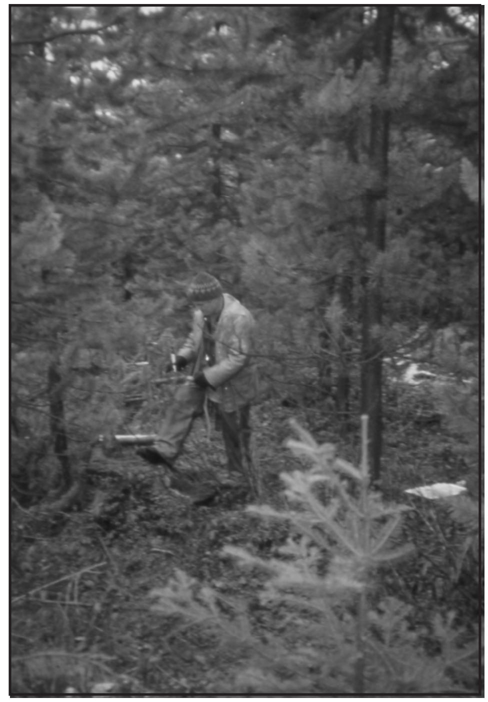


Figure 8. John Murphy at the 1986 Gramaphone Creek Bulkley Valley progeny test site making "forward" genetic selections for the BV seed orchard expansion project.

Lodgepole pine seed orchard expansion grafting continued in 2000 with some 14,000 grafts made, which were directed toward six orchard expansions. Overall graft 'take' was relatively low in 2000 at about 64%. We expect to graft approximately the same number of rootstock in 2001 for the six interior orchard expansion projects.

We have joined J.S. Thrower and Associates in submitting an FRBC/BCSC proposal to study Pli branching traits and how they are affected by seed source and family (genetics) and by planting site productivity (S.I.), elevation and latitude (environment).

Western White Pine

Our white pine crossing continues at KFC with the objective of accumulating genes controlling different mechanisms of blister rust resistance into individual trees. Host/pathogen relationship theory predicts longer lasting, more secure host resistance to pathogen attacks when genes for multiple resistance mechanisms are present ("horizontal resistance") versus when but a single resistance gene is present ("vertical resistance"). Our current white pine seed orchards (coast and interior) contain parents that were progeny screened for single resistance mechanisms (with a single gene for each mechanism assumed). Pathologists recognize four or five separate rust resistance mechanisms. Thus, much of the seed coming from our current orchards will contain genes for two mechanisms and therefore result in trees with excellent disease resistance properties. However, for future orchards we would like parents to each have two or more different resistance genes, thereby increasing the proportion of orchard seed having good horizontal resistance to the rust pathogen.

The white pine realized genetic gain trial sites were planted in 1998 with representative seed orchard seedlots and wild control seedlots. Their purpose is to allow estimates of gains in rust resistance that we expect from our seed orchard seedlots. The first rust evaluations for these sites will occur fall 2003.

Ponderosa Pine

In 1992 a ponderosa pine provenance seedsource trial was planted on three Okanagan-Shuswap sites. Seventy-three seed sources were sampled, 42 from the U.S. northern Rocky Mountain area and 31 from throughout southern B.C. After eight field seasons volume growth data were used to rank the sources and develop a single tree selection index for the purpose of thinning two of the trial sites for future seed production (the third site was abandoned early in the trial). The resulting selection scheme scored trees by considering the average performance of their seed source compared to other seed sources combined with measures of their individual tree performances relative to other trees of their own source. One plantation at the MOF Skimikin seed orchard site was thinned from 2,352 test trees to 467 seed production parents (approximately top 20%). The estimated genetic gain from future seedlots is 12% for rotation age volume production. Trees from U.S. sources were slightly disproportionately represented in the resulting orchard population with 58% of test trees (U.S.) contributing 63% of orchard parents. Pollen and cone production will be delayed for several years, as ponderosa typically doesn't begin reproducing until about 15 years from seed. The Grandview PRT plantation may be thinned in 2001 from 3,432 trees to a select population of 246 with an expected volume gain of about 10%.

Figure 9. Skimikin seed orchard ponderosa pine provenance trial plantation thinned to top 20% of trees based on 9 year volumes....a future Py seed orchard with an estimated genetic worth for rotation volume of 12%.

Paper Birch

While our paper birch genecology and population improvement work over the past six years has been funded by the B.C. Science Council (not FRBC/OTIP), the growing interest in the management of this species in both pure and mixed stands justifies its mention here. A collaborative research effort between the MOF, UNBC and the University of Idaho resulted in the planting of three sites (Sandpoint, Idaho, Salmon Arm and Prince George) with a wide range of paper birch (*Betula papyrifera*) seed sources. Paper birch ranges from a few isolated Vancouver Island stands eastward to the coastal-interior transition mountains (mostly eastside) and to the western slopes of the Rocky Mountains and from northern Idaho to the southern Yukon. Little is known about the genecology of this tree and safe seed transfer limits. Seed source testing began in 1996 with the planting of six field sites with 18 seed sources. Both sources and sites span the five interior forest regions. The current project was designed to learn about the effects of latitude, longitude and elevation of seed source, nursery of origin and field planting locations on growth, growth timing and general adaptedness. Forty-seven seed sources representing five elevational transects (low to high) representing five latitudes, and two longitudinal transects (coast to interior, north and south) were all grown at three nursery locations (Prince George, Salmon Arm and Northern Idaho) and reciprocally planted at the three sites described above. First year survival was above 90% at each site.

2.2.4 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 after choosing the few surviving trees to intense attacks). A major gene resistance 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. Interior populations have been augmented by the Idaho material. This project concerns 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. We also wish to look at hybridising Eurasian five needle pines as a way of infusing durable resistance.

Work Completed to March 31st 2001:

This year we are planting a series of F-1 trial that includes material gathered from Dorena (the Dorena diallels made in the 1980's) along with some crosses made from the CFS material. Seedlings were grown at Green Timbers for outplanting to trials. We are currently planting 4 sites – 3 on Vancouver Island and one on the Sunshine Coast. Gary Jensen and Rich Hunt of the CFS have been involved in the inoculation of these seedlots which they grew at CLRS and are transferred to Skimikin . We continued the scion collection program that was started last year based on the CFS list. In May of 2001 we shall to continue our F-1 breeding program – last year was very windy and blustery and we have had Dr. John Owens construct some nylon frames that may better help.

Rich Hunt and John King attended a field tour in May with Dr. Bro Kinloch to look at the Happy Camp trials in Northern California. Happy Camp has been used as a monitoring site looking at the spread of a virulent rust race to MGR. Evidence to date indicates virulence spreads slowly in sugar pine but there certainly were some important questions to answer – the scariest thing we saw was virulence to MGR in a very small white pine trial. We had to scratch our head as to why there should be a virulence response to just a handful of white pine with sugar pine all around.(where is the selection pressure to bring this about?). Also alarming is a possible virulence response at the Sechelt trial. We invited Dr. Bro Kinloch to look at this and had a trip to Texada with Bro, Patti Brown, Rich Hunt, John King and Dr. Joerg Bohlmann of UBC last September. Rich Hunt does not believe this is a virulence response to MGR and feels we may be seeing the mysterious Mech-X proposed by Richard Sniezko of Dorena. The mystery is ongoing and we are planning a visit to the site this May. We hope also to invite Dr. George Newcombe of the University of Idaho. Dr. Newcombe has worked on these dominant gene defences in poplars and he would be a good addition to our sleuthing of this matter. At the meeting in May (to be held in conjunction with a species meeting) we shall review the idea of MGR deployment and what guidelines might be needed. A group of us (Don Pigott, Patti Brown, Tim Crowder, Michael Stoehr and John King) went down to Dorena in January. We had a good meeting with Joe Linn the Director at the Dorena station that we hope will pave the way to buy MGR.

We have measured the older provenance trials (Mike Meagher's – CFS trials) as planned; it became imperative after seeing the Whidbey Island Pine trial of Washington State DNR. The southern Oregon sources were really blown away (poor growth and high susceptibility – this has made us wary of importing Dorena seed – and the MGR pollen purchase a better bet). We hope with these measurements to establish better white pine transfer guidelines for the Coast.

2.2.5 Sitka Spruce Breeding

John King

Figure 10. John King explains weevil resistance, Port McNeil

Sitka Spruce - Screening and Breeding of Populations

Outline of Project:

Our major emphasis is on genetic resistance but we have a small ancillary program centred around producing information on genetic resources appropriate to the Queen Charlotte Islands.

Genetic resistance to the white pine weevil damage in spruce has been noted now for several years. This resistance can be quite marked with resistant families having only 1/10th 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 March 31st 2001:

A research workshop,followed by a field tour visit to the Sayward sites and North Island, is soon to be conducted at Lake Cowichan (April 3rd -6th) . This meeting will allow us to reflect on our progress to date in understanding the mechanisms of resistance and how they are inherited. It will allow us to focus on how we should proceed in this area. One of the key new people we have to help us is Dr Joerg Bohlmann of UBC, together with Dr. Aine Plant of SFU and the continued commitment of Dr Rene Alfaro and his team at the CFS – we will continue to make great progress.

Besides regular brushing and maintenance work we received weevil assessment measurement provided by George Brown of the CFS and are now able to complete an analysis of the first two series of OP screenings and 3 series of clonal trials (EP 702.06). With this data we are establishing breeding and seed orchards. Grafts have already been established at the WFP Saanichton Forestry Centre and are soon to be established at Yellow Point Propagation seed orchard at Yellow Point. Don Illingworth continued to collect scions this year for additional establishment and we did approximately 1200 grafts at Cowichan Lake Research Station. Don Pigott moved advanced ramets from the Sayward clonal trials to Puckle Road where we have established a breeding orchard.

Breeding was carried out by Cathy Cook of WFP and it provided the first year of a concentrated effort at producing an F-1 population. Enough seed was produced so that we could make available seed to WFP's OTIP proposal 0602 to provide material for vegetative cuttings. We are also hoping to make material available for embling production – this will be discussed at the species meeting planned for April 10th. We will continue to breed at Sayward this year but should be able to shift to Puckle Road and Saanichton over the next few years.

Site establishment was concentrated to some follow up work on the Queen Charlottes (3 sites). This was some additional UK Forestry Commission families + extra WFP polycross families. With past material this provides a nice base of material for genetic testing for the Queen Charlotte Island... We have also been conducting a lot of catch up maintenance and tagging on the Queen Charlottes.

We have set up temperature monitors on the series of small trials we established the year before last. We hope through these to monitor hazard rating as part of a genetic worth for resistance system. We received through Dr Alfaro and Robert McDonald a series of TIPSY runs that should allow us to convert our resistant scores to better GW values. We have just received this but should be able to implement this through the Technical Report that we are currently writing up. This document along with a web-site should provide fingertip information on all aspects of the Sitka spruce program. This write up is underway but should be a deliverable in this next year.

Nass / Skeena Transition Spruce – Investigation of Genetic Variability

Outline of Project:

The coast mountains of B.C. provides a natural barrier between coastal Sitka spruce and interior spruce (white and engelmann). But in certain areas of the sub-maritime and in areas where rivers cut through the ranges such as the Nass and Skeena Rivers of the North Coast B.C. natural hybrids occur between these species. These hybrid areas besides having tremendous genetic diversity caused by the hybridization are also an area of extreme environmental variability (the transition between coastal and interior climates). Selection pressures on spruce seedlings include: weevil hazard - in general having interior genes helps in reducing hazard to terminal weevil by 50%; frost tolerance - interior spruce can greatly increase hardiness to frost; growth rate is greatly increased by having a strong Sitka component.

All three of these selection pressures have a strong influence on health and adaptability of spruce trees. But their influences on the genetic component is opposite: frost and weevil tolerance are favoured by interior spruce and growth rate - which influences adaptability in a seedlings ability to overcome brush hazard, browsing and weevil attack recovery - favours Sitka genes. These opposing trends cause difficulty in prescribing seedlots for the transition area. Right now seed transfer movement are very limited (only 1/2 degree of latitude compared to 3 degrees for most other species). This has caused a great deal of difficulty in using spruce in this area.

Objective:

To provide for a series of single-tree collections from North Coast and other spruce transition areas as a basis for long term field trials - included in the trials will be known F1 crosses and other pedigreed crosses depending on available material. Information from these trials will help in establishing guidelines for seed movement of spruce and will help us understand the importance of the genetic origin of seedlots and the environmental pressures they face. Collaborative nursery and DNA work with UBC and BCRI will be used as support to long term field trials in understanding genetic and environmental diversity.

2.2.6 Coastal Douglas-fir

Michael Stoehr, Norm Pomeroy and Keith Bird

Coastal Douglas-fir

Second generation seed orchards are now established on several industry and Ministry sites. Using selections from the second generation testing (EP 708), breeding for the production of third generation seed orchards is under way, with Phase 1 breeding completed. To minimize inbreeding in advanced generation seed orchards, we opted to use sublines for the selection of seed orchard material. In subline breeding, inbreeding effects stay within sublines and as only one tree per subline will be selected for seed orchards, inbreeding is eliminated from seed orchards. This year, the first phase progeny tests were weeded and tagged and assessed for survival. There are two components to the progeny testing of this advanced generation material: First, all parents in the sublines are (general-combining-ability), “GCA-tested”. This involves control crossing of all parents with a standard, average breeding value polymix. The results of these progeny tests yield information on the genetic quality of the tested parents. The second component consists of full-sib family tests. These tests are used for the selection of superior genotypes for the establishment of seed orchards and future breeding populations. Based on the GCA-tests, the best parents within sublines are recombined (crossed) and their best offspring selected. Thus, these full-sib family tests are established as 5x5 family blocks for effective within family selection. Eight sublines out of a total of 31 are in this first phase of testing. Phase 2 with roughly 12 sublines will be sown in 2002.

Realized gain trials established in 1996 on six coastal sites were weeded this year with height and diameter measurements scheduled for 2002. Early results indicate that our top breeding value families are performing very well and anticipated gains as estimated from progeny tests will be realized.

Sub-Maritime Douglas-fir (Transition Zone Douglas-fir)

A genecological study of Douglas-fir in the sub-maritime seed zone was established on six sites to assist in the delineation of seed transfer zones. All sites were weeded and tagged with height measurements scheduled for the spring 0f 2002. In parallel, a laboratory study is in progress at UBC (a continuation of work initiated by BC Research Inc.) to evaluate adaptive traits. Specifically, moisture stress resistance as expressed as cavitation is examined on selected families that are also represented in the six field tests. Preliminary results show that families that are performing well on the coast are also fast growing in the transition zone. Of interest is the good performance of interior-coastal "hybrids" in the transition zone as well as in similar tests in the interior.

Hi-elevation Douglas-fir

In co-operation with Canfor (Patti Brown), two high elevation test sites were established to examine the performance of parents in the high elevation seed orchard at Sechelt (Canfor). This year, the two sites (Mt. Cain and Sutton Creek near Woss on Vancouver Island) were weeded and heights measured. The height measurements were used to rank parents and rogue the orchard from below, i.e., remove the bottom 30% of parents. Top-cross coastal Douglas-fir families that were included in the tests show good performance with rankings on both sites in the top 15%.

2.2.7 Western Redcedar Gene Resource Management

John Russell

Activities for the western redcedar gene resource management program involve gene conservation, genecology, tree breeding and technical support. The following activities occurred over the last year:

- **Gene Conservation:** Over 200 new parents from Washington and Oregon were cloned and established in the gene archives at CLRS. Besides contributing to the "*ex-situ*" gene pool, these parents will also be included in the breeding and testing program.
- **Genecolgy:** All genecology test sites were maintained as needed. Ten-year measurements on the open-pollinated progeny trials will be collected next year.
- **Breeding:** Seed was collected from 100 polycross families from last springs breeding. This year, 300 polycross families were bred, for a total of 750 to-date. Approximately 250 of these are from coastal Washington and Oregon.
- **Progeny Testing:** Five progeny test sites were established this spring throughout the coastal maritime including a second site in the Queen Charlotte Islands. An additional site was established in the south submaritime. To-date, 25 progeny sites testing over 450 polycrossed families have been established. All sites were maintained to minimise competing vegetation and deer browsing. Four nutrient poor sites were fertilised last spring. The first series established in 1998 will be measured for 5-year heights next fall.
- **Realised gain and inbreeding study:**

  Four realised gain trials were established on coastal sites, comparing seedlots from wildstands (upper and lower crown), first generation seed orchards (upper and lower crown), polycrossed first generation seed orchards and elite full-sib families. The study, which used area-based plots, was designed to evaluate growth and yield difference due to genetic selection and inbreeding reduction.

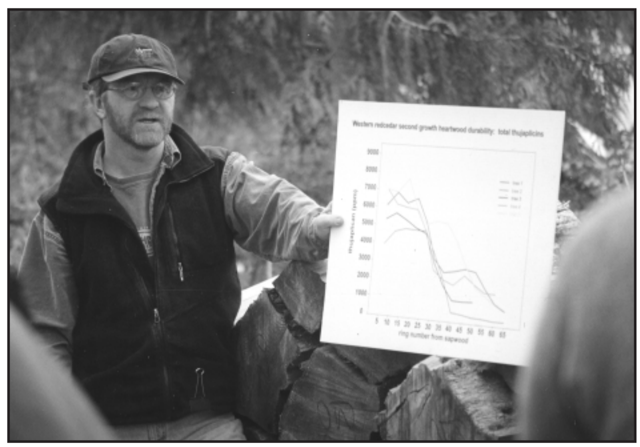


Figure 11. John Russell discusses Cwr wood quality issues

- **Wood durability:** The objective of this study is to screen western redcedar clones for enhanced natural durability by analysing wood cores for tropolones, in particular the thujaplicans. It is anticipated that breeding values for increased wood durability will be developed for 300 clones by the end of this project. This year, the study concentrated on developing heritabilities for 30 parents by studying parent:offspring regressions. Thirty-five clones from Mt. Newton seed orchard, 2 copies each, were cored and analysed for tropolone content. Ten-year-old trees from six progeny from each of the 35 families on each of 2 sites were also sampled for tropolone content. Results are forthcoming. Information from this study will allow us to determine the efficiency of sampling parent trees for natural durability as reflected in the progeny.

2.2.8 Yellow-cedar Gene Resource Management

John Russell

Activities for the yellow-cedar gene resource management program involve gene conservation, genecology, tree breeding and technical support. The following activities occurred over the last year:

- **Genecology:** The first series of six provenance test sites were measured for 10-year heights. There is continued evidence of random population variation in response to environmental conditions at all test sites. Ten-year data will be collected from four sites from the second-series next fall. Any changes to seed transfer will be proposed after evaluation of data from both series.
- **Selections:** Fifty selected clones have been established at CLRS for advanced generation breeding, including clones from Western Forest Products testing program. These clones are a subset of the selected clones now being established in production hedge orchards. All selected clones will also be established at a high elevation site yet to be chosen. This will ensure that male and/or female production will be optimised on these valuable selections. A further 50 clones will be selected over the next few years from the clonal progeny trials.
- **Clonal Progeny Testing:** Three annual series of clonal progeny have been established. Over 5000 clones from 400 full-sib families have been planted. Three to four test sites were established at each series. All sites have high survival and are growing well. Five-year data will be collected this coming fall from the first series. Selections from this, and future series, will be established in existing hedge and breeding orchards.
- **Clonal Forestry:** The objective of this technical support project is to determine the most efficient technique for maintaining donor stock juvenility and thus rooted cutting quality. The study includes over 100 clones that have been established from seedlot 9777 every 2 to 4 years from seed and from previously rooted cuttings from the original seedlings. The oldest donors are now 18 years old. Another round of serial propagation was completed this year. Two series of trials from the hedges have been established. One series, established on 2 sites, is now 5 years old and data on growth, form and survival has just been collected. The other series has just been established on two sites in coastal BC.
- **Realised gain and competition study:** Selected clones are now being established into production hedges. It is timely to develop appropriate clonal deployment guidelines to ensure adequate genetic diversity and maximum volume production. This year, elite clones were planted in monoclonal, diclonal and multiclonal configurations as area-based plots on four sites. Also included were wildstand control plots. Growth and yield data from these trials will assist in developing appropriate deployment guidelines as well as realised gain information.

2.2.9 Interior Spruce, Interior Douglas-fir and western larch tree breeding report: 1999-2000

B. Jaquish, V. Ashley, D. Wallden, G. Phillips, & B. Hooge

Interior Spruce

Activity through the reporting period generally focused on maintaining and measuring first and second-generation progeny tests, various research installations, and somatic embryogenesis (SE) candidacy tests in the central Interior. The nine second-generation full-sib progeny tests in the Prince George (PG), East Kootenay (EK) and Bulkley Valley (BV) seed planning units (SPU), which were established in 1996, 1997 and 1999, respectively, were brushed and irrigated as necessary. Six-year height measurement of the PG series will be completed in fall 2001.

In the first generation tests, 15-year height measurements were made on six sites in the EP 819 Series II open-pollinated (OP) progeny tests. Data from this series was combined with two other data sets and used to estimate new breeding values (BV) based on 15-year height for all tested parents in the new PG SPU. Seed orchard roguing and expansion will be based on these new breeding values. In addition, these new BV's will be used to establish a new seed orchard at the Vernon Seed Orchard Company for the PG high elevation (>1200 m) SPU. One site (PGTIS) in the EP 819 series was thinned and wood disks were collected for wood relative density determination. Three sites in the Peace River (PR) zone also received brushing and maintenance. In the southern Interior, maintenance and six-year height measurements were completed for four polycross tests in the Nelson (NE) SPU and two polycross tests in the Thompson Okanagan (TO) SPU. Data analyses have been completed and results will be used to guide seed orchard roguing and expansion. Ten and six-year heights were also measured on the Sawmill Ck. white/engelmann spruce provenance test and the three EK realized gain/demonstration plantations, respectively. These four plantations are located near Cranbrook.

Seven SE candidacy tests in the PG Forest Region were brushed and six were measured. Data analyses for these tests are ongoing. At Kalamalka, in fall 1999 more than 14,000 white pine weevils (*Pissodes strobi* Peck) were augmented to the natural population in a full-sib progeny test of putatively resistant and susceptible parents. Augmentation resulted in very uniform weevil pressure across the plantation.

Figure 12. susceptible x susceptible

Figure 13. resistant x resistant

Attack and top kill data were collected throughout 2000. Results are presented and discussed elsewhere in this document (Alfaro *et al*).

The recent merging of seven small seed zones in the central Interior into one large Prince George zone required the pooling of 1134 parents. OP progeny tests of these parents were established in three separate test series (EP 670, and EP 819 Series 1 and II established in 1974, 1984 and 1986, respectively). Breeding values have been estimated for the 1134 parents using Best Linear Prediction and breeding is in progress to establish a new test population for second-generation selection. The breeding program consists of crossing the top 144 parents in a partial diallel mating design. Despite a small flower crop in spring 2000, 128 crosses were completed and 93 pollen lots were collected.

Interior Douglas-fir

Four progeny test sites in the 15-year-old Shuswap Adams series of the NE seed planning unit were brushed and measured. Two sites (Barriere Lake and Adams Lake) were also access pruned. Data analyses are in progress and when completed will be used to guide seed orchard development. Several Douglas-fir research installations were maintained and measured. Twenty-five year height and diameter were measured in the Trinity Valley range-wide provenance test. Data analyses are in progress and preliminary results confirm the continued superior growth of seed sources from the BC submaritime zone and the east slopes of the US Cascade Mountains. Many seed sources from the southern Rocky Mountains and Mexico are exhibiting serious signs of maladaptation. Compared with local sources, these southern sources typically exhibit slower growth, more winter dessication and higher incidences of Douglas-fir needle cast (*Rhabdocline pseudotsugae* Syd.) Within ten years most of these southern sources are expected to be dead. The 10-year-old Hidden Lake area-based yield study was measured, thinned and pruned. The objective of this study is to compare genetic entry rankings and establish relationships between 4-tree row plots and 144 tree square plots. Two research sites at the Skimikin Seed Orchard (the Interior Douglas-fir elevational transect study and the submaritime seed source study) were also thinned and access pruned.

Figure 14. Top ranked family in submaritime Douglas-fir progeny tests at Skimikin

Finally, the EK Douglas-fir test at Skimikin was terminated and wood disks were collected for wood relative density determination.

The Interior Douglas-fir advanced-generation breeding project is focusing initially on the NE low zone. The 2000 Douglas-fir flower crop was very light and only 52 controlled crosses were completed.

Western larch

Figure 15. A 4-year-old family in the Lamb Ck western larch progeny tests

The western larch program tree improvement is developing rapidly. While the two seed orchards at Kalamalka are producing sizeable quantities of seed, progeny tests are maturing and providing genetic information required to rogue and improve the genetic quality of the seed orchards.

Presently, western larch tree improvement in BC uses two seed planning units: East Kootenay (EK) and Nelson (NE). In total, 610 OP families have been established in two series of progeny tests in each SPU. In 2000, three sites in the 10-year-old EK Series I test and four sites in the 6-year-old EK Series II test were brushed and measured. Results are presented in the following table (2).

Series	Site	Age (yrs)	Site mean height (cm)	Range of family heights (cm)	Survival (%)	Damage (%)	h2ind(se)	h2family(se)
One	Lamb Ck	10	383.3	255 - 482	84.8	5.9	.34 (.06)	.62 (.12)
	Sawmill Ck	10	356.7	242 - 454	91.8	14.4	.27 (.05)	.56 (.12)
	Semlin Ck	10	339.5	227 - 458	95.9	8.1	.36 (.06)	.64 (.12)
Two	Angus Ck	6	235.6	170 - 293	86.5	1.8	.20 (.05)	.45 (.13)
	Lamb Ck	6	196.6	132 - 235	96.5	2.4	.29 (.06)	.55 (.13)
	Semlin II	6	239.6	182 - 281	91.2	5.9	.26 (.06)	.53 (.13)
	Upper Lamb	6	170.9	120 - 211	88.2	3.4	.14 (.04)	.39 (.13)

Table 2. Summary of East Kootenay Series I and II western larch progeny tests.

A total of 51 controlled crosses were made in the western larch advanced-generation breeding program.

In fall 2000, the 10-year-old Lamb Ck. range-wide western larch provenance test was maintained and measured. Preliminary results were consistent with published results from young tests in Idaho (Rehfeldt 1995). The tallest and shortest provenances originated from north Idaho and Oregon, respectively (Table 3).

Zone of origin	Number of seed sources	Mean 10-year height (cm)	Survival (%)	Damage (%)
North Idaho	15	371.6	95.0	3.5
Central Montana	11	367.3	95.2	1.1
Western Montana	48	367.2	94.6	2.9
West Kootenay	11	360.1	94.8	3.2
East Kootenay	12	358.7	95.5	1.6
South Idaho	18	350.8	91.5	2.1
Washington	11	339.7	93.8	2.0
Oregon	4	307.3	88.3	2.6

Table 3. Ten-year results from the Lamb Ck range-wide western larch provenance test by zone of origin.

2.3 Operational Tree Improvement Program

2.3.1 The Call for Proposals and Funding Distribution.

The 2000/2001 Call for Proposals was issued on December 1,1999. Forest Renewal approved overall funding of $4,705,000 for the program of which $1,545,000 was identified by Council for OTIP projects. The Call for Proposals was widely distributed throughout the Forest Industry and included licensees, districts, regions, universities, orchardists, private researchers, contractors and biotechnology firms. Proposals were to be returned by January 14, 2000. As in the past, this program strives to ensure that funding is received by proponents as soon as possible. Procedures are succinct and delays are kept to a minimum. This industry is very dependent on biological timing and it is important to ensure that funding is in place prior to initiation of the field season. A total of 116 projects were received totaling $2,4410,000. The Interior and Coastal TAC committees struck review committees to evaluate proposals by the mid-February. Final approval was granted by Council in early March. Funding for Tree Breeding activities and for Seed Planning and Information Tools were also identified and presented for Council approval at the same time. Both Extension and Communication and Gene Conservation Programs had overall funding approved. However specific projects were not ratified until later in the year and were dependent on the development of goals and priorities by the overseeing TACs to guide project selection.

2.3.2 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.

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.

2.3.3 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.

Orchard Projects

2.3.4 Sechelt Seed Orchards

Patti Brown

Canadian Forest Products Ltd has increased the amount and genetic worth of the seed it produces from it's Sechelt Seed Orchard site with the help of FRBC's OTIP funding program since 1997. Five OTIP funded projects covering 5 coastal species were carried out at the Sechelt Seed Orchard Site in the fiscal year 2000/01.

The objectives of SPU1101 were to maintain and increase the number of high gain yellow-cedar donors. We have currently initiated and maintain 6000 one and two year old donors with a breeding value (BV), of greater than eight. Twenty-five hundred new donors were started this year from those clones with a BV of greater than 10. The 1500 original donor selections (age 2) were intensively pruned back three to four times throughout the year to induce more juvenile growth (and therefore rooting success) from these donors in the future. All donors were fertilized and pruned regularly throughout the year to increase cutting yields.

Two projects were undertaken for western redcedar in 2000/01 (SPU0201). Two hundred ramets were induced with GA_3 in May and 200 ramets were induced in early August. Ten ramets were left as control. The induction was done in conjunction with an OTIP study being done by Oldrich Hak to determine the effect of timing on the amount of males and females produced. A very heavy crop resulted in the 100 ramets treated in both May and August, a light to moderate crop was produced in the May only treatment, a light crop for the August only treatment and no crop for the control ramets. The end result is a potentially operational crop in 250 of the 300 treated ramets. The second project involved weeding, fertilizing and pruning the 3000 one and two year old ramets being held until the progeny test results for the red cedar series is available at which time they will be rogued to the top 10%.

The efforts for our white pine program focused on obtaining greater resistance by continuing to use the best slow canker or major gene resistance(MGR) pollens on the existing ramets to get better seed and by replacing ramets in the orchard with clones with a greater degree of slow canker growth. OTIP project SPU0801 saw 20,000 potential seedlings with MGR resistance and 30,000 potential seedlings with slow canker traits collected and processed. Further, a potential 50,000 slow canker seedlings will result from the pollinations made in June 2000. Four hundred ramets with better slow canker resistance were grafted and will be placed in holding beds while the roots develop enough to integrate into the main orchard.

Project SPU0101 was conducted to obtain greater quantities of seed and higher genetic gain from our Douglas-fir orchard #116. All healthy ramets (325) were induced in May/June of 2000 as the five year progeny test results were not available until the fall of 2000. This allowed a potential crop to develop in all clones since the best ones would not be known until after the induction period. Eighty of the poorest performing clones will then be removed prior to pollination in 2001 to prevent pollen contamination to the better parents. Pollen from six clones in the high elevation progeny test were collected from Orchard #177 to apply to Orchard #116 in 2001.

SPU0302 was done mainly to develop future high gain crops from both Orchard #133 and Orchard #179 but also tried to capitalise on a small crop produced in a light pollen year. 290 ramets with BV's greater than 3 were induced in May/June of 2000 to produce a controlled cross and SMP crop in 2001. SMP was applied to a small crop in April 2000. Enough seed for only 30,000 seedlings was produced due to insect damage from insects not previously found to affect hemlock seed. The *leptoglossus* population was light and kept in control manually. Twenty cones from each clone were collected and stored to determine the efficacy of SMP in a light year; however, with the insect damage that occurred this year 20 cones may not be enough. Orchard #179 was pruned in the fall of 2000 to increase the future cone producing surface area in this developing second generation orchard.

2.3.5 Kalamalka Seed Orchards

Chris Walsh

For 2000/2001 at Kalamalka Seed Orchards there were ten OTIP projects approved under the operational production sub-program. The funding allowed us to enhance the effectiveness of our orchards in delivering improved seed. Activities included:

- Improving orchard composition through grafting higher breeding value ramets, maintaining recently grafted high value ramets destined for orchards, transplanting the older higher value ramets to the orchards and roguing lower value ramets from the orchards;

- Improving orchard seed quantity and quality through pollen management, including collection of high breeding value pollen and the application of Supplemental Mass Pollination; and
- Improving orchard productivity through pest management and other management activities.

Project	Species	SPZ	Orchard	Grafts Made	Maintained	Rootstock	Trans-plants
SPU0401	Sx	NE	305	400	132	200	
SPU0502	Sx	NE	306	400	31	200	
SPU0701	Pli	NE	307		110		
SPU1302	Lw	NE	332	180			73
SPU1401	Sx	PG	209		391		
SPU1501	Pw	KQ	335		413		95
SPU2501	Sx	EK	304		272		
SPU3401	Lw	EK	333	68			
SPU3501	Sx	BV	620		103		

Table 4. Orchard Composition Activities by Project

Project	Species	SPZ	Orchard	Pollen Collected (litres, dry)	Trees Pollinated
SPU0401	Sx	NE	305	4	
SPU0502	Sx	NE	306	4	
SPU0701	Pli	NE	307	5	878
SPU1302	Lw	NE	332	1.5	703
SPU1401	Sx	PG	209	2	
SPU1501	Pw	KQ	335	1	1516
SPU3501	Sx	BV	620	2	333

Table 5. Pollen Management Activities by Project

In addition to collecting and processing pollen, funding also permitted us to purchase blister rust tolerant white pine pollen from the Inland Empire Tree Improvement Co-operative.

Pest management activities funded included:

- use of Safer's Soap sprays to control galling adelgids,
- removal of weevil infested spruce leaders to reduce weevil populations,
- removal of pine pitch moths damaging orchard tree stems,
- baiting for control of rodents feeding on tree roots,
- sanitation picking of cones in orchards with non-collectible crops to reduce pest populations,
- pesticide sprays to control *leptoglossus*, and
- pesticide sprays to control spittle bugs and needle sheath miners in lodgepole pine orchards.

Other management activities to boost productivity and gain included foliar analysis to determine the nutrient status of orchard trees.

The OTIP funding was instrumental in increasing both the quantity and quality of seed produced. At Kalamalka in 2000, over 88 kg of western larch, lodgepole pine, western white pine and interior spruce seed was produced, equivalent to over 8 million seedlings. Kalamalka seed is being used over large areas of the interior of the province.

Figure 16. Applying pollen to the spruce high-density orchard (SPU3501)

2.3.6 North Island Seed Orchards

Gord Morrow

SPU0103: Orchard #149 and Orchard #162 Ramet Replacements

This project saw the establishment of 451 ramets from 10 high gain Coastal Douglas-fir (Fdc) clones in two orchards at the Bowser site. The new clones represent the best orchard material available for the Maritime Zone from the Ministry of Forests' Fdc breeding program. Over the last ten years planting locations within these orchard had become available through losses attributed to graft incompatibility. Establishment of the new material restores the numbers of ramets in both orchard to their designed levels and improves their genetic gain for both stem volume and radial density. Improvements in the potential genetic worth of the orchards' seedlots are summarised in the following table:

	Genetic Worth							
Orchard	Ramets		Volume			Density		
	New	Total	Old	New	Var.	Old	New	Var.
149	258	1007	9.3	11.2	-0.7	-0.9	-0.7	0.2
162	193	1946	14.1	14.6	-1.3	-1.4	-1.3	0.1

Table 6. Genetic worth in orchards 149 & 162

SPU0105 FDC Orchard #149 Crop Initiation.

469 ramets of Orchard #149 were exposed to reproductive buds induction techniques to increase the size and quality of the potential year 2001 crop. Treatment of ramets with stem girdling combined with stem injections of Gibberellic Acid ($GA_{4/7}$). Stem girdles consisted of double semi-circumferential knife cuts below the crown. Treatments have combined with a favourable cone induction spring in 2000 to produce the orchard's first potentially large production crop. The potential crop for 2001 is currently estimated to be in excess of 375 hectoliters. This crop, if fully realised, will help relieve the current shortage of A class seed in the low elevation Maritime zone.

2.3.7 PRT Armstrong – Grandview Seed Orchards

Hilary Graham

FRBC-OTIP activities in three Lodgepole pine orchards

The PRT Armstrong – Grandview Seed Orchard site includes three Lodgepole pine orchards which have received FRBC funding for activities to increase the yield and genetic gain of seed produced. Orchards #308 and #311 provide seed for the Thompson-Okanagan (TO) low elevation seed planning unit (SPU), and orchard #313 provides seed for the Nelson (NE) low elevation SPU. Orchard #308 is a provenance-based orchard with an estimated genetic gain of 6%. Orchards #311 and #313 are 1.5 generation orchards each with an estimated genetic gain of about 16%.

In the year 2000, three major activities were conducted with FRBC funding in orchards #311 and #313 and two in orchard #308. These activities were phenological surveys (all Pli orchards), pollen monitoring (all Pli orchards), and supplemental mass pollination (SMP) in orchards #311 and #313 only. Each activity is described below and is referenced by the project number.

Phenological surveys: (SPUs 0703 and 1005)

Reproductive phenological surveys were performed in all Lodgepole pine orchards to determine the timing and order of seed-cone receptivity among seed orchard's clones inside the orchard pollen flights. The information generated was used to guide pollen management activities, including SMP, to increase seed set.

In addition to the timing of pollen shed, the amount of pollen produced per tree was assessed and recorded. The data will be used to calculate the genetic worth of seed produced in the orchards in 2001.

Finally, the data collected from the surveys was condensed to provide a clone by clone summary of pollen flight and seed-cone receptivity in each orchard.

Pollen monitoring: (SPUs 0702 and 1001)

Pollen monitoring was performed concurrently with the phenological surveys. Just prior to pollen flight, 1-day pollen monitors were installed in all three orchards, at the orchard boundaries, and in the Lodgepole pine holding area on site. At the start of pollen flight, all monitors were equipped with a glass microscope slide covered with a film of Vaseline. The slides collected flying pollen and were replaced daily with a clean slide.

For the duration of 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, counts of pollen grains were done on the slides collected and the amount of pollen was determined for each monitor. This data provides information on the amount of pollen within each orchard, going between the orchards, and from the holding area.

Pollen monitoring indicated that there was a substantial pollen supply in orchard #308 and therefore SMP was not conducted in this orchard. However, both orchards #311 and #313 did require SMP as the natural pollen cloud was too small to provide adequate pollination.

Supplemental mass pollination (SMP): (SPU's 0704 and 1002)

The last major activity to be performed was pollen collection and SMP. Young pine orchards typically suffer from a lack of pollen in the first few years of production. In both the Pli Thompson-Okanagan low and the Nelson low seed planning units there is a large deficit in the amount of seed produced to meet current needs. Therefore, to increase seed set and production in these young orchards, we conducted SMP in both orchards and collected pollen to use for SMP in 2001. It is expected that SMP will greatly improve seed set by providing pollen in the absence of an adequate natural pollen cloud.

During the pollen flight period in 2000 pollen was collected from orchards #311 and #313. Whole pollen buds were manually collected by clone and brought into the laboratory for drying and processing.

When processing was complete, pollen was tested for moisture content (6-8% target) and put into freezer storage when it achieved target levels. During the storage phase and just prior to reapplication the pollen will be tested for germination. More than14 litres of pollen were collected and processed for the SMP efforts in 2001.

Lastly, orchards #311 and #313 were pollinated (SMP) in 2000 with stored pollen from a 1999 collection (previous FRBC-OTIP project). Surveys were conducted prior to each pollination to identify and tag the trees with receptive seed-cones to allow the pollen applicator crew to move quickly from tree to tree; applying the pollen only to receptive seed-cones. Three applications of pollen were made to trees in each orchard during the receptive period.

With the early confirmation of new FRBC funding and an inventory of pollen from 1999-2000 FRBC-OTIP work, projects SPU0702 and SPU1001 were completed as planned. Employees were trained to collect, process, and apply pollen as well as conduct phenological surveys. These skills will be used again in 2001 and future years to ensure continued improvements to seed supply and quality.

The activities conducted in 2000/01 under FRBC-OTIP ultimately move us closer towards our goal of increasing the amount and quality of A-class seed for the Pli NE low and Pli TO low seed planning units.

2.3.8 Prince George Tree Improvement Station (PGTIS)

Carole Fleetham

Activities to increase the quantity and quality of lodgepole pine seed.

Three projects (SPU1203, 1702 and 1802) were conducted at PGTIS in 2000-2001. Emphasis was placed on the application of high gain stored pollen to improve the genetic worth of the seedlots from lodgepole pine seed orchards 220, 223 and 228.

Pollen was also collected from trees on site and in clone banks at Red Rock for application in future years. Approximately 51 litres of pollen with an average breeding value of 11% have been stored.

A significant crop of cones was harvested from the three orchards. Orchards 220, 233 and 228 produced 51.3 hectolitres or 20.5 kilograms of seed. These seedlots have an average genetic worth of 6%.

Some crop induction work was completed in the summer of 2000. Crown pruning to promote branchiness and flower production was also carried out.

Trees in all orchards were sprayed with Nova and/or Topas to control lophodermella needle cast disease and western gall rust. Root collar weevil habitat was controlled by reducing vegetation at the base of the trees with the application of Vision herbicide. Monitoring for both disease and insects continues.

Determination of the efficacy and contribution of SMP on seed produced in three lodgepole pine seed orchards.

In 1999, under OTIP 371, supplemental mass pollination techniques were used to apply pollen with unique DNA markers to lodgepole pine orchards 307, 311 and 228 in order to determine the effectiveness of SMP. A minimum of two branches from each of 6 clones (orchard 228) or 20 clones (orchards 307 and 311) received each of the following three treatments:

- Wind pollen and SMP pollen
- SMP pollen only
- Wind pollen only

Under SPU0708, cones were collected from each of the three treatments in the fall of 2000 and the average number of filled seed per cone per treatment determined. One hundred filled seed from each of the treatments were randomly selected and sent to B.C. Research Inc. to determine the efficacy of SMP procedures used in 1999. These results will be available mid-April 2001.

In spring, 2001 this trial was repeated in orchard 228. The same unique DNA pollen was applied.

2.3.9 Riverside Seed Orchards

George Nicholson

Project 1601 - Orchard Quality & Quantity Boost in Orchard 310

Pollen monitors were constructed and pollen data collected during pollen flight between May 18 to May 25th.

Phenology data was collected and no protandry was observed.

A small misting trial to enhance humidity during pollen flight was conducted this year.

New grafts received were repotted and kept in a holding bed to increase the quality of the graft prior to planting in the orchard.

There was no SMP carried out in the orchard this spring.

Project 1602 - Pest Management in Orchard 310

An insect monitoring and treatment regime was carried out in orchard 310 to protect ramet health and seed quality. Control treatments for Leptoglossus were applied four times from May to September to reduce seed loss by feeding insects.

Hand removal of Sequoia pitch moth larvae was done twice to control damage to ramets.

Western gall rust was removed from ramets in early spring to reduce infection within the orchard.

Two applications of fungicide were applied to control needle cast caused from above normal rainfall in spring and early summer.

Project 2801- Orchard Quality & Quantity in Orchard 303

Scion material was collected to produce 500 grafts that were completed at Skimikin nursery and will be planted in the orchard in spring of 2002. These grafts all have high breeding values and will replace ramets that have been rogued.

A total of 180 ramets with negative or low breeding values were rogued from the orchard.

No controlled pollination or supplemental mass pollination was carried out this year due to very low flowering in this orchard.

Project 2802 - Pest Management in Orchard 303

An insect monitoring and treatment regime was carried out in orchard 303 to protect ramet health and seed quality. A treatment was carried out in early March to control Adelgids.

Control treatments were also carried out for cone and seed insects during the year.

2.3.10 Skimikin SeedOrchards

Keith Cox

Work was funded in eight of the seed orchards at Skimikin in 2000.

Projects SPU0404 & SPU0501:

The West Kootenay spruce orchards (301 and 302) were surveyed for cones, insects, and disease. Conelet samples were taken to monitor for the spruce cone maggot. The replacement grafts in the holding area were maintained by pruning, root pruning, weeding, irrigating, fertilizing, and staking.

Project SPU1405:

The Central Plateau spruce seed orchards (205 and 206) were also monitored for cones, insects, and disease. A spray trial was done in orchard 206 to test a predictive model being developed to forecast damage from inland spruce cone rust (*Chrysomyxa pirolata*). To advance this work 75 trees were injected in orchard 206 to provide cones for a larger spray trial in 2001.

Project SPU1503:

A cone induction trial was done in the white pine orchard (609) in the spring to test the timing of the application of the flowering hormone gibberillic acid (GA). This orchard was sprayed several times over the season to protect to crop from the conifer seed bug (*Leptoglossus occidentalis*). The white pine orchard had the only cones in the area and the seed bugs kept coming in and building up in numbers after each spray. A total of 20 hectolitres of cones were harvested in August. A conelet survey was done, indicating a medium sized crop for 2001. White pine pollen was vacuumed and handpicked to provide pollen for SMP work at the younger orchard (335) at Bailey Road.

Eighty-two litres of buds were collected.

Project SPU3502:

In the Bulkley Valley spruce orchards (207, 208, and 229), the trees with the highest breeding values were identified. One hundred ninety-five trees were injected with GA in May and drought stressed until the end of June to induce a crop for 2001. Part of the cone rust spray trial was done in orchard 208. Two sacks of cones were sanitation picked and sent to Jon Sweeney in New Brunswick to further research on the spruce cone maggot (*Strobylmia anthracina*), a Canada wide pest of spruce cones. In the fall, 299 trees were removed from orchards 207 and 208 based on 15 year progeny data.

Figure 17. Roguing orchard 208 - Skimikin

The trees were felled, skidded to the edge of the orchards, and eventually shipped to the Salmon River to be used for stream-bank restoration work.

The stumps were pulled out by a rubber-tired excavator and hauled away. The holes were roughly levelled in the fall and will need more work in the spring of 2001, after they have settled.

Foliar samples were taken in all the orchards in October to monitor nutrient levels and determine fertilizer prescriptions.

Figure 18. Stump removal at Skimikin - Orchard207

2.3.11 Saanich Seed Orchards

Dan Rudolph

Three projects were carried out at the Ministry of Forests' Saanich site this year. Two of these projects were extensions of previous proposals. All three proposals have been submitted for consideration to the OTIP review committee for 2001/2002.

SPU0804: Enhancing Seed Production from Rust Resistant White Pine.

Orchard #175 is one of three orchards providing white pine seed for coastal reforestation needs. Currently, there is insufficient production from these orchards to meet these needs. The amount of pollen available at the time of optimum receptivity can be a limiting factor to the amount of seed produced. This project involved: the supplemental mass pollination necessary to increase the amount of pollen available, the phenology surveys necessary to ensure applications were made at the proper time and the collection of the crop produced from the SMP treatments the previous year.

SPU1901: Graft Maintenance of Saanich Douglas-fir Holding Area.

Approximately 3,000 grafts from 122 clones have been established over the last four years in a holding bed on-site. The stock is to be the source of the genetic upgrading of orchard #120 that was rogued and thinned in 1999. Proper growing stock maintenance is critical in order to ensure that stock is of sufficient size and vigour to withstand transplant shock and thrive after outplanting. The objective of this project was to provide this necessary maintenance prior to orchard outplanting.

SPU1902: Cone Induction of Low Elevation Sub-Maritime Zone Douglas-fir.

Douglas-fir seed needs for the sub-maritime seed zone have changed over the last several years. Where previously the emphasis was on providing seed for elevations greater than 900 metres, the emphasis now is on providing seed for low and mid-elevation bands. Orchard #120, which used to provide high elevation seed for the sub-maritime seed zone, has been rogued of all parents originating from elevations greater than 900 metres. The rogued orchard can now provide seed for the 400 to 1100 metre elevation band; seed which better meets the current demand for this zone.

At the same time that the orchard was rogued, it was also thinned in order to provide space for orchard #181 so that now there are currently only about 25% of the previous number of orchard trees available for seed production. In order to maximize production from these remaining trees it was necessary to embark on a vigorous cone induction program.

Work Completed:

SPU0804:

Though the objective of this project was to increase seed set through the use of supplemental mass pollination, in order to achieve this goal it was necessary to do several other things as well:

- Female phenology was monitored to determine the time of peak receptivity.
- Male phenology was monitored to determine the time of optimum pollen maturity.
- Male buds were collected at the appropriate stage of development.
- The pollen was extracted and those lots needed for future SMP programs were processed for storage ensuring that moisture content levels for freezer storage were not exceeded.
- Pollen was re-applied at times of maximum female receptivity for each ramet. Applications were made every second day for the duration of receptivity and, because receptivity varied both according to flower position in the crown and between clones, ramets typically received multiple applications.
- The crop produced from this treatment in 1999 was harvested and sent to the Tree Seed Centre for extraction.

SPU1901:

While stock in the holding beds received the care intended in the proposal, a vandalism attack in the spring resulted in the complete or partial loss of approximately 800 ramets from 32 clones. There still remain over 2,000 ramets from 90 clones, however, and during the course of the growing season this stock was maintained by: rootstock and crown pruning, fertilization, irrigation, graft maintenance, identity maintenance, mulching and weed control.

SPU1902:

Approximately 100 trees received an induction treatment consisting of a combination of a double overlapping girdle and injection of $GA_{4/7}$ at the time of vegetative budburst. Treated trees were monitored for vigour throughout the growing season to ensure undue plant stress and/or mortality was minimised. Bud surveys were conducted early in 2001 to determine the efficacy of the treatment.

Final Results or End Product:

SPU0804:

All crop activities associated with the SMP program were completed. The cone harvest remains to be completed in late summer, 2001. The 1999 SMP treatment yielded a crop of 10.643 kilograms or approximately 650,000 seeds.

SPU1901:

All ramets not affected by vandalism were maintained through the growing season and show good growth and form. Non-vandalism related mortality was negligible.

SPU1902:

Eighty-five percent of the trees in the treated block are rated as either medium or heavy cone producers this year.

2.3.12 TimberWest Forest Corporation - Mt. Newton Seed Orchards

Tim Crowder

This report covers four projects carried out at the seed orchard in 2000/01. These were:

- SPU 0106 Upgrading of Douglas-fir orchard #134
- SPU0205 Upgrading and crop enhancement in Redcedar orchard #140
- SPU 0808 Upgrading White Pine orchard #403
- SPU 0901 Maintenance and management of *Abies amabilis* orchard #129

Total budgeted costs for these projects were $52,471 or approximately 0.5% of the funds directed to tree improvement by FRBC in 2000/2001.

TimberWest Forest Corp. operates exclusively on Vancouver Island and adjacent islands in Johnston Strait and currently owns 334,000 hectares of forest land with an annual harvest of 2.4 million cubic metres, and also owns harvesting rights on Crown lands of 1.2 million cubic metres

Mt. Newton seed orchards, owned and operated by TimberWest Forest Corp. is located in Central Saanich, 20 Km north of Victoria. The 40 hectare site has nine seed orchards and two cutting hedges. The facility is designed to provide all TimberWest seed needs and has a long term seed supply agreement with Weyerhauser Canada for Red and Yellow cedar and Western Hemlock and also sells surplus seed on the open market.

The emphasis of these projects is to increase the "genetic value" of the seed produced from several of the orchards on the site. This is in an effort to meet the Forest Genetics Council goal of doubling the genetic gain by 2007 of 75% of all planting stock used in BC. A number of different techniques are used to achieve this, the main one being to propagate by grafting or rooting, clones that have been identified by research to be superior to the clones within the current orchards. This was carried out in the Douglas-fir orchards with 500 trees planted and a further 1500 grafted and held as potted stock, 2550 redcedar trees were planting in holding beds and 320 White Pine Blister Rust Resistant grafts were made. While this technique can significantly increase the long term gains from seed orchards the trees need to grow for 7 to 10 years before full seed production can be achieved, and results from progeny tests only become available sporadically.

Figure 19. Successful grafts

It is important to establish newly identified clones in orchards as soon as possible in order to capture the gains that have been identified by the breeding and testing programs which take at least 15 years to complete.

A technique that can enhance the gain in the short term is the stimulation of larger than normal crops on existing clones within the orchard that have the highest genetic values. This will give an immediate increase in "genetic gain" but is limited to the best existing trees in the orchard and was carried out on 48 Redcedar and 500 *Abies amabilis* trees this year.

In order to ensure high seed yields within the cones pollen is collected, extracted and re-applied to the open flowers. 1.5 litres of red cedar and 5.0 litres of *Abies amabilis* pollen was collected, processed and re-applied this year.

A small amount of controlled pollination seed was produced in the Redcedar to start a high gain rooted cutting hedge.

In order to ensure that the last remaining Pacific Silver Fir orchard remains intact some FRBC funds were used to maintain orchard #129 so that it will be available for on-going trials into the orchard management of this species that currently ranks ninth in the 43 programs funded.

2.3.13 Vernon Seed Orchard Company
Tim Lee

Vernon Seed Orchard Company (VSOC) located in Vernon, B.C., is a Joint Venture Company that is the seed production facility of four forest companies operating in the north central parts of British Columbia. Along with the company needs, and the Ministry of Forest 25% share, the entire seed requirement for each Seed Planning Zone is part of each orchards planning. With the significant combined seedling requirements for the company's needs, VSOC was formed to reduce the cost exposure/economy of scale for one company going alone. The partners are committed to the next step, the deployment of this proven genetic material to the B.C. landscape.

VSOC manages eight 1.5-generation orchards for the north central interior of British Columbia. There are two White Spruce, three Lodgepole Pine, and three Douglas-fir orchards for seven Seed Planning Zones. The genetic gain of seed produced from the orchards will range from around the 10% for the Pine and will rise to around 20% for the Spruce and the Douglas-fir. This production supports the Forest Genetic Council position to increase gain and "Class-A" Seed availability by the year 2007.

Since the site began development in 1989, there has been a flurry of activity to plant and now push for production from each orchard at the earliest age possible. Initially the demand for our orchards is always far in excess of what can be supplied but through management techniques that promote earliest production, the shortage can be limited.

In the last few years OTIP funding has aided VSOC to directly correct orchard problems, as well as fund the production of "CLASS A" Seed for B.C. crown lands. This year we re-planted a number of orchard positions that will help VSOC attain the 100% establishment level next year. Young orchard stock requires individual attention during its first production years in order to attain optimum seed yields. Mature orchards on the other hand don't require as intense pollen work, as the natural pollen flight usually takes over during the orchards normal production cycle.

Demand for specialty seed crops comes to the forefront in mature orchards as breeders and managers seek to supply the needs of a certain Seed Planning Unit. Through OTIP funding, Control Cross seedlot production is a common means of supplying this specialty crop. One such specialty crop is the weevil resistant seed for re-planted blocks that are hit each year and suffer huge setbacks.

Orchard health is a factor that requires constant monitoring and action if problems arise with insects, disease or nutrient deficiencies. Through annual work with professionals and laboratories for plant health, orchards maintain a high production potential for the following year.

As an orchards mature the family representation may change as further information is processed with regards to growth potential and natural attributes that our crown lands require for good growth during its rotation. As changes come forward, orchards require roguing to remove gain losses in poor families, and allowing new to be added that bring further improvements to the orchards genetic gains in the future.

Operational Tree Improvement Program has promoted many issues in orchard management that have improved the way we do business. It has allowed orchard personnel to challenge orchards potential to not only increase seed availability but to also improve the genetic gain achieved in that production. Some of the project items that are performed each year in orchards with OTIP funding are a great benefit to Seed supply in our programs.

Our thanks also goes to all those who work in the back ground, that with their continued support much is accomplished in British Columbia's Seed supply.

2.3.14 Saanich Forestry Centre
Annette Van Niejenhuis

Western Forest Products (WFP) owns seed orchards licensed by the Ministry of Forests to produce high quality seed and stecklings for coastal British Columbia. The orchards are located at the Saanich Forestry Centre (SFC) and the Lost Lake Field Operation on south Vancouver Island. The primary objective of the management of these orchards is to provide seed to Company Operations from the North Coast to the south end of Vancouver Island. Of the 43 ranked Seed Planning Units, 15 are included in tenures managed by WFP. The Company manages seed and hedge orchards to meet needs in seven of the ranked Seed Planning Units.

Crops were managed and harvested from six orchards in 2000. Two western redcedar orchards, two western hemlock orchards, and two coastal Douglas-fir orchards yielded seed for more than 8.8 million plantables. Other mature licensed orchards were not managed due to large seed inventories on hand from past crops.

Figure 20. Harvesting Hw pollen flowers from top breeding value trees at Lost Lake

To improve the quality of seed obtained from the mature low-elevation western hemlock orchard at Lost Lake, low breeding value individuals were removed. Supplemental mass pollination (SPU0304); together with an excellent cone set and good harvest management resulted in a bumper crop. This is WFP's first significant high-gain crop in hemlock, with average volume gain projected to exceed nine per cent at rotation. Seed from this crop is suitable for Maritime sites from South Vancouver Island north to latitudes of 53º 30', and to elevations of 600 m. A small custom seedlot was developed in the high elevation hemlock orchard at Lost Lake for Maritime sites up to 725 m elevations.

The coastal Douglas-fir orchards yielded average crops with a projected average gain in volume of 11% at rotation. Seed from these seedlots are suitable for Maritime and Georgia Lowlands sites north to 52º 18', and to elevations of 700m. The bulk of the crop resulted from supplemental mass pollination (SPU0107).

Yields were extremely low in both western redcedar orchard crops in 2000; seeds per cone were in the order of 25% of historical average yields in orchard 128. Results of the supplemental mass pollination work completed in 1999 indicate that a significant improvement in seed quality is realized by this effort.

Figure 21. Harvesting Fdc from the lift

At present, intensive pollen management strategies are being implemented in Cw 128 for a significant crop of highly out-crossed seed for 2001. If the out-crossing is proven in DNA analysis, the crop should produce stock showing a 5% gain in volume at rotation. (SPU0206).

Intense planting activity occurred at SFC in the fall of 2000. Four new orchards were established and the bulk of a fifth orchard was planted:

- The new western redcedar low elevation orchard contains 509 trees. The estimated average gain in volume at rotation from seed produced in this orchard is 8 per cent. Seed from this orchard can be used in all Vancouver Island tenures and all Mainland tenures south of 52º 50', to elevations of

600 m. This orchard was designed to test alternate methods of pollen management for increased out-crossing.

- All low elevation western redcedar in test was grafted at SFC in early 2000 (OTIP408 – 99/00). This material will be used to replace low-gain individuals with high-gain individuals when test results become available. The purpose of this project is to realize the gains from the progeny-testing program at the earliest possible date.
- The new western redcedar Queen Charlotte Islands orchard contains 160 trees. The design of the orchard facilitates early roguing with four trees planted near each final orchard position. Only the best as proven by progeny results will remain post-roguing. Seed from this orchard can be used in all Maritime zones from 49º 46' north to the Alaska Panhandle to elevations of 650m.
- The new high elevation western hemlock orchard contains 275 trees. All trees in the orchard are in test, and additional trees in test may be added to the orchard to provide a significant quality boost in seed produced from the post-rogue orchard. Seed from this orchard is appropriate for all coastal maritime lands south of 53º 31' for the elevation band from 400m to 1000m.
- The new western hemlock Queen Charlotte Islands orchard contains 116 trees. All are in progeny tests, and roguing based on test results will improve the quality of the seed. The orchard provides seed for Queen Charlotte Islands tenures to elevation of 535 m, and is currently in test on the North Coast.
- The Sitka spruce weevil resistant orchard now contains 330 trees, up from about 100 trees at the beginning of 2000. Weevil-resistance of this orchard is currently (from early test results) estimated to average six, or 60 trees out of 1000 planted with this stock on average would be attacked in a given year in a high weevil hazard area. Seed from this orchard is appropriate for all coastal maritime tenures north to 53º 42' and to elevations of 400m, with testing in place to extend the elevation range. Pest control and fertilization applications were applied provide branch structure sooner (SPU0601).

Repair and maintenance of the vandalized western hemlock orchard continued at SFC.

Figure 22. Some successful repairs in Hw 170

New grafts were made of all the stock in the orchard to replace the damaged trees in the event that repair efforts fail. Surplus copies of some clones were made available by the Cowichan Lake Research Station, and replaced a number of destroyed ramets. Funding for this work was received in part from Forest Renewal BC (SPU0304).

WFP personnel implemented the Sitka spruce breeding program at field trial locations. This project (SPU0602), yielded control-cross seed for further testing of weevil resistance, and significant amounts of surplus seed for operational reforestation purposes. WFP's share of the surplus control-cross seed should deliver more than 80,000 highly weevil-resistant Sitka spruce plantables for the 2003 spring planting program.

Results of more than a decade of yellow cypress field trials are paying back with the establishment of high-gain hedge orchards at SFC. As more data becomes available, new selections will be added to the orchards. Rejuvenation of selected hedges continued (SPU1103). Problems at the nursery resulted in a crop failure; this rejuvenation will be repeated in 2001. Effort will be made to rejuvenate and bulk-up all clones with projected gain at rotation exceeding 12%.

More than 11,000 ramets representing some 200 tested clones with projected gain at rotation greater than 5% are located in hedge orchards at SFC. As these are young hedges, production per hedge is very low. In order to maximize their production, shoot tips were pinched in mid-summer, thereby encouraging lateral growth. In addition, fertilizer applications and pest control improved the productivity of these high-gain hedges. The treatments resulted in increased delivery of gain to operational reforestation programs (SPU1104).

2.3.15 Yellow-Cedar Seed Orchard Cone Induction and Seed Production

Don Piggott

PROJECT SPU 1105 DESCRIPTION/OVERVIEW

This project involves the induction of cones using GA_3 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 Weyerhaeuser Company's Seed Orchard #137, located at two sites, and the MOF Cowichan Lake Research Station (CLRS) clone bank through GA_3 cone induction.
- 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 to be obtained.

PROGRESS REPORT

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

In April 1998 the Rheinhart 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 GA_3 in 1998 were also chosen. The 21 clones chosen were represented at Rheinhart Lake, at the original orchard site at Yellow Point, and in the clone banks at Mesachie Lake.

Weather stations were set up to record temperature and rainfall at Yellow Point and at Rheinhart Lake. Weather data was already being collected at Mesachie lake.

GA_3 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 Rheinhart Lake site. Sixteen trees were treated three times, four were treated twice, and ten were treated once.

In order to spray the trees quickly and efficiently, a 12 volt pump was mounted on a plastic tote bin. A cigarette lighter adapter plugged into the truck supplied the power. One hundred and twenty-five feet of garden hose and a simple spray nozzle were used for the application.

In August visual inspections indicated no phyto-toxicity and all trees appeared to be healthy. 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 general a significant response to the GA_3 applications was observed at both Mesachie Lake and Rheinhart 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 Rheinhart Lake on the wildings. All of the wildings treated developed reproductive buds while untreated trees had few or no male or female buds.

In 1999 access to the Rheinhart Lake site was not possible until June 3 and at that time there was still more than one metre of snow. Total snow accumulations that winter were in excess of nine metres. Significant branch damage of the many larger ramets was due to the unusually heavy snow press. Damage was sometimes substantial on naturals and planted trees of other species adjacent to the site.

In June and July of 1999 trees of the same 20 clones that were treated with GA_3 at Rheinhart Lake, Yellow Point, and Mesachie Lake were assessed for number of cones. Numbers of cones were counted on 3 branches per tree (60 cm per branch). Cones initiated prior to the induction treatments were also tabulated.

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 . Preliminary observations indicated a much higher filled seed per cone content at Rheinhart Lake than at Yellow Point. Significantly more cones were induced at Yellow Point seed orchard than at either of the other two.

In June and July of 2000 the same twenty-one clones that were treated at the three sites in 1998 were again sprayed with GA_3 at the Rheinhart Lake and Mesachie Lake sites. The Yellow Point site had been sold.

In the fall of 2000 the treated ramets of the twenty-one clones were assessed for both male and female flowers. The response was less significant than the 1998 application, indicating a need for more studies on timing, and rates of application.

The cones initiated by the 1998 treatment were harvested , the seed extracted, and cleaned, and are currently being stratified for germination testing (OTIP 423).

Technical Support Projects:

2.3.16 Douglas-Fir Cone Gall Midge Pheromone Monitoring and "Attract-and-Kill" Control.

Robb Bennett

Background:

Douglas-fir cone gall midge (DFCGM), *Contarinia oregonensis*, is the major pest of Douglas-fir seed orchards in the Pacific Northwest, including BC. Larvae gall cones scales, reducing seedset and extractability. Monitoring is currently by dissection of conelets and microscopic examination for eggs, which is time consuming. The only control method is spraying broad-spectrum insecticides, with the attendant problems of worker and environmental hazard. A recently characterised sex pheromone might be used as a trap lure to develop a monitoring program, which is more effective and efficient than the current one. It can also be used in a novel control technique known as "attract-and-kill", in which the pheromone is formulated in a paste with a tiny amount of insecticide. Droplets are placed in seed orchard trees. Adult male gall midges are attracted to the droplets; when they contact the droplets they are killed. If enough males are killed, mating is reduced and no fertile eggs are laid.

1. Monitoring of DFCGM(SPU0102):

Methods:

Twenty-seven operational monitoring blocks in coastal Douglas-fir seed orchards in Washington and Oregon were established between 20 and 30 March 2000. In each block, 20 DFCGM pheromone baited traps were hung from 20 trees at heights of 1.5-2 m. Numbers of male DFCGM captured were recorded from 17-28 April, after completion of the Douglas-fir pollination period. At this time, 50 conelets were randomly collected from each block and dissected to determine the number of DFCGM egg infested scales per conelet. At each block, an estimate of percentage crop trees was made by counting all trees with at least 5 conelets each. From 30 July to 3 August, 50 mature cones were collected from each block that had remained insecticide free during the growing season. These cones were dissected to determine the number of DFCGM gall infested scales per half cone.

From these data, relationships between DFCGM adult populations, egg infestation of conelets, cone damage, and potential crop size were determined through regression analysis.

Results:

Crop sizes varied widely between sites with percentage of crop trees ranging from 8-90%. The majority of orchard blocks (18 of 27) had $\geq$ 50% crop trees. There was a highly significant relationship between mean numbers of egg infested scales and galled scales; both showed highly significant relationships with mean numbers of trapped DFCGM males. These relationships were much stronger when percentage of crop trees within blocks were incorporated into the analysis. In seed orchard blocks with $\geq$ 50% crop trees, egg infested and galled scales were strongly related to male trap catches without multiplying numbers of egg infested or galled scales by the percentage of crop trees.

The results provide the foundation for a highly accurate and successful DFCGM monitoring program using sex pheromone baited insect traps. The 2001 field season will provide the final data needed to consolidate the program for user delivery.

2. "Attract-and-kill" For Control Of DFCGM

Methods:

Tiny amounts of DFCGM "Attract-and-kill" formulation (DFCGM pheromone impregnated pyrethroid paste) were applied to trunks and branches of all trees in 5 selected blocks in the Saanich and Bowser Douglas-fir seed orchards in late March 2000. Trees in adjacent blocks were left untreated as controls. Pheromone baited insect traps were placed in treatment and control trees to assess numbers of male DFCGM in each block. Traps catches and egg infested scale counts (50 conelet samples) were assessed in mid-April after completion of DFCGM adult flight and the Douglas-fir pollination period. Cone crops were very low at both Saanich and Bowser in 2000 and there were essentially no cones left to evaluate gall damage at harvest time.

Results:

Results were variable but on at least one site there was a highly significant reduction of DFCGM numbers in the treatment block. Essentially all male midges were killed in treatment block (treatment traps accounted for 0.8% of total trap captures) although control traps averaged over 26.3 male DFCGM each (99.2% of trap captures). However, egg counts in the "attract-and-kill" areas were not lower than in control areas. These may have been unfertilized eggs ("attract-and-kill" was successful); or they may be from females which originated and mated outside the orchards, then flew in to lay fertilized eggs (outside contamination); or it may be due to the pheromone paste and traps being applied to the lower portions of the trees, while cones were on the upper portions.

Based on these results, whole site treatments using the 'attract-and-kill' formulation are planned for the 2001 field season; droplets and traps will be situated in the cone-bearing region of the trees, and damage, not just eggs, will be assessed during the season.

2.3.17 Douglas-Fir Seedlot Rating using Chloroplast DNA Markers.

Michael Stoehr and John Nelson

Background:

The accuracy and precision of genetic worth (GW) calculations are becoming more important as genetic gains are incorporated into allowable cut calculations and seed price determinations. Currently, the seed lot rating protocol requires input variables determined/estimated by seed orchard managers as outlined in the protocol. Generally, information on clonal gamete contribution, pollen monitoring, phenology of orchard receptivity, and the start date of orchard pollen shed is included in the GW calculations. The pollen monitoring data supply information on pollen contamination, based on the assumption that background pollen sheds first and the within-orchard monitor captures a portion of this background pollen. Based on this "efficiency" of the inside-orchard monitors to capture background pollen prior to orchard receptivity, a level of contamination is calculated for each seed lot. The origin of the paternal genetic material is an integral part of genetic worth (GW) determination.

Recently, chloroplast DNA (cpDNA) markers have been employed to elucidate paternity in Douglas-fir. However more markers are needed to increase our distinguishing power in orchards with background trees that are similar genetically to orchard trees. With an additional four to five markers, our distinguishing power may be above 90%. Once the markers are developed, the 1999 production of orchard 149 will be genotyped as will 100 surrounding trees. This information will be used in GW calculation.

Activity (SPU0108):

For the development of more cpDNA markers, chloroplast DNA was extracted from several Douglas-fir trees and subsequently digested with the restriction enzyme Sau3a. Digested cpDNA was inserted into a pUC18 vector roughly 100 inserts of 1kb will be randomly sequenced. This will cover about 80% of the chloroplast genome. These sequences will then be compared to published plant chloroplast genomes and screened for mutational hotspots. These hotspots are likely candidates to exhibit intraspecific variation and therefore the potential as additional markers.

Another approach to develop more markers is the further investigation of the polymorphic region that amplifies with the primer pair Tf/Tr. In sequence comparisons with existing Douglas-fir cpDNA sequences obtained from GENBANK, there are indications that several regions up- and down-stream from the locus that is amplified by Tf/Tr will be polymorphic. If this is the case, more markers will be developed after sequencing.

2.3.18 Refinement of Western Redcedar Breeding Zones and Seed Transfer Guidelines Through Nursery Population Screening for Keithia Leaf Blight Resistance

Harry Kope

Keithia leaf blight is caused by a fungal foliar disease that attacks the leaves and stems of all age classes of western redcedar trees in the coastal and interior ranges of the species in the Pacific Northwest. The fungus is strongly regulated to coincide with host phenology and climatic conditions. When Keithia leaf blight reaches epidemic proportions, western red cedar seedlings may be killed during its first growing season. As well, Keithia leaf blight may be a pioneering fungal pathogen that induces stress on western red cedar allowing a further succession of disease causing organisms.

The objective of this study (SPU0202) was to survey a broad base of coastal populations of western red cedar seed, representing different elevation and moisture transects, for Keithia leaf blight resistance and to recommend refinement of existing seed transfer guidelines and breeding zones.

During 1999, seed from 28 populations with five open-pollinated families per population representing various site associations within the coastal wet maritime and the submaritime subzones, for a total of 140 families, were sown and thinned. Disease inoculum was placed among the seedlings to artificially inoculate the seedlings/cuttings. The seedlings/cuttings are being grown under operational greenhouse conditions at MoF Extensioin Services nursery. A single branch from each seedling was assessed for disease severity using colour image analysis.

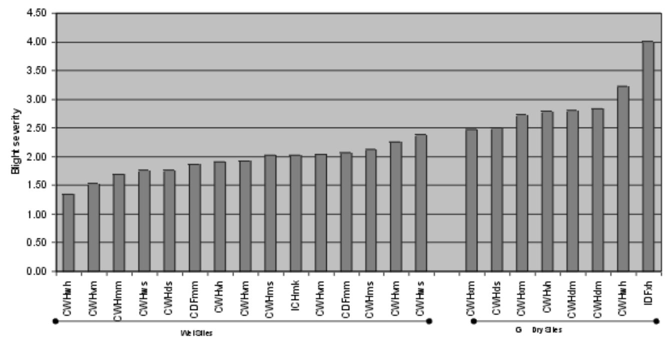


Figure 23. Keithia leaf blight severity (%) occurring on seedlings of coastal populations of Yc.

Differences in western redcedar populations were noted with respect to blight severity. The results had populations that originated from drier biogeoclimatic zones, group among the higher blight severity values. And it followed that the populations that originated from the wetter biogeoclimatic zones had lower blight severity values (Fig. 1). The variation in severity of the endemic foliar fungal blight on different populations of western red cedar corroborates a similar earlier finding, and it appears to make an exception to the generalist adaptation strategy.

2.3.19 Development of Vegetative Propagation Techniques for Western Redcedar.

Bevin Wigmore and John Russell

Background:

Controlled crossing of elite families of western redcedar could eliminate selfing in the orchards, but it is an expensive process. Bulking-up of control-crossed seed through rooted cuttings could mitigate the costs. However, protocols for vegetative propagation of western redcedar are lacking.

Objective:

The objective of this project (SPU0204) is to develop techniques for the production of stock plants and rooted cuttings of western redcedar.

Figure 24. One of more than 8500 Cw grafts

Progress to Date:

This is the second year of a three year project. There are currently over 700 one- and two-year-old stock plants, from five half-sib families, being tested for response to various cultural techniques and environments. Cuttings from many of these stock plants have just been set. Also, cuttings have recently been taken and set from a long-term serially-propagated hedge at the MoF Cowichan Lake Research Station. From the cuttings set last year, 1200 were lifted and will be planted as a field demonstration by TimberWest.

As this is a multi-year project, some experiments are still in progress, while data from others has not yet been analysed. Thus it is too early to report on recommended procedures for production of stock plants and cuttings. Western redcedar roots readily and it appears that it will be feasible to do on a large scale.

2.3.20 Pollen Collection, Storage and Viability Tests for Western Redcedar

Joe Webber

Six western redcedar (Cw) pollen lots were collected in 1999 using high humidity and low temperature drying and extraction techniques described in last year's OTIP summary report. Pollen was stored under three conditions: three moisture content ranges (10-12%, 15-20% and 25-30%), two storage temperatures (+5ºC and –25ºC), and two storage atmospheres (air and nitrogen). The lots were taken out of storage in February, 2000 and tested for respiration, %conductivity and %germination (SPU0207). The following tabulation summarizes the mean average pollen lot moisture content for each of the three ranges and their corresponding viability responses.

In Vitro Viability Assays for Cw Pollen Stored One Year

Mean of Six Lots

MC Class	Temp	Atm	%MC	RESP	%COND	%GERM
10-12%	+5C	Air	10.2	3.3	74.2	21.0
		Nit	10.2	4.3	76.6	21.0
	-25C	Air	10.2	5.4	59.1	36.2
		Nit	10.2	5.8	75.0	32.5
15-20%	+5C	Air	19.3	1.0	74.6	0.0
		Nit	19.3	0.7	74.2	0.0
	-25C	Air	19.3	8.0	62.4	38.3
		Nit	19.3	6.4	66.3	39.6
25-30%	+5C	Air	29.1	0.7	76.5	0.0
		Nit	29.1	1.0	72.0	0.0
	-25C	Air	29.1	6.7	67.3	38.0
		Nit	29.1	6.8	63.8	34.3

Table7. In Vitro Viability Assays

The viability response values are very low compared to other species. For good pollen, we normally expect respiration values greater than 20 μLO_2/mL/gdw, conductivity values to be lower than 30% and germination to be greater than 60%. These values for Cw pollen stored one year are poor. We tested a total of 72 pollen treatment combinations (6 pollen lots, 3%MC ranges, 2 temperatures, and 2 atmospheres). For testing its fertility (controlled crossing), it was not possible to put all 72 lots on ramet. Instead, we put the 12 storage conditions per pollen lot on each of 6 separate clones. We could only get 24 bags per ramet so we used 6 clones with three ramets each to complete this test.

Of the 432 crosses made (72 combinations per lot on each of six seed cone trees), only 216 yielded greater than 2-3 cones. Of these 216 crosses, we estimate about 72% of the cones that were pollinated aborted. Abortion was the most obvious result of this test. Abortion was particularly high for the higher moisture content pollen range stored at +5ºC.

The seed potential of Cw has an upper limit of about 16 based on the number of bract-scales present with functional ovules. However, about half of these ovules normally abort either from poor development, cold temperatures during pollination or insect damage (cone midge). Average seed potential or total seed per cone (TSPC) for Cw is, therefore, about 8. For this test, TSPC averaged about 6. Pollen quality also affected cone abortion, especially for the higher moisture content range stored at +5ºC. The following tabulated statement shows the mean (n=36) percent abortion, cone dry weight, TSPC, FSPC and the number of cones collected for each of the 12 treatment combinations.

In Vitro Viability Assays for Cw Pollen Stored One Year							
Mean Rate of % Abortion, Cone Dry weight and Seed Yields for Six Lots							
MC Class	Temp	Atm	% Abort	DryWt	TSPC	FSPC	N
10-12%	+5C	Air	64.2	0.039	7.1	0.27	23
		Nit	75.6	0.043	0.3	0.29	20
	-25C	Air	60.0	0.045	7.1	0.81	19
		Nit	70.9	0.041	6.9	0.66	21
15-20%	+5C	Air	77.4	0.034	6.3	0.01	16
		Nit	69.9	0.036	5.6	0.02	19
	-25C	Air	67.7	0.043	7.1	0.94	22
		Nit	67.9	0.040	6.6	0.87	18
25-30%	+5C	Air	92.2	0.030	4.1	0.00	6
		Nit	84.6	0.040	4.5	0.09	14
	-25C	Air	63.4	0.040	6.8	0.93	21
		Nit	68.7	0.040	7.1	0.98	17

Table 8. In Vitro Assays

The best storage condition appears to be the mid-moisture content range (15-20%) stored at –25CºC. Atmosphere did not appear to improve fertility potential at either storage temperatures.

For the cones that did mature, seed yields (expressed as filled seed per cone, FSPC) averaged less than 0.5. For pollen lots stored under our best conditions (mid moisture content range, -25ºC), average seed yields were doubled but still less than 1 FSPC.

Seed yields from our stored lots were compared to both non-stored pollen (fresh) and open pollinated (OP) seed yields. OP yields averaged 1.6 FSPC and fresh averaged 2.9; however, about half of the bags pollinated with fresh pollen did not produce any TSPC or FSPC. If we exclude those bags that produced poor cones, then our yields from fresh pollen rises to about 5 FSPC.

It is believed that the storage conditions used for this test maintained pollen quality over the one-year duration. The poor seed yields we observed from this storage trial likely reflect the quality of the pollen before going into storage. From the data collected for *in vitro* viability and fertility, it appears that when handling Cw pollen, its moisture content should not be reduced to below 15% moisture content. Unlike other conifer species, moisture contents up to 30 can be safely stored under freezer temperatures (-25ºC).

Studies to determine the best handling of Cw pollen after extraction and before long term storage continue.

2.3.21 Improving Genetic Quality and Operational Efficiency of Seed Production in Western Redcedar Seed Orchards.

Oldrich Hak

Western redcedar orchards have the potential to improve the genetic gain of seed through the reduction of selfing.

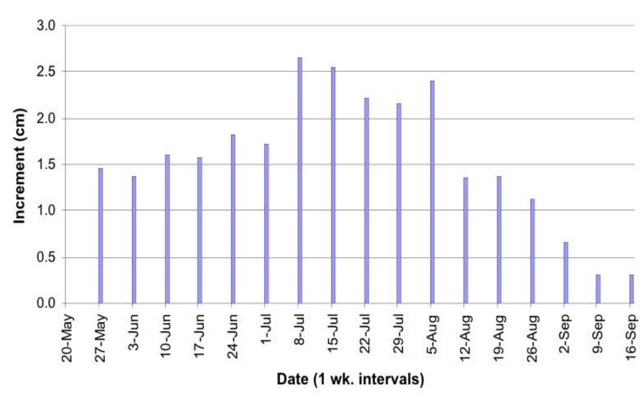


Figure 25. Trial 1. – Cw terminal shoot increments (yr.2000)

Calibrating the induction of female cones at specific positions in the crown, away from the male cones, and increasing the proportion of female to male cones in the crown is the objective of the project (SPU0208).

During the first year of the project, two trials have been established to calibrate cone induction treatments to specific positions in the crown, to a specific time period, to the rate of shoot extension and to heat sums at the site. Cone induction treatments have been completed and data for weekly shoot extension collected (Figure 25). Assessment of male and female cone production and data compilation were completed in March 2001. Data analyses will be done during the next phase of the overall project (i.e. 2001/02 fiscal year) and the results will be presented in a report.

2.3.22 Controlling Selfing Rates in Natural And Seed Orchard Populations of Western RedCedar

Kermit Ritland, Yousry El-Kassaby, Don Pigott and Annette Van Niejenhuis

The effectiveness of blowing and supplemental mass pollination (SMP) in reducing self-fertilization was evaluated in the Lost Lake western redcedar (Cw) seed orchard(SPU0209). Previous studies have demonstrated considerable selfing in Cw seed orchards. Because Cw is effectively monomorphic for isozyme markers, in preparation for this work we have developed a set of microsatellite primer-pairs for Cw; these can assay highly polymorphic (informative) marker loci. In Spring 1999, we left 1/4 of the orchard as an untreated control, blew pollen over 1/2 of the orchard, and applied SMP to the other 1/4 of the orchard. A total of 900 seed progeny were assayed from these three treatments, and evaluated for outcrossing rate.

The following estimates of outcrossing rate (t) were obtained from this experiment. Blowing resulted in t=0.69, SMP gave t=0.95, and control was t=0.76. Outcrossing rates were lowest on the bottom south of the tree (s=0.72), intermediate on the bottom north (s=0.81) and highest on the treetop (s=0.88). Thus, SMP is quite effective at reducing selfing; alternatively, seed from the top of the tree can be preferentially harvested for reducing selfing. Interestingly, blowing had essentially no effect in controlling selfing in this study. In general, redcedar seed produced by natural pollination in the seed orchard shows considerable selfing, roughly one-quarter of the seed are selfed. Given John Russell’s studies that demonstrate inbreeding depression in Cw, controlling selfing rates in Cw seed orchards is of paramount importance.

Other Cw orchard operators are encouraged to contact KR (email kermit.ritland@ubc.ca) regarding studies of self-pollination in their own systems.

2.3.23 Induction of Western Redcedar (Cw) in Natural Stands to Reduce Inbreeding and Improve Genetic Quality

Michael Peterson

Background:

No breeding program or Cw seed orchards for the submaritime and maritime areas above 700 m elevation exists in BC at present. This is despite a current annual demand of 1 million and 700,000 seedlings for SPU's: 27, Cw, SM all, 200 – 1000 m and 33, Cw, M, and high 600+ m. Natural crops in these SPU’s have been infrequent with selfing rates of up to 70% occurring, causing up to a 10% volume loss at rotation. In the absence of an elaborate tree breeding or seed orchard program, developing low-cost seed production areas could result in 10% volume gain for 1.7 million seedlings annually by minimising selfing.

Observations within another project, (OTIP 07-C) where GA_3 was applied to western redcedar trees near Port McNeill in 1999, indicated a significant response in the production of male and female strobili.

Project (SPU2701) Description/Overview:

Cone inductions are being carried out on Cw trees in plantations where surrounding natural stands provide pollen to produce a seed supply with minimal selfing to deliver a modest genetic gain with up to a 5-10% gain in volume growth at rotation. Inductions are being carried out in two seed planning units where no current breeding programs exists.

Objectives:

- To increase seed production on Cw trees using GA_3 in plantations within two seed planning units where seed orchards are not going to meet the seed needs.

- To minimise selfing by locating plantations of cone-bearing age where a good source of background (natural) unrelated pollen is available.

Activities:

- Candidate plantations for cone induction with good sources of background pollen were selected in each of the two SPU's: 27, Cw, SM all, in the Tsitika watershed and 33, Cw, M high at Rutherford Creek near Whistler where current annual seedling requirements are 1 and 0.7 million seedlings respectively.
- During the spring of 2000, approximately 50 Cw trees in each of the two plantations were marked, and size and age recorded. GA_3 was applied to each tree at both locations three times at a rate of 0.2 g of Activol per tree. In October, all treated trees were evaluated for treatment efficacy compared to untreated controls. The number of induced male and female strobili were recorded and a rating of low, medium, or heavy was applied to each tree. In most cases the rating was heavy, indicating a good response.
- Spring 2001(February - March); phenological observations are currently being made to monitor cone abortion rates and synchronicity with the natural stand pollen.
- Cones will be collected in the fall, 2001 from upper and lower crowns, and seed extracted and tested for germination and viability. Seed yield data per cone, within tree and between tree will be collected. Temperature, rainfall and pollen shed information are being collected at each site. Evaluation of selfing will be conducted through DNA analysis.

Final Results or End Product:

The project will develop a seed source that minimises selfing and aims for a 5-10% gain in volume at rotation over control lots, in areas where there is a high annual seedling demand (1.7 million) but no tree improvement activities are in place. Companies or agencies currently planting Cw in the Submaritime and Maritime seed planning zones at higher elevation will benefit directly from the increased production of seed from trees where selfing has been minimised.

2.3.24 Measurement of Operational Field Trials of Western Hemlock Cuttings.

Patti Brown

This project (SPU0301) compares the two year growth of hemlock cuttings and seedlings from two operational seedlots, produced by three different nurseries. The two year measurement results of this operational field trial were similar to another cutting vs. seedling research trial planted in 1998. In summary, there were no significant differences between the height or diameter growth of seedlings and cuttings. While the average height growth for the cuttings was 37.6 cm and the seedlings was 42.1cm, the differences were not significant due to strong interactions between nursery and stocktype, and seedlot and stocktype.

Site	Nursery	Seedlot	Stocktype	Ht2000	Dm2000	Ht Growth	Dm Growth
HG9	Arbutus	60376	Cutting	63.2	9.6	32.6	6.1
			Seedling	79.2	10.7	51	6.7
	PRTCR	60376	Cutting	79.1	11.2	48.5	6.9
			Seedling	79.2	10.7	52.2	6.9
	PRTCR	60377	Cutting	81	12	52.4	8.1
			Seedling	74.1	10.4	47	6.4
TS28	Arbutus	60376	Cutting	59.4	8.3	30.2	4.5
			Seedling	55.3	8.7	29.4	5
	PRTCR	60376	Cutting	47.6	7	20.5	3.4
			Seedling	65.2	10.1	42	6.4
	PRTCR	60377	Cutting	67.4	10	36.4	6.3
			Seedling	65.9	9.7	34.3	5.6
	Sylvan	60376	Cutting	70.5	10.4	39.9	6.7
			Seedling	61.6	10.1	37.6	6.5

Table 9. Two-year Height and diameter results

An analysis of variance was also run on the comments section. There were no significant differences between stock types, nurseries or sites for traits such as chlorosis, sweep, dead trees or poor status; however, there was a significant difference in the amount of forking at the nursery level with the number of forks being twice as common in the stock grown at PRTCR. This suggests forking is caused by a particular nursery culture regime.

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

Mathew Koshy

Objectives:

This project (SPU0303), will evaluate fiber morphometric traits of 59 selected families, which are part of the breeding population in British Columbia. Relative density, fiber length, fibril angle, and 12 other morphometric traits, ring width (RW), number of cells per ring (C/R), mean cell size (CS), mean double wall thickness (DW), mean DW/CS (R), early-wood percentage (EW%), transition wood percentage (TW %), late wood percentage (LW%), Morks' index (MI), DW/CS ratio in early wood (REW), DW/CS ratio in transition wood (RTW), and DW/CS ratio in late wood (RLW), will be assessed. Based on these morphometric traits, various other fibre and structural properties will also be derived. Image analysis techniques will be used for the measurement. This evaluation will help rank the parental families and study the genetic effects and genetic correlations of the traits. Such information will greatly help in selecting high yielding and high wood quality parent trees for inclusion in the seed orchards. It will also help develop appropriate breeding program for the species. Twenty-seven of the above families are already evaluated during the previous year. Current project is a continuation of the above work to complete the 59 families and to prepare the report.

Results:

Ring measurements on 29 families were completed during the reporting period. Measurements were carried out in 16-19 rings per tree (pith to bark) depending on the number of rings available for each tree at breast height. Family means for 15 rings from pith are included in the report. Morphometric traits in five rings (rings 2-6 from bark) in a disk sample are being measured during January-March 2001.

Ring width

Family means for ring width (mm), percent early wood, and percent late wood have been calculated in readiness for analysis. Ring width profile for 15 rings from pith for 10 families are given in Figure 26.

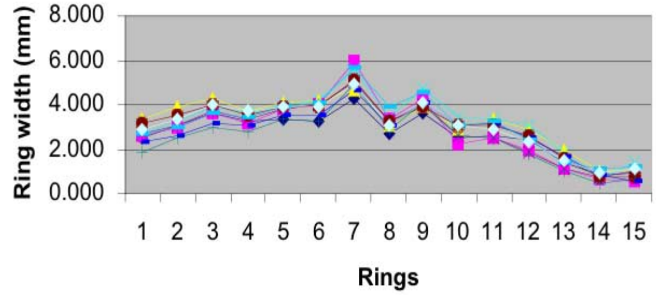


Figure 26. Ring width profile in 15 rings for 10 families

Ring density

An initial measurement of wood relative density is carried out using WinDendro. However, these measurements may not be the best, as it is based on light reflectance. A more reliable measurement using cellular measurements and gravimetric methods will be carried out later for rings 2-6 from bark, when morphometric measurements are carried out. Figure 27 gives a profile of ring density in the first 15 rings from pith for 10 families.

Evaluation of morphometric traits

Transverse sections of rings 2-6 from bark are cut in the remaining samples from 29 families to assess morphometric traits. Measurements will be completed by end of March, 2001. Statistical analysis and preparation for final report are expected to be completed by April, 2001

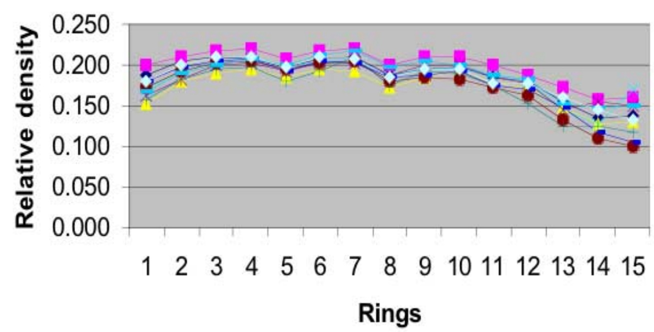


Figure 27. Relative density profile for 10 families

Deliverables:

A summary of the evaluation of anatomical wood quality traits for the 29 families will be reported. The information will rank the families for different wood quality traits.

2.3.26 Fingerprinting of High Breeding Value Clones

Kermit Ritland, Carol Ritland, Craig Newton and Shirley Peng

Microsatellites are highly informative (polymorphic) genetic markers with numerous applications in breeding and seed orchard assays, but must usually be developed specifically for each species. The purpose of the current activity (SPU0306) was to develop microsatellite markers for western hemlock, and as their first application, to fingerprint 30 trees of high breeding value.

We received 192 bacterial clones from Craig Newton (BCRI), each containing a piece of DNA from western hemlock containing an AT-repeat microsatellite. Each clone was sequenced for both DNA strands. Of the 192, primer pairs were designed for 87, and of these, 71 yielded "polymerase chain reaction" amplified products. When run acrylimide gels, we successfully obtained 31 polymorphic microsatellite loci (11 others were monomorphic and the remaining 29 were irresolvable).

With these 31 polymorphic microsatellite markers, we are currently characterizing levels of heterozygosity and documenting inheritance, using the 30 high-breeding value clones and sets of their progeny. This will also allow characterization of the co-ancestry of these trees. In succeeding years, we will use these markers to estimate seedlot GW values, to monitor changes in genetic variation during the process of hemlock breeding, and possibly to predict specific combining ability among these 30 top clones, on the basis of estimated coancestry.

2.3.27 A Comparison of Inbreeding Rates Between 'A' and 'B' Seedlots Of Western Hemlock

Kermit Ritland and Hugh Wellman

In realized gain trials of western hemlock , orchard mean seed lots out-performed wild stand commercial collections by 5-8% instead of the expected 2% now accorded unimproved orchard seed. Under project SPU0307, we have been examining if this is due to removal of inbreeding from seed produced in the orchard. Isozymes were used to estimate the inbreeding coefficient in each of 10 orchard seed lots and 10 wild stand commercial collections. While low, inbreeding coefficients were slightly higher from wild stand collections (F=0.028) compared to seed orchard seed lots (F=0.006). This corresponds to about a 4% difference of selfing; however, inbreeding depression alone cannot explain the 5-8% performance gain, as even complete death of selfed seed cannot give such gains. As orchard seed is also outcrossed to parents from other populations, performance gains may result from a heterotic effect of such outbreeding. The genetic divergence among the 10 wild stand collections was Fst=0.030, indicating the potential for such an effect. We are now examining among-collection variation of F in an attempt to disentangle the two effects.

2.3.28 Variability in Nursery Growth of Genetically Improved Western Hemlock Seedlings

Bevin Wigmore and Charlie Cartwright

Background:

Nurseries have reported that Hw seedlings from A-class seed are taller and more variable in the nursery than those from B-class seed, and are therefore more difficult to grow to specifications. In particular there is an impression that A-class seedlings respond differently to short-day treatments, and that they grow longer into the fall. If A-class seedlings do grow longer into the fall, then frost hardiness may be affected.

Objectives:

The objectives of this project (SPU0308) are to quantify the amount of morphological variation within several Hw seedlots throughout one growing season, to examine the effects of thinning on morphological variability, and to compare fall frost hardiness among A-class and B-class seedlings.

Progress to Date:

Twenty-five seedlots, comprising 15 B-class, seven A-class, and three full-sib lots, were sown in February 2000 at the MoF Extension Services nursery in Surrey. One half of each seedlot was single-sown, while the other half was double-sown and thinned. Thinning was done using the operational procedure of removing either the smallest germinant or the one closest to the edge of the cavity.

Heights of a random sample of seedlings from each seedlot and sowing treatment were measured monthly throughout the growing season. Dormancy was induced with drought stress – no black-out was applied. In November, frost hardiness testing on all seedlots was carried out at the Ministry of Forests Glyn Road Research Station using chlorophyll fluorescence. Height, caliper, dry weight, visible frost damage and other morphological parameters were measured at the end of the growing season.

Results:

While all data has not been analyzed at the time of writing, the following are some of the statistically significant results that have been obtained.

- The ‘A’ lots were taller than the ‘B’ lots.
- This difference was apparent early in the growing season, and increased throughout the growing season (Figure 1).
- The coefficients of variation for height were equivalent among ‘A’ and ‘B’ lots; i.e. the ‘A’ lots, although taller, were not more variable.
- The ‘A’ lots had a larger root-collar diameter then the ‘B’ lots.
- The ‘A’ lots had greater shoot dry weight than the ‘B’ lots.
- The ‘B’ lots had greater root dry weight than the ‘A’ lots.
- The ‘B’ lots had a greater root:shoot ratio than the ‘A’ lots.
- The ‘A’ lots had more visible frost damage in one of the three experimental blocks.
- There was no difference in final height between single-sown and double-sown trees.
- The single-sown trees had a larger root-collar diameter than did the double-sown/thinned trees.
- Surprisingly, there was no difference in variability, either in height or in diameter, between the single-sown and the double-sown trees.

When the rest of the analysis is complete, a report will be prepared for the nursery and tree improvement communities.

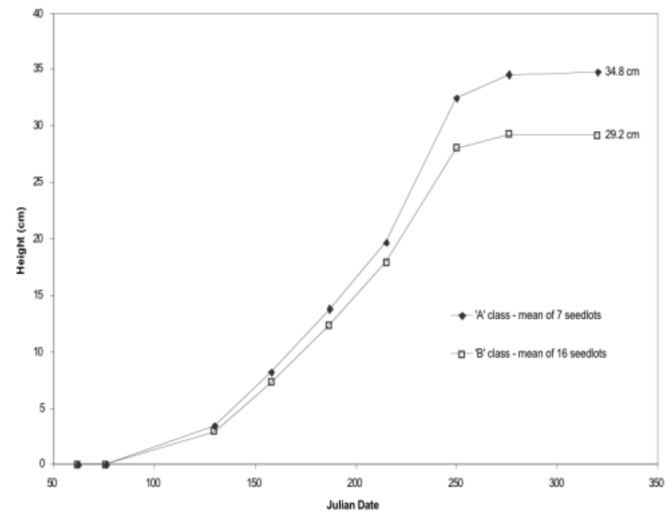


Figure 28. Nursery growth curves for ‘A’ class and ‘B’ class Hw seedlots.

2.3.29 Estimation of Propensity to Self in Elite Seed Orchard Clones of Western Hemlock.

Oldrich Hak

Previous studies have shown that the propensity of western hemlock orchard clones to self-pollinate shows strong family effects. This factor is particularly important in clonal row orchard designs. Once the problem clones are identified, managers can avoid planting ramets of these clones adjacent to each other, or employ some form of pollen management (i.e. SMP), or collect from these trees in years where no remedies could be undertaken. Minimizing selfing in orchard seed will assure that the growth potential of high gain lots is not compromised by inbreeding.

In this project (SPU0309), the propensity to self was estimated for 31 high breeding value orchard clones. Controlled crossings were done at the Cowichan Lake Research Station and in collaboration with the Sechelt Seed Orchard at Canfor and the Lost Lake Seed Orchard at Western Forest Products. Two selfed and two out-crossed isolations were done on each of the high breeding value parents. Poly-mix for out-crossings was formulated using an equal amount of pollen collected from 6 unrelated lower breeding value families. Seed from selfed and out-crossed cones was extracted, the number of empty and filled seed was counted, and the percent of filled seed for each isolation bag was determined.

Of the 31 clones tested, sufficient data points were obtained for 24. Problems included cones that did not open, broken branches, and pollen shortage.

Family effects were generally quite strong, as was assumed from the literature, but variation from family to family was surprising. A full quarter of the clones, for which the data was strong enough, had selfing success (i.e. filled seed as a proportion of total seed) in excess of 25%, with one clone reaching 60%. Half of the clones had family values less than 10%. In light of the results, it was decided to continue the evaluation of selfing in order to cover clones that had missing data points.

2.3.30 Five Year Performance of Four Spruce Seed Orchard and Wild Seedlots Summer Planted on Six Different Dates.

Chris Hawkins

In the early 1990s silviculture foresters expressed concerns about the field performance of spruce seed orchard stock. Observations from early trials to address this issue revealed that summer planted stock, regardless of seed origin or nursery culture, had more malformed shoots than did spring planted material. Presented are the five-year results of performance trials that were implemented to examine the differences and similarities between nursery, planting time, seed planning zone (SPZ) and seed source (seed orchard vs. wild seed) on spruce seedling establishment, growth and form (SPU0403).

Seed orchard and wild seedlots from NE (Nelson) and PG (Prince George) SPZ were grown at four nurseries (Reid Collins, Skimikin, and Red Rock Research (with blackout), and Red Rock Research (other)), and summer planted in 1995. Stock was hot-planted on 6 dates (May15, May 30, June 15, July 1, July 15, and August 3) at both Skimikin and Red Rock. Second year results indicated that late June - early July summer plant dates minimized shoot malformation at both sites. Growth was not maximized.

Mean pooled heights were different between sites after five seasons (Figure 1). The greatest growth was at Skimikin, which was 60% greater than at Red Rock. The large variations in height are in part attributed to differences in soil structure: the soil at Red Rock was extremely low in organic material and high in sancontent.

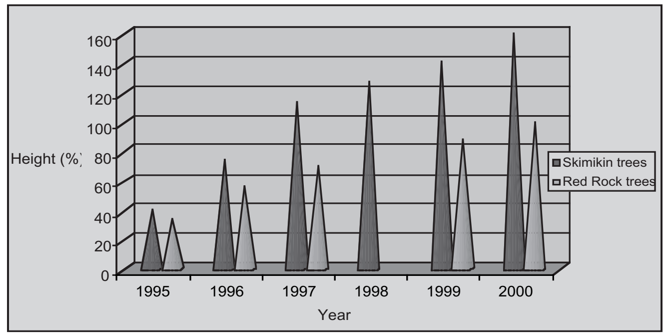


Figure 29. Relative height growth (%) from 1995 to 2000 between trees grown at Red Rock near Prince George and trees grown at Skimikin near Salmon Arm.

(Note: Tree heights were measured in 2000. Because many form problems with the trees grown at Red Rock resulted in a poor estimate of the 1998 height, the 1998 heights for Red Rock are left out of the analysis).

Planting time

By year 5 the best planting time at Red Rock was about June 15 while the best planting time at Skimikin was later in the season (around August 3rd), regardless of nursery, SPZ or seed source (Figure30). 2).

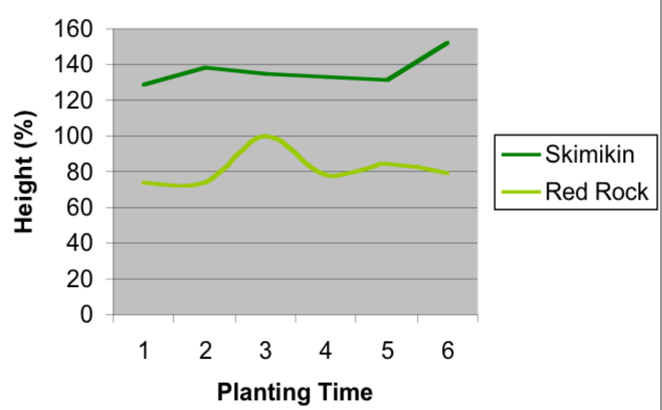


Figure 30. Relative 5 year height by planting time at Skimikin and Red Rock.

Nursery

Nursery relationship remained the same over the 5 years at both sites. At planting, there was a significant effect of nursery on seedling height. This was confirmed at year 5 at both sites as well. The general nursery relationship for both sites is presented in Figure 31. Blackout treatment was used at nurseries that exhibited poor height growth (2) or good height growth (4). Therefore, five year height growth is not directly related to nursery blackout treatment.

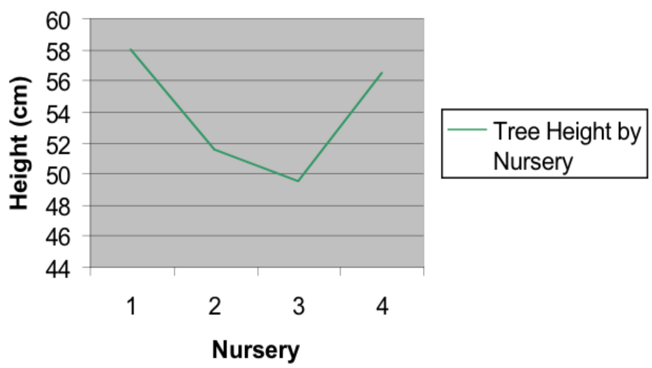


Figure 31. Five year height by nursery at Skimikin.

Nursery x Planting Time

Interestingly, at the optimum plant date (time) at both sites, there was little difference among nurseries for height growth at that site (Figure32). 4).

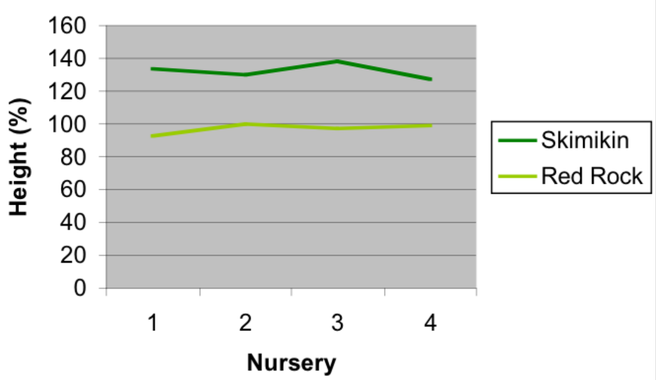


Figure 32. Relative height growth by nursery for the optimum plant time at Skimikin (early August) and Red Rock (mid June).

This observation raises an interesting question: Is this the optimum planting time for all nurseries, or is this time perhaps simply better suited for the nurseries that produce stock that does the poorest at other times?

Seed Planning Zone

PG SPZ produced the greatest mean growth at both sites. SPZ showed no difference at initial planting but by year five the difference was significant.

Seed Orchard Seed vs. Wild Seed

Overall, seed orchard seed resulted in greater growth at both sites, as it had in the nursery. Seed orchard growth was about 5.4% and 3% better than wild seed at Salmon Arm and Prince George respectively. Although this appears to be a subtle difference, a 3% increase in height growth can produce as much as a 6% increase in volume, which is approximately the same as the rating assigned to the seedlot used.

Tree Form: Salmon Arm

Form damage in 2000 indicated that about 64% of the saplings were 'thrifty' (healthy with good form) while only 9% had form related problems. The latter is within the expected, normal range for spruce. The data further suggests that summer plant does not result in significant increases in form related problems at this site.

Prince George

Form observations for 2000 showed that 9% of the saplings were 'thrifty' while 31% had significant form related problems. There was no difference between seed orchard and wild seedlots. As there was no correlation to nursery blackout, it is speculated that the poor form observed at Red Rock resulted from the lack of heavy snow pack, and thaw-freeze events that ultimately damaged the apical meristem and subsequent growth of the saplings. As indicated in Figure 1, few trees had gone three years without damage. However, the increased form damage could be related to summer planting and/or its interaction with climate (more severe at Red Rock than Skimikin).

Conclusions

It appears there is an optimum summer plant window for spruce, which varies considerably for different Biogeoclimatic Zones: mid June near Prince George and early August near Salmon Arm. Further, stock grown in nurseries that generally have significantly poorer growth, do not differ at the optimum plant time.

Seed orchard seed had significantly better growth than wild stand seedlots.

Interestingly, the PG material did best at both sites.

The data with respect to time of planting are in part a function of the macroclimate in 1995. To verify the optimum planting window, a smaller version of this trial would have to be initiated over two or three summer plant seasons.

2.3.31 Cone and Seed Pest Management- Interior Operations.

Robb Bennett

Objectives SPU0405:

This funding covered operational expenses for the Interior seed pest management biologist's activities. Specifically the objectives were:

- Provide pest management extension services to all interior MoF and private seed orchards and natural stand cone and seed dealers including pest surveys, identifications, and management direction; damage estimates/predictions; etc.
- Develop new and improve existing pest management protocols
- Prepare written extension reports for presentation to orchard managers and/or publication in venues such as Seed and Seedling Extension Topics, Forest Health Progress, Canadian Entomologist, etc.
- Participate in training of professional foresters and biologists, orchard managers, and related technical staff in cone and seed pest management practices.
- Facilitate cone and seed pest management related research activities through collaboration with provincial, national, and international researchers whenever possible and feasible.

Results:

During the period 1 April 2000 - 31 March 2001, the Interior seed pest management biologist (Dr. Ward Strong) provided the following services to the cone and seed production community and others:

- 141 seed orchard site visits, pest surveys and identification, and damage predictions and assessments
- 35 written pest survey reports to orchard managers and other seed production personnel
- 44 other pest identification services to MoF personnel and others
- 12 extension education presentations to secondary school, college and university students
- 3 professional presentations to BC Seed Orchard Staff Group and other groups
- Numerous "tail-gate" type extension presentations to operational seed production personnel.
- 9 in-house seed orchard pest management research projects initiated, continued, or completed.
- Collaborated and cooperated with university, research institution, and other personel in eight other research projects.

Publications resulting from these activities:

Strong, W.B. Spittlebugs Reduce Seedset in Interior Lodgepole Pine. Seed and Seedling Extension Topics 12(1), August 2000.

Strong, W. B. and R. G. Bennett. in prep. Sample plan for the Cooley spruce gall adelgid, *Adelges cooleyi* (Homoptera, Adelgidae) in British Columbia spruce seed orchards. for submission to The Canadian Entomologist.

Strong, W. B., S. L. Bates, M. Stoehr. 2001. *Leptoglossus occidentalis* (Hemiptera: Coreidae) reduces seedset in lodgepole pine (*Pinus contorta* Douglas var *latifolia* Engleman). Canadian Entomologist (submitted)

Sopow, S.L., J.D. Shorthouse, W. B. Strong, D.T. Quiring. 2001. Evidence For Long-Distance, Chemical Gall Induction By An Insect. Ecology (submitted)

2.3.32 Class A Seed Zones In Southeastern BC.

Sally Aitken, Greg O'Neill and Barry Jaquish

A genecological study (SPU0408) was performed to determine appropriate deployment distances for interior spruce seed within the new interior Class 'A' SPZs in southeastern BC. Sixty-nine open-pollinated families from throughout the Nelson (formerly Mica, Shuswap Adams, and West Kootenay) and East Kootenay SPZs were evaluated in a seedling common-garden experiment at UBC. Fifteen morphological, phenological and physiological traits were examined during the second year in raised nursery beds in each of three test environments (warm, wet soil; warm, dry soil; and cold, wet soil).

Genetic variation among locations was strong and significant for almost all traits, and was overwhelmingly patterned on elevation, corroborating first year results of this study. Regressions of elevation on all traits were seldom and weakly improved by squared or interaction geographic variables, climatic variables, or multiple regression. Genetic variation was unrelated to longitude and weakly related to latitude.

Transfer distances were developed using the Rehfeldt approach of identifying the least significant difference between genetically distinguishable populations indicated that populations separated bymore than 270 m elevation or 2.9° latitude differ significantly. The results indicate that longitudinal transfer in this area could be unrestricted as there is no apparent genetic differentiation between the Nelson and East Kootenay Class A SPZs for interior spruce. However, the steep elevational clines for some traits (Figure 1) suggest that increasing the number of elevational sub-zones in this area may be worthwhile given the large elevational range across which spruce is planted in this region (500 to 2000 m).

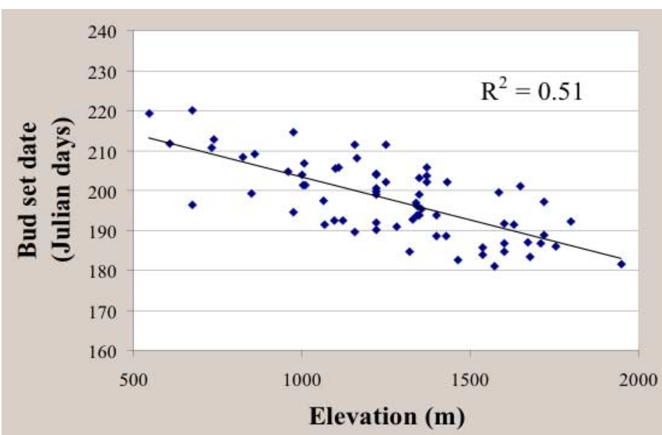


Figure 33. Bud set date vs. elevation for 69 Sx families from SE BC.

Further analyses will employ principal components to describe genetic variation, and will relate genetic variation to biogeoclimatic ecosystem classification units, in order to refine appropriate SPZ delineation and seed transfer distances. In addition, data from a high elevation field site established in 2000 will contribute to the understanding of the genecology of interior spruce in southeastern BC.

2.3.33 Software for Calculating Genetic Worth of Weevil Resistant Stock

Rene Alfaro, John King, George Brown, Michelle Meier, Robert MacDonald and Ken Mitchell

A computer program, TassSwat, was developed to determine the potential gains in spruce productivity when using stock with different degrees of genetic resistance to the white pine weevil. Spruce Weevil Attack (Swat), works with the Tree and Stand Simulator (Tass), a model developed by the BC Ministry of Forests 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 TassSwat program delivers an interactive simulation of spruce weevil outbreaks in a plantation over time, and graphically reports the impacts of the weevil population on the

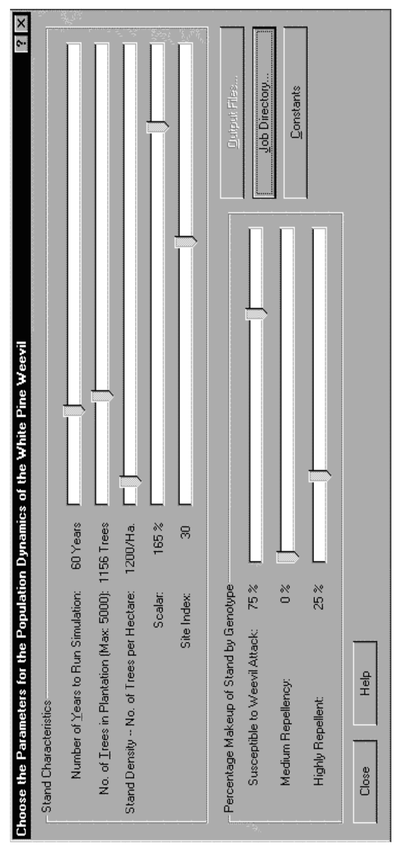


Figure 34. Parameters window of the TassSwat model.

stand, including weevil epidemiology and attack success. The program represents the life cycle of the insect, including dispersal to new trees, egg laying, emergence of new insects and winter mortality. These aspects of the weevil life cycle are affected by tree defenses and by crown cover.

The integrated TassSwat model is currently password protected and can be accessed over the Internet through the Swat Dynamics program. Through this interactive program, users describe their initial stand conditions and submit them to the remote TassSwat engine residing at the BC Ministry of Forests Research Branch. Processing occurs at the remote site and users are informed when their job has completed. Output statistics for stand yield, weevil counts and tree attack rates over the lifetime of the stand are downloaded and graphically displayed. Simulations are configured by the user through two main windows, the parameters window and the constants dialogue window. Users specify the desired stand characteristics in the parameters window (Figure 34), which allows the user to specify the size of the plantation, the site index and the relative proportion of resistant stock to use.

The constants dialogue window displays various parameters used to calculate the probability and extent of weevil attack in the plantation over time. The weevils' tree selection process is simulated in Swat and is affected by leader length, resistance and crown closure. The genotype box allows the user to specify the degree of tree resistance through two mechanisms, repellency and toxicity. Repellency is a condition of genotypes, which causes colonizing weevils to depart from a tree, and toxicity is the ability of resistant trees to kill weevil larvae. Constants can be updated or revised depending on the needs of the user.

After a run has been processed, the simulation output is downloaded and graphically displayed. Users can view the development and spread of a weevil outbreak in a plantation over the lifetime of the stand (Figure 35).

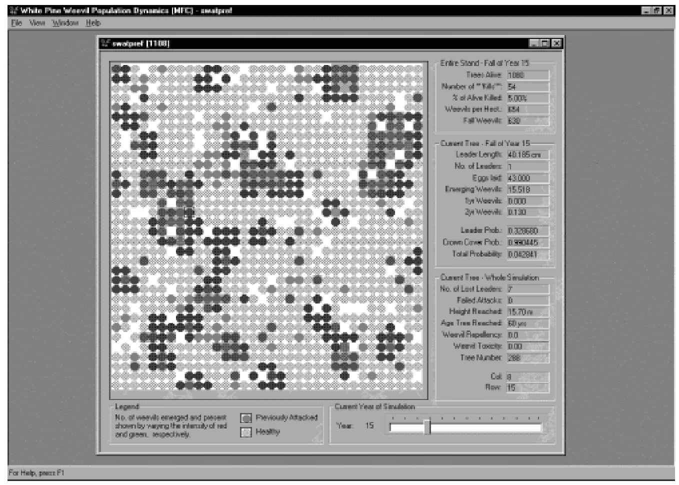


Figure 35. Simulation output of the TassSwat model.

Excel charts of weevil epidemiology, attack success and weevil effects on the stand can also be viewed. The program also produces volume age data after taking into consideration the effects of weevil on productivity

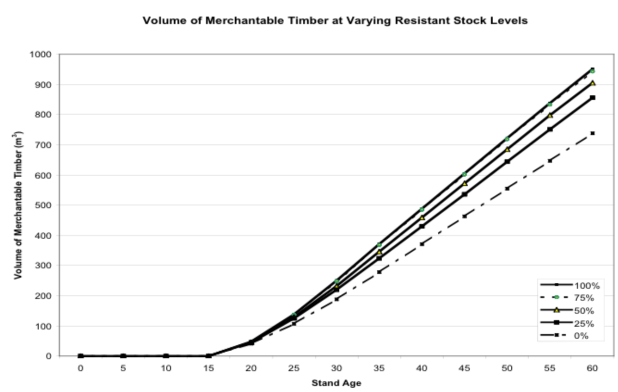


Figure 36. Volume age curves produced with the TassSwat program.

(Figure 36). These volume age curves simulate stand development with different proportions of resistant stock (Site Index 30, 1200 tree/ha).

The TassSwat program is currently being tested and calibrated for utilization in the tree breeding program of British Columbia.

When complete, this program will allow for the estimation of growth and yield of plantations of various resistance configurations. This information is crucial to make informed decisions regarding the level of resistant trees to use in different ecosystems [OTIP 409].

2.3.34 Screening of Interior Spruce Controlled-cross Progeny for Resistance to the White Pine Weevil

Rene Alfaro, Barry Jaquish, John King, George Brown and Lara van Akker

Introduction:

Figure 37. The white pine weevil, Pissodes strobi.

The white pine weevil (Pissodes strobi Peck) is the most damaging pest of young spruce and pines in northwestern North America. Its main hosts in British Columbia are Sitka spruce (Picea sitchensis (Bong.) Carr.), white spruce (P. glauca (Moench) Voss) and Engelmann spruce (P. engelmanii Parry). In early spring (late March, April), adult weevils emerge from overwintering in the duff and after mating, females oviposit in the upper section of the previous year's leader. The larvae mine downwards, consuming the phloem, girdling and killing the leader. Pupation occurs in chambers excavated in the xylem. New adults emerge from the leaders from late July to September, they feed for a while, and when temperatures drop and photoperiod shortens, go into hibernation in the duff. Leader destruction results in stem defects, such as crooks and forks, which reduce lumber quality and can reduce the yield of host trees by as much as 40%, depending on infestation levels.

Control methods are necessary since damage from this insect has forced forest managers to virtually eliminate the planting of Sitka spruce in coastal BC. In the interior, there are approximately 43,000 ha of pure interior spruce plantations that are currently of weevil susceptible age. Several control methods have been tried but none has proven completely successful.

Genetic resistance offers a new avenue for management of this forest pest.

A cooperative project between the Canadian Forest Service (CFS) and the MoF was launched in the late 1980's to accelerate the screening of Sitka and interior spruce families for resistance to white pine weevil attack. Consequently, Dr. Rene Alfaro and collaborators at the CFS are monitoring several well-replicated sites, and spruce families that maintain resistance under extreme weevil pressure are being identified. In total, twelve sites in BC and two in Oregon, encompassing over 1200 spruce families are being screened for weevil resistance (Table 10).

Site	Initial Planting Date	# Families	# Trees	Year of weevil enhancement	# weevils added/tree[a]	# resistant families
Armishaw +Glenrov. Savward	1992	168	2581	Sept/96	4	101[e]
Espinosa Creek. Zeballos	1991	151	2331	--	---	102[e]
Browns Main. Po Renfrew[b]	1994	72	813	Oct/97	3	1
Camp Creek. Clearwater	1984	139	4332	--	---	7
Jordan River[c]	1991	75	1722	Oct/94	3	4
North Arm. Cowichan Lk[c]	1992	75	1477	May/96	2	4
Big Tree Creek. Savward	1974	321	4389	--	---	11
Kaouk Creek. Fai Harbour	1984	38	629	--	---	11*
Snowdon Forest. Campbell R[b]	1994	72	1336	Sept/99	3	1
Camp 4. Campbe R.	1995	84	2124	Sept/99	3	6
Kalamalka Research Station	1995	42	3001	Oct/99	3	13
Hamlet. Oregon[d]	1994	24	2304	1997	--	in progress
Nehalem. Oregon[d]	1994	24	2304	1997	--	in progress
	Totals	1285	29343			

Table 10. MoF and Oregon State progeny trials being monitored by the CFS in the screening of Pissodes strobi resistant

* These are individual clones

a indicates only natural infestations monitored

b Browns Main and Snowdon are replicates of the same families

c Jordan River and Cowichan are replicates of the same families

d Hamlet and Nehalem are replicates of the same families; both trials were seeded with infested leaders

e These are clones affected by low attack levels, therefore resistance status is still uncertain.

Families were considered resistant if 25% or fewer trees sustained top-kills.

As new results emerge from these trials, updates are prepared for dissemination to the MoF and industrial clients. The resulting data will facilitate continuing selection of parent trees used for mass-propagation of material for operational planting, for seed orchard inclusion and for breeding.

The resistance screening program, partners and collaborators is described in the following Web page:

http://www.pfc.forestry.ca/landscape/weevil/resistance/index.html.

The biology and management of white pine weevil in Canada is described in:

http://www.pfc.forestry.ca/landscape/weevil/

The first attempt at screening interior spruce for weevil resistance utilized natural attack rates in progeny from 174 wind-pollinated families, replicated at three test sites (Aleza Lake, Quesnel and Red Rock) in north central BC. Several years after planting, weevil resistance rankings (averaged over the three sites) were calculated based on the damage sustained by each family. Weevil resistance has been shown to be highly heritable in interior spruce, with family heritability values estimated at 0.70 and 0.77. The rankings allowed for the selection of parents, and the production of progeny, so that weevil resistance in the F1 generation could be examined. One such second-generation weevil screening trial was initiated at the Kalamalka Research Station. This trial consists of progeny from controlled crosses in parents were identified as either: a) both putatively weevil resistant, b) one parent putatively weevil resistant and one weevil susceptible, or c) both parents weevil susceptible. In this report we describe a study that commenced in early 1999 at Kalamalka, to determine levels of weevil resistance at this trial.

In addition to the screening program, the CFS has also undertaken a number of studies to correlate resistance with anatomical features of the apical and lateral shoots. Also included are results of the resin canal analysis of the families in this trial.

Materials and Methods (SPU0604):The Kalamalka Research Station Weevil Resistance Trial

In May 1995, a spruce progeny trial was established at the Kalamalka Research Station, Vernon, BC. A total of 3150 trees were planted consisting of 42 controlled crosses obtained from 9 female parents and 11 male parents. Sixteen of the crosses were putative resistant female x resistant male (RXR) (crosses 1 – 16); 20 of the crosses were putative resistant female x susceptible male (RXS) (crosses 17 – 36); and 6 of the crosses were susceptible female x susceptible male (SXS) (crosses 37 – 42). Twenty-five progeny from each cross were planted in plots with 3 replications for a total of 126 plots (25 trees per plot x 42 plots (= crosses) x 3 replications = 3150 trees (126 plots)).

Resin Canal Samples

In June 1999, leader and lateral branch samples were collected from each of the 42 crosses to examine the constitutive bark resin canals. All samples were collected from replicate one. From each cross, one lateral branch from the 1998 whorl was clipped from each of 10 separate trees which had not been previously attacked by the white pine weevil.

Branch samples were measured (length), clipped and kept cool until they were brought back to the lab at the Pacific Forestry Centre (PFC). A five centimetre section of each branch was placed in a scintillation vial, in FAA for approximately 48 hours. The sample was then transferred to 70% ethanol. Cross sections, sixty microns thick, were made using a sliding microtome. Sections were mounted on glass slides and stained with .1% aqueous Safranin. Slides were scanned using a light microscope and the following measurements recorded: radius, bark thickness, and number and density of inner and outer resin canals. The number of samples collected is indicated below:

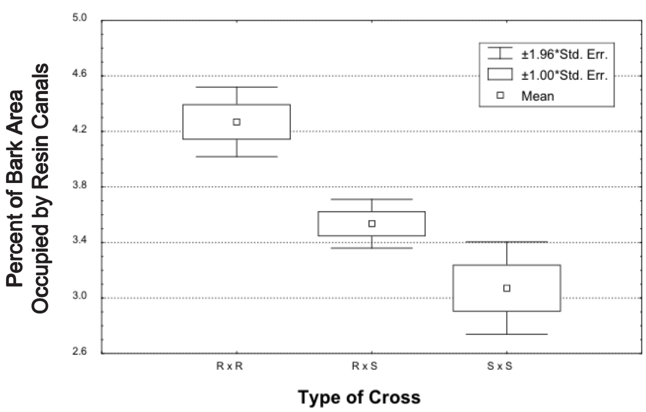
Leaders	*42 Crosses x 1 offspring/cross =*	*42 samples*
Laterals	*42 Crosses x 10 offspring/cross =*	*420 samples*
		Total: 462 samples

Weevil Screening

In 1999, the trial was assessed for current and past weevil attack. Then, to accelerate the screening process, a weevil augmentation was initiated. To achieve this, 700 weevil-infested leaders were clipped from surrounding spruce trees at the Kalamalka site. The leaders were brought to PFC and placed in cages. As the adult weevils emerged they were collected and placed in five gallon pails containing food (cut spruce branches) and water. Over 10,000 weevils were collected and maintained at PFC until the time of augmentation. In early October 1999, three weevils were placed on each tree in the Kalamalka trial. The trial was assessed in August 2000, to determine attack rates.

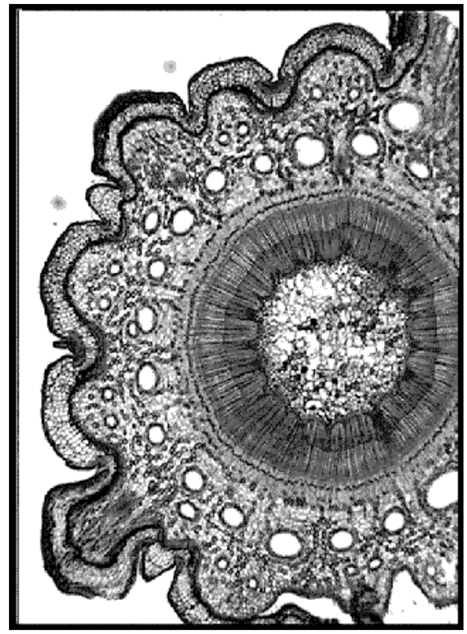
Results: Resin Canal Samples

Analysis of resin canal samples indicated that constitutive bark resin canals of resistant x resistant crosses were significantly denser than in bark from either, resistant x susceptible or susceptible x susceptible crosses, both in terms of cross-section area (Figures 40i, and 40ii) and number. The fact that the resistant x susceptible crosses showed intermediate density of resin canals indicates that resin canal density may be a quantitative trait. Representative images of cross sections obtained from both a susceptible x susceptible cross and resistant x resistant cross are shown in Figure 38. A detailed statistical analysis of these data was made available to the MoF in 2000 (Alfaro et al. 2000).

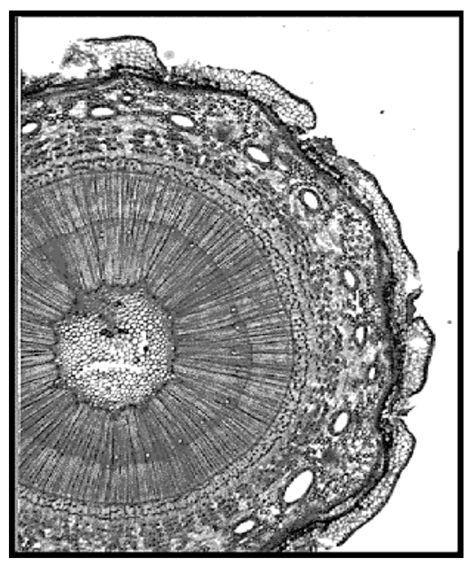


Legend: RxR = Weevil resistant x resistant, RxS = resistant x susceptible and SxS = susceptible x susceptible crosses. n(RxR) = 160; n(RxS) = 200; n(SxS) = 60.

Figure 38. Proportion of bark area occupied by resin canals in lateral branches for various crosses.



i) Both parents susceptible



ii) Both parents resistant

Figure 40. Images of cross-sections of a lateral branches.

Attack rates following weevil augmentation

The addition of weevils to the trial worked exceptionally well. Uniform weevil pressure was applied to all the trees, resulting in elevated attack rates. There was a clear distinction between cross types: RxR crosses had significantly fewer attacks (12% of trees sustained top kills) than RxS (48%) or SxS crosses (66%) (Figure 41) confirming the heritability of resistance to weevil. Data and computer files have been prepared and made available to the MoF.

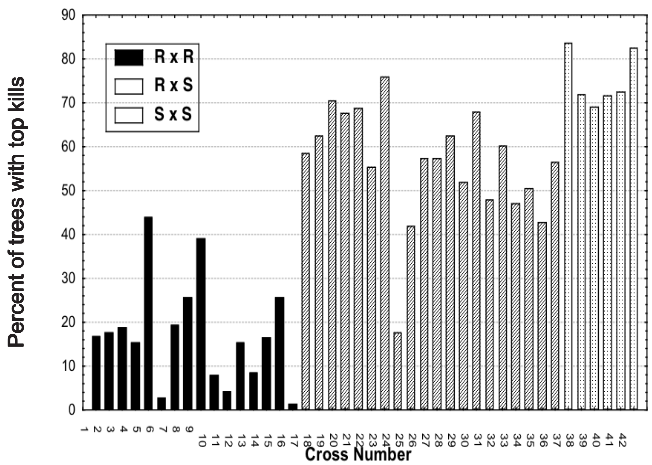


Figure 41. Percent of trees in each cross that sustained top kills between 1995 and 2000.

Discussion:

With the exceptions of crosses 5, 9 and 15, weevil resistance appears to be holding in the resistant x resistant crosses (Figure 41). This supports the previous work of Kiss and Yanchuk (1991) and King et al. (1997) where weevil resistance was shown to be a highly heritable trait.

Bark resin canals play an important role in the resistance of spruce to weevil attack. This conclusion is based on the work presented herein as well as that previously done on Sitka spruce by Tomlin and Borden (1994, 1997) and on interior spruce by Alfaro et al. (1997) and Tomlin et al. (1998). Resin canals may act as physical barriers to feeding and oviposition by the adult since resin repels colonizing adults and pitch drowns eggs and young larvae if resin canals are punctured during the feeding process.

In addition to this first line of defense, spruce is able to turn on an inducible defense, the production of traumatic resin. The resin, which is more fluid than constitutive bark resin, flows rapidly into larval galleries. Also, it is possible that some resistant trees contain other defensive chemicals such as phenols or juvenile hormone analogs, which may impair weevil physiology.

2.3.35 Technical Support to Increase Seedset in Southern Interior Pli Orchards

Gary Giampa

Background:

Our objective (SPU0705) was to supply essential technical assistance to a Ministry of Forests Research Branch team with their “Enhancing seed production in North Okanagan Pli seed orchards” project. The Research Branch team was using Kalamalka orchard 307 and PRT’s Grandview orchard 308 for their studies. The staff at Kalamalka was available to provide labour and assist with technical tasks as required. It was not possible for the Research Branch team to be on site at all times during the field season as they are based out of Victoria. For this reason it was imperative that local staff were available to monitor the project and take care of routine maintenance

Activities:

During the 2000 field season Kalamalka staff were active at both Kalamalka and Grandview sites. The Research Branch team was assisted with a variety of duties including:

- Setting up and maintaining irrigation, including installation of a four inch supply line.
- Selecting and flagging branches on individual trial trees.
- Observing and recording pollen flight data, flower receptivity.
- Collecting and applying pollen.
- Installing and removing isolation bags. Installing insect bags.
- Monitoring and controlling pitch moth on trial trees.
- Conducting a variety of phenology and vigour surveys.
- Collecting samples.

By the end of the 2000 field season the project was set up and running smoothly. The Kalamalka staff are familiar with the objectives of the project and are trained to provide further technical assistance in the future.

2.3.36 Mating Disruption of Sequoia Pitch Moth

Ward Strong

Figure 42. Adult pitch moth

Background:

Interior lodgepole pine seed orchards suffer from low seedset. This may in part be due to attack by the Sequoia pitch moth, *Synanthedon sequoiae*. Phloem-feeding larvae create pitch masses on the bole, which reduces tree vigour and weekens the tree bole, leading to breakage of a valuable genetically-improved tree. Currently, pitch moths are dug out with screwdrivers, which does not stop tree damage, is very labour intensive (required up to 3 times per season), and is an unpleasant job for field staff. The incidence of pitch moth attacks has been rising over the past few years, requiring increased expense for manual control.

Control of pitch moths through mating disruption (the use of synthetic sex pheromones to prevent mate-finding) would be a simple, inexpensive and environmentally friendly method of preventing tree damage, thus helping ensure that FGC goals for seed production are met in an economical way.

Figure 43. Pitch moth larva

Methods:

On May 15-16, 2000 (SPU0707), two release devices (a small rubber septum injected with pheromone) were placed in each of 750 trees in one orchard at Kalamalka Forestry Center, for a total of ca. 0.6 g/ha pheromone. A similar nearby orchard was left untreated as a control. These orchards had very high densities of pitch moth adults in a 1999 pheromone trapping study. Four pheromone traps were hung in each orchard to monitor the success of mating disruption: if male moths can't find the traps, they probably can't find the females either, and disruption is assumed to be successful. Traps were monitored weekly (June 2 - July 20). A series of 16 other traps were placed in seed orchards throughout the Vernon area and checked every other week (June 2- July27).

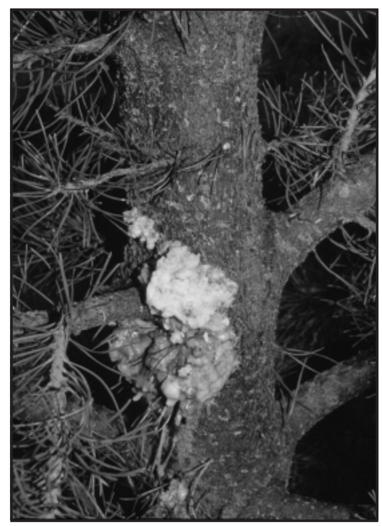


Figure 44. Damage

Results:

Only a single pitch moth adult was caught in the pheromone traps all season. This individual was caught in the untreated orchard on June 30. Only three pitch moth adults were caught in other traps in the Vernon area. Apparently the incidence of adult pitch moths was extremely low in 2000, precluding our ability to test mating disruption. The reason for the low adult numbers is not clear. However, pitch moths spend two years in the larval stage. The life cycle might be synchronized so that most adults emerge one year, while few emerge the next. There were many larval pitch masses in the trees in 2000, so we anticipate an abundance of adults in 2001. An OTIP proposal to repeat this project in 2001 has been submitted.

2.3.37 Mating Disruption of White Pine Cone Borer

Ward Strong

Figure 45. Adult Moth: the white pine cone borer

Background:

Since 1997, the White Pine Cone Borer, *Eucosma rescissoriana* has caused significant seed losses at the Skimikin white pine seed orchard. Moths fly in May; larvae bore through cones eating seeds. Insecticide applications are unfeasible due to the height of trees, and environmental and worker hazard. An alternative control technique is mating disruption using pheromones, insect sex attractants. If enough pheromone is released into the orchard, male moths can't find females, mating doesn't occur, and no fertile eggs are laid.

Figure 46. White pine cone borer larvae

Methods:

Polyvinyl laminate impregnated with Eucosma pheromone was purchased in early Spring 2000 (SPU1502). Traps and monitoring pheromone devices were also purchased. However, due to circumstances beyond the investigator's control, experimental setup never occurred, and the procedures had to be postponed for one year. Pheromone release devices are in deep-freeze storage (where they are indefinitely stable) and the experiment will be continued in the year 2001.

Results:

Because this experiment has been postponed for one year, there are no results to report. A report will be submitted to the 2001 OTIP Annual Reports on the results of 2001 field activities.

2.3.38 Mating Disruption of Douglas-fir Pitch Moth

Robb Bennett

Background:

The Douglas-fir pitch moth causes pitch masses on lodgepole pine stems in seed orchards at the Prince George Tree Improvement Station, leading to reduced tree vigour and breakage. Currently no control measures are in place. Control of the adults with mating disruption, using insect sex pheromones to prevent mate-finding, would be an attractive control method since it is environmentally friendly and simple to use. This trial (SPU1204) tested whether mating disruption is a feasible means of controlling the Douglas-fir pitch moth.

Methods:

Disruption devices containing pitch moth sex pheromone were like twist-ties. One was tied to every tree in mating disruption areas. Four large areas in different seed orchards were used for mating disruption; six untreated areas were used as controls. In all areas, pheromone traps were placed to check adult densities and disruption efficacy. If disruption is successful, then males should not be able to find the traps and catches should be reduced. Pitch masses in all areas were surveyed to determine whether masses contained larvae. The developmental stage (instar) of larvae found was also determined.

Results:

In untreated areas, a total of 26 pitch moths were caught, while none were caught in the disruption areas. The mating disruption definitely reduced the ability of males to find traps, and therefore presumably their ability to find female moths. This indicates mating disruption was successful. Also, only 4.8% of pitch masses in one mating-disruption area contained larvae, a decline from the 23% in 1999. Mating disruption has been applied to this area for 3 years; the decline in occupied pitch masses is another indication of successful disruption. However, there were larvae of the youngest age class in the disruption areas, suggesting that some mating and egg-laying does occur, even in the disruption areas. The investigators suggest that manual removal of pitch masses may help reduce populations, and that the sex pheromone be better characterized before more mating disruption studies are conducted.

2.3.39 Determination of the Efficacy and Contribution of Supplemental Mass Pollination on Seed Produced in Three Lodgepole Pine Seed Orchards

Chris Walsh

The project (SPU0708) was initiated by Clare Hewson and, upon his retirement, was inherited by Chris Walsh (Kalamalka and Grandview portion) and Carole Fleetham (PGTIS portion).

Kalamalka and Grandview:

In 1998, funded by OTIP179, pollen was collected from seven clones exhibiting unique DNA markers within Orchard 307 at Kalamalka. In 1999, funded by OTIP371, a mixture of these pollen lots was applied to Orchard 307 at Kalamalka and Orchard 311 at Grandview. Branches were identified in each orchard and divided into three treatments:

- SMP only – these conelets were bagged throughout the pollination period, except for during the SMP application.
- Open only – these conelets were left exposed throughout the pollination period, except for a brief time (< 1hr) during each SMP application, when they were bagged.
- Control – these conelets were left exposed at all times and so received natural pollen and the SMP pollen.

Pollen was applied following normal operational procedures.

In 2000, the cones were collected, bulked by treatment and clone, and seed was extracted, cleaned, x-rayed and counted. Filled seed per cone (FSPC) results (Figure 1) were quite variable but followed the expected trend: Overall, the control treatment had the most seed, followed by the "open only" treatment. The "SMP only" treatment resulted in the fewest seeds per cone. This was true even in Orchard 311 where, being a young orchard, there was not a large natural pollen cloud. (See chart.) Differences between the control and the "open only" were not statistically significant, suggesting that the SMP in this project did not increase FSPC.

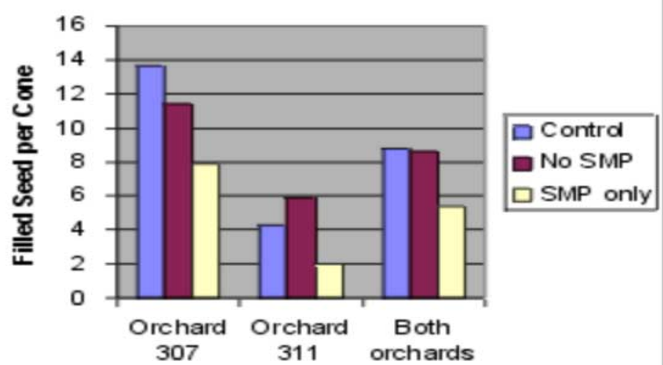


Figure 47. SMP Efficiency (Orchards 307 and 311)

Seed was then bulked by treatment for each orchard and a sub-sample of 100 seed was taken from each of the six lots. These seeds are currently being analyzed for paternity. The results should show whether it is possible to influence male parentage through the application of SMP, in an orchard with either a low or a high level of natural pollen.

2.3.40 Lodgepole Pine Pollen Monitoring in the Shuswap
Keith Cox

As the low seedset issue in the lodgepole pine orchards in the Vernon area has not been resolved yet, one possibility is that the new lodgepole pine orchards will have to be located in a cooler, damper climate. The Shuswap would be a logical option so pollen monitors were set up at three sites to determine the levels of local pollen that exist at each of the three locations. Under SPU07089 the monitors were set up at Skimikin, Tappen, and the North Broadview area of Salmon Arm. The monitors, with seven-day clocks and charts, were supplied by Joe Webber. They were set up in the three locations prior to the lodgepole pine pollen flight and the charts were changed each week until the flight was over. The charts were then sent to the Kalamalka Forestry Centre to have one person read all the charts as monitors had also been set up in Lumby, and near the Enderby cliffs. The results are not available at this time.

2.3.41 Enhancing Seed Production in the North Okanagan Lodgepole Pine Seed Orchards
Joe Webber

Introduction:
Seed set in north Okanagan lodgepole pine seed orchards has been poor for many years. The fall down in seed yields has been attributed to the seed bug (*Leptoglossus*), inadequate pollen supply and interrupted reproductive development due to adverse climatic conditions. Assuming that the seed bug and pollen supply can be controlled, then it is our contention that higher seed set can be attained through better cultural techniques, in particular irrigation (both the amount and distribution of water delivered). High temperatures (>25ºC) and low humidity (high vapour pressure deficit, VPD) during critical stages of reproductive development may be limiting further development.

Project Outline:
To test our hypothesis (SPU0711), two north Okanagan seed orchards were used: the MoF Kalamalka Seed Orchard 307 in Vernon (KAL), and Pacific Reforestation Technologies Seed Orchard 308 near Armstrong (PRT), BC. In each orchard, four experimental blocks were established to test the effect of improved irrigation, crown cooling through misting, the interaction between misting and irrigation and a control block. To determine treatment effects, the following measurements were made:

- the amount of ambient orchard pollen and its synchrony with receptive female cones in each treatment block; and,
- the effect of treatments on 2nd year seed cone survival, cone size, total seed per cone, and filled seed per cone; and,

Supplemental mass pollination was carried out on a sub-sample of trees to determine if ambient orchard pollen supply was limiting. Pollen monitors were installed in each of the four blocks to determine the level of ambient orchard pollen supply and the synchrony between orchard pollen shed and seed cone receptivity. Meteorological data (temperature and humidity), were collected in each block to determine the extent of high temperature (>25ºC) and low humidity (high VPD) on cone development and seed set (2nd year cones). On sample trees within each block, we assessed the phenological development of pollen and seed cones, counted the number of first and second year cones, sampled both 1st and 2nd year cone mass, determined seed yields and seed weight in 2nd year cones and assessed tree vigour by treatment block.

Results:
- Pollen supply was not limiting. It was among the highest level measured in any conifer orchard.
- Pollen viability, measured by in vitro assays, was also high (field fertility is currently being tested).
- Phenology (seed or pollen cone development) was not affected by treatments.
- Synchrony between pollen shed and seed cone receptivity was good.
- Spring and fall cone counts of first- and second-year-seed cones showed no significant effects to treatment. However, variation between orchards was apparent. KAL showed higher average pollen cluster counts per main whorl branch, higher spring counts of first- and second-year seed cones, and higher cone retention for first-year seed cones.

- Cone mass for first- and second-year seed cones varied by block and by orchard site. At KAL, misting significantly increased first-year dry cone mass but treatments had no effect on second-year cone mass. At PRT, no irrigation effects were observed and the misting system was not tested due to poor line pressure. There were little differences in dry cone weight between orchards for first-year cones but at PRT, second-year dry cone weight was about 20% less.
- Seed yields, expressed as the number of total seed per cone (TSPC), the number of filled seed (with mature embryo) per cone (FSPC) and seed weight (mean +/- standard errors) varied by treatments at KAL but not at PRT (see tables). Results from 2000 treatments suggest that crown misting had a significant effect on second-year cone development. Since crown misting did not begin until after the pollination period (April 27), the treatment likely was affecting ovule fertilization and early embryo development, which occurs in June. Due to equipment failure, misting in the irrigation block (Irrigation/Mist) did not occur for most of June. This may explain the small but non-significant increases in seed yields.

Irrigation improved seed yields somewhat at KAL but the magnitude was not significant (no effects at PRT). It is likely that irrigation water uptake is limiting seed yields but improved yields due to irrigation are not expected to be noted until root volume has expanded to increase water uptake (1–2 more years).

KAL 2000				
	Control	Irrigation/Mist	Irrigation	Mist
Cone Yields				
Total Seed per Cone	22.4 (2.4)	23.3 (2.2)	23.3 (1.9)	25.1 (2.5)
Filled Seed per Cone	9.7 (1.6)	13.0 (1.5)	11.9 (1.4)	15.9 (1.9)
Seed weight (mg)	4.1 (0.14)	4.2 (0.16)	4.6 (0.24)	4.4 (0.10)
PRT 2000				
	Control	Irrigation/(Mist)	Irrigation	(Mist)
Cone Yields				
Total Seed per Cone	20.4 (2.3)	16.1 (2.0)	16.2 (2.1)	18.2 (2.0)
Filled Seed per Cone	8.1 (1.1)	5.2 (0.67)	6.4 (1.1)	7.5 (1.1)
Seed weight (mg)	3.9 (0.19)	3.9 (0.14)	3.6 (0.17)	4.0 (0.18)

Table 11. Seed yields at KAL and PRT

Note: misting treatment at PRT was not tested because of low line pressure but will be tested for the year 2001.

Conclusion:

The first year results from the KAL misting block provide an important clue to one possible cause of the chronic low seed yields in north Okanagan lodgepole pine seed orchards. Misting during June and July led to significant increases in seed yields. However, we can not rule out the possibility that wetting the crowns during periods of high temperature (and low humidity) actually allowed the crowns to take up more water through the foliage. It is likely that both mechanisms (crown cooling and increased water uptake) are contributing. Misting is effectively helping the reproductive development of second year cones (June) when resumption of pollen germination, fertilization, and early embryo development occur. Higher seed yields (FSPC) will occur as the root volume increases in response to better irrigation technique.

2.3.42 Deployment of Major Gene Resistance into White Pine (*Pinus monticola*) Seed Orchards

Abul Ekramoddoullah

Objectives (SPU0802):

- To grow seedlings of control crosses of MGR in Puckle road seed orchard (May 2000)
- To inoculate white pine seedlings of control crosses of MGR in Puckle road seed orchard in (August of 2000 and 2001)
- To evaluate inoculated seedlings for resistance (May 2000 through March 2002)
- To stratify seeds of control crosses of MGR with the interior white pine (Mike Carlson's cross) and grow these seedlings (December 2000- May 2001).
- To inoculate seedlings (as in 3) for resistance (August of 2001 and 2002).

Output and Deliverables:

- This project would have over a thousand resistant seedlings by December 2000 to provide enough materials for seed orchards to produce improved seeds and to produce pollens for future crosses with BC white pine trees.
- One hundred resistant (MGR X slow-canker growth) seedlings by August 2002.
- Forty scions from canker-free seedlings by August 2000.

Progress: Materials and Methods

Seedlots 3277 and 3278 of western white pine were collected from Dorena, Oregon, USA. seed orchard trees. Seedlot 3277 is from tree with USA registration # 119-15045-845x open pollinated while seedlot 3278 is from tree with USA registration # 119-15045-845X15045-841x open pollinated . These parental trees carry major gene resistance (Cr_2) to the white pine blister rust fungus. According to Mandelial segregation, 50 % the seedlot of 3277 would carry Cr_2 while 75% of seedlot 3278 would carry Cr_2.

Seeds were stratified and grown in styroblock using a well established protocol. Seedlings were grown in 1994, 1996, and 1997. Four- month old seedlings were inoculated with blister rust fungus by placing them in Ribes' garden in late August and re-inoculated in the following year. The high level infection on the Ribes is maintained with composite inoculum from six British Columbia sources by natural ureadial infection following initial infection with aeciospores of the blister rust fungus, Cronartium ribicola. Foliar symptoms were monitored monthly for a year evaluate the success of inoculation and the development of immediate hypersensitive reaction (Kinloch et al). The resistance and susceptibility in all experiments were recorded by the presence /absence of stem cankers following two inoculations. Usually trees that developed cankers following first inoculation were either not included in the second inoculation. Over nineteen hundred seedling representing two seedlots were screened for their susceptibility/resistance to the fungal isolates.

Results and Discussion:

In our first experiment, 120 seedlings representing two seedlots were inoculated in 1994. A large number of seedlings died of root infection from Fusarium. Of the surviving 63 seedlings, foliar symptoms were scored in 1995 (Table 12) necrotic-type hypersensitive reaction. Based on these symptoms, 29% of seedlings derived from seedlot 3277 and 74% derived from seedlots 3288 exhibited hypersensitive response. There appears to an agreement with Mandelian segregation of dominant gene resistance. However, one has to be cautious about this agreement which was not based on the number seedlings inoculated. Since scoring of foliar symptoms for hypersensitivity is difficult, we confirmed the phenotype by the lack of stem cankers. Root disease killed all but seven trees. Following two inoculations, the seven survivors are still canker free. Forty scions derived from these trees were also inoculated twice. Thirty- four of these trees were canker free while six scions developed cankers in their root stocks. Two of these died while other six cankers on scions are limited to the root stocks.

Seedlot	3277	3278
# of seedlings inoculated in the first year.	44	76
InoculationYear	1994 & 1995	1994 & 1995
# of seedlings survived* following examination	35	38
% Putative Hypersensitivity As of August 1995	29	74
# canker free trees as of Sept. 2000	3	4
Expected ratio	1:01	
Actual results		

**Trees died of Fusarium/Phythium infection.*

Table 12. Screening of seedlings sown in May 1994.

In second experiment (Table 13), another batch of seeds were collected and sown. Sixty-four seedlings representing the two seedlots sown in May 1996 were first innoculated in September 1996. The foliar symptoms were scored in Jan 1997. Fifty percent of the seedlot 3277 and 46% the seedlot appeared to have a hypersensitive response. Although there was no difference in the ratio of hypersensitivity response between these two seedlots, there was a difference in terms of cankers which was scored several months after the second inoculation. Thus, forty-six percent of seedlings of seedlot 3277 developed cankers while only 23% of seedlings of seedlot 3278 had cankers.

Seedlot	3277	3278	3277	3278
# of seedlings during first inoculation				
Inoculation Year	24	40	20	37
	Aug 1996 & Aug 1998	Aug 1996 & Aug 1998	Aug 1997 & Aug 1998	Aug 1997 & Aug 1998
% Putative HR based				
foliar symptoms as examined on Jan 1997	50	46		
% cankered trees as of Jan 1998	46	23		
# canker free trees Sept 2000	8	28	10	22

Table 13. Screening of seedling sown in May 1996

In a third experiment (Table 14), 784 seedling representing two seedlots were first inoculated. Root-rot from *Fusarium/Phythium* infection killed a large number of seedlings. Of the surviving four hundred seventy three seedlings, 29% of seedlings from seedlot 3277 and 11% of seedlings of seedlot 3278 had stem cankers.

Seedlot	3277	3278
# of seedlings during first inoculation	448	336
Inoculation Year	1997 & 1998	1997 & 1998
# Survived following fusarium infection	277	196
% cankered trees Sept. 1998	29	11
# canker free trees Sept 2000	214	182

Table 14. Screening of seedlings sown in 1997

In the fourth experiment (Table 15), 946 seedlings were inoculated at sixteen-months of age. A significant fraction of these seedlings were killed by root-rot. Among the survivors, 23% of seedlot 3277 and 18% of seedlot 3278 had developed cankers.

Seedlot	3277	3278
# of seedlings during first inoculation	498	448
Inoculation Year	1998 & 1999	1998 & 1999
# Survived following fusarium infection	337	381
% cankered trees for survivors Sept. 99	23	18
# canker free trees Sept 2000	324	372

Table 15. Screening of seedlings sown in 1997

Due to infection of seedlings with *Fusarium/Phythium* a Mandelian segregation of dominant gene resistance of western white pine seedlings could not be established. In general, seedlot 3278 was more resistant than the seedlot 3277. It is, however, clear that the western white pine carrying the major gene resistance to the rust fungi is also resistant to the BC isolates of the fungus.

2.3.43 Results of Cone Induction/ Enhancement Trials for 2000/2001

John N Owens and Luke Chandler,

The original 2000-2001 proposal designated the western white pine (Pw) clonal orchard at the BCMF Saanich Seed Orchard. Unfortunately, trees were destroyed in this orchard by vandals and we had to seek an alternate site in which there were enough trees to carry out the trial. Tim Crowder at Timber West offered his orchard. Although there were fewer trees and they were older and more variable in size, it was a suitable alternative site for the first year of the study which would include one spring (April-May) treatment and one fall (September-November) treatment. However, there were not enough trees to do a trial in the second year.

Design and treatments in the first year trial (2000-2001) Spring study

On long shoot terminal buds (LSTB) of Pw, large distal axillary apices begin differentiation into seed cone buds shortly after dormancy (Owens and Molder, 1977a), the occurrence of which can be identified by increasing mitoses. Previously it was determined that LSTB resumed growth in early April and bract initiation began in early May (Owens and Molder, 1977a,b). Four larger, mature trees at the orchard and one tree at the University of Victoria were monitored for an increase of mitotic activity in distal lateral apices of LSTB following the methods of Grob and Owens (1994). Juvenile trees were not monitored to avoid destructive sampling of experimental trees. Unexpectedly, LSTB of juvenile trees showed visible signs of growth earlier than their older counterparts. Elongation of shoots from juvenile and older trees was followed to record differences.

One hundred trees ranging in height (93 -170 cm) were selected for the spring 2000 experiment. Shorter trees were left for the fall treatment by which time they would have undergone another seasons' growth. Each of the one hundred trees was randomly assigned to one of five treatments. Treatments were as follows:

- (T-1) Control (0.2 ml 80% EtOH)
- (T-2) $GA_{4/7}$
- (T-3) $GA_{4/7}$ + fertilizer
- (T-4) $GA_{4/7}$ + fertilizer + girdling
- (T-5) $GA_{4/7}$ + fertilizer + girdling + tenting

Gibberellin-treated trees were injected twice (17 April and 25 April) with 10 mg in 0.2 ml 80% ethanol each time. Fertilized trees received ammonium nitrate fertilizer (32-0-0-11S) once (19 April) at an active concentration of 31.4 g∞l-1 around a 1 meter diameter base (400 kg∞hectare-1). Girdling was done at the time of the first GA application with a cable saw as two semi-circular cuts 1-2 cm apart on opposite sides of the stem at least 2 cm above the point of grafting. A-frame style tents, made from 2 x 2 in boards and heavy polyethylene film, were constructed and placed over trees on 18-19 April and removed 8 June. Tents were vented at the top and bottom to allow excess heat to escape. Thermocouple wires, the ends of which were protected from solar radiation by two plastic spoons, measured temperatures inside three tents (one at the top of each tent and one in mid-crown). The outside temperature was measured for the duration of tenting. Thermocouples at the top of the tents were monitored to ensure temperatures did not become excessive. Temperature readings were taken every 30 seconds and 10-minute averages recorded with a Campbell Scientific 21X data logger.

Fall study

Treatments and experimental design for fall pollen-cone enhancement (and perhaps seed cone preconditioning) were similar to that in the Spring experiment. Injecting of $GA_{4/7}$, fertilizing, girdling, and tenting was done the same way, as was the control treatment. In the fall treatment, trees were tented on 3-4 September, injected with $GA_{4/7}$ on 5 September and 11 September, and fertilized on 12 September. Tents were removed in November.

Results from the first year trial (2000-2001)

Results are only available for the spring trial. The fall trial was completed in November 2000 but results on pollen-cone and seed-cone induction/enhancement will not be known until cones emerge in May-June 2001.

Spring 2000 Trial

The spring 2000 trial was intended to enhance seed-cone production for pollination in May-June 2000. Pollen-cone buds were already initiated in the fall 1999. Table 16 and Figure 47 show the results form the spring 2000 treatment. Control, $GA_{4/7}$ and $GA_{4/7}$ + fertilizer + girdling and $GA_{4/7}$ + fertilizer + girdling + tenting treatments yielded 1.5 and 2.1 cones per tree (30 and 40 cones/treatment), respectively. Table 17 shows the effect of tenting on temperatures within the tents compared to ambient temperatures.

Treatment	No. of cones (n=20 per treatment)	Avg. No. of cones per ramet
per ramet		
Control (95%Et0H)	14	0.7 ± 0.27
GA 4/7	8	0.4 ± 0.15
GA + fertilizer	14	0.7 ± 0.21
GA + fert. + girdling	30	1.5 ± 0.39
GA + fert. + gird. + tenting	42	2.1 ± 0.48

Table 16. Cone enhancement in western white pine (Pinus monticola) with Spring 2000 treatments. Total number of cones and average number of cones (± SE) produced on juvenile trees after cone induction treatments.

Time	Tent-high	Tent-low	Outside
6:50-10:50	16.43	16.43	12.45
10:50-14:50	21.64	21.15	15.7
14:50-18:50	21.09	20.12	15.65
18:50-22:50	11.17	11.12	10.82
22:50-6:50	7.41	7.35	7.83
Max	40.6	37.46	29.28
Min	-2.63	-2.95	-2.04

Table 17. Temperatures averaged for the duration of tenting (19 April - 8 June). Six thermocouples placed inside three tents either at the top of the tent (tent-high) or in the mid-crown of the tree (tent-low) and two thermocouples on trees outside tents to measure temperatures.

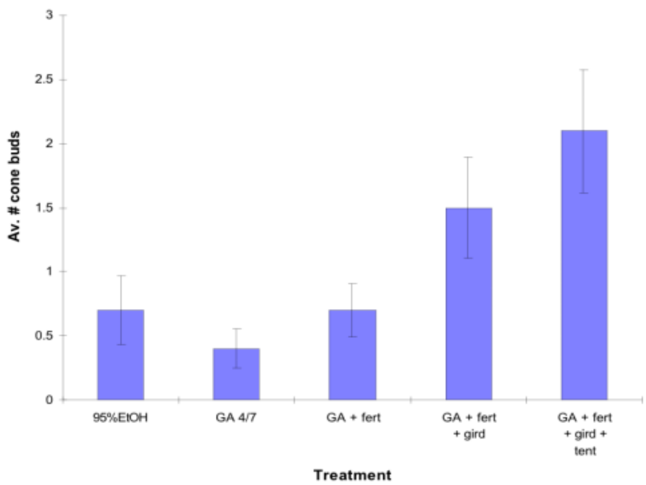


Figure 48. Seed-cone induction/enhancement in western white pine (*Pinus monticola*) with spring 2000 treatments

Materials/tree		Person hours/tree	
$GA_{4/7}$	$0.70	Monitoring	15 min
Fertilizer	0.10	$GA_{4/7}$ + Fert	15 min
Tents*			
Polyethylene	5.70	Construction	30 min
Lumber	13.00	Field assembly	30 min
Hardware	1.50		
Total cost/tree	$21.00	Total time/tree	1 hr. 30 min/tree

Table 18. Estimated cost per treatment and tree at the coastal site: Initial cost

Wood frames, as we have constructed them, can be quickly taken down, stacked, stored and used several (5-10) times. The polyethylene on the front and back could be used for about two trials but that on the two sides would have to be replaced with each trial.

Materials/tree		Person hours/tree	
$GA_{4/7}$ + Fertilizer	$0.80		30 min
Tenting	$ 2.00		30 min
Monitoring			15 min
Total cost/tree	$2.80	Total time/tree	1 hr. 15 min/tree

Table 19. Cost for subsequent uses of tents per tree

Literature cited

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2.3.44 Seed Production In Lodgepole Pine Seed Orchards: A Developmental Perspective

John Owens

Introduction

In order to meet the demand for Class A lodgepole pine seed by 2007, it is estimated that, at the present rate of cone and seed production from existing orchards, up to 60,000 new ramets will be required. One of the largest orchards is the Ministry of Forests (MoF) orchard at Kalamalka (KAL) and this is a logical place to expand the existing orchards. The infrastructure is already in place. However, over the past few years filled seed production at KAL has been only 20 to 50 percent of that obtained at the M of F orchard near Prince George (PGTIS). Before the decision is made as to where to establish new orchards and how many new ramets will be required, we need to know why seed production per cone is so much less at KAL and are there orchard management techniques that can be applied to increase the seed production per cone at KAL to a level approaching that at PGTIS.

The approach has been developmental; looking at the pollination process and subsequent cone and seed development at several stages in order to determine the causes of low seed set at KAL and when these causes occur. Using control and open pollinations, cones are sampled and dissected at the time of pollination to determine the pollination success (pollen adhering to the arms of the ovules, Pollen-on) and after cones have closed to determine the percentage of ovules that were successfully pollinated (pollen taken into the ovules, Pollen-in). Since lodgepole has a two-year reproductive cycle, cones are also sampled at fertilization, after winter dormancy, to determine the percentage of ovules per cone that are successfully fertilized (fertilization success). Cones are sampled again at maturity and all seed is extracted to determine the seed efficiency per cone (filled seed per cone) as well as the percentage of other types of seed within the cone that may be empty, rudimentary or insect damaged. The causes and time of seed loss can be determined based on our developmental (anatomical) studies. Cone counts are also made at pollination, within one month after pollination, after winter dormancy and at cone maturity to determine the time and amount of cone loss. This approach allows us to determine the reproductive success at different orchards and the relative importance of different causes for low seed set and cone survival. From this we should be able to recommend measures that will increase seed production at KAL.

Specific objectives of the 2000-2001 proposal (SPU1003).

- To compare the pollination process using the same clones at KAL and PGTIS and some of the same clones at an intermediate site at PRT-Armstrong.
- To determine the precise times and causes of seed and cone loss at the three orchards using control and open-pollinations.
- To determine the importance and the time and method by which seeds are lost as a result of self-pollination.
- To determine the phenology, size, time of production and proportion of ovules producing a pollination drop at the dry KAL site and the wet PGTIS site.
- To set up a preliminary trial to determine the effect of misting on pollination drop production and pollination success at KAL.

Materials and methods:

During the first year of our study, three seed orchards were studied intensively: KAL and PGTIS having low and high seed production, respectively, and an intermediate orchard (PRT at Armstrong). Some observations were also made at the Vernon Seed Orchard site (VSOC). Pollen flight was monitored daily at all four orchards and seed cone phenology was monitored daily at the first three orchards. Seed cones were assigned to stages 0-7, photographed and dissected to observe the stage of ovule development and receptivity at all stages. Six clones common to the KAL and PGTIS were studied in the same manner at both sites. Six other clones were studied in the same manner at PRT. Cones were pollinated with .5ml of a polymix of pollen at Stage Three, Four or Five, or pollinated at all three stages (multiple) while other cones were left for open pollination and served as controls. For the experiment on the effects of selfing, four clones common to KAL and PGTIS were selected and pollen collected. Cones on each clone were self-pollinated, cross-pollinated or left for open pollination. Cones were sampled at pollination, after pollen was taken into the ovules and near the end of the first season. Collections and fixations will continue in the second year (2001) at fertilization and during embryo and seed development. Ovules are sampled and fixed for paraffin sections and for infrastructure using the transmission electron microscope (TEM). Paraffin-embedded specimens have been sectioned and observed microscopically and TEM specimens have been embedded for collections made up to dormancy in 2000. Cone counts were made at pollination, about one month after pollination and at dormancy in 2000. The presence and abundance of pollination drops was determined from cones dissected at receptivity for the same clones at KAL and PGTIS. PVC pipes with two misting heads were erected into the upper crown of 10 trees at KAL and trees were misted for about one hour, from 6 to 7 am, every morning during the receptive period. Cones were sampled from these trees and from nearby un-misted trees before and immediately after the misting each day and taken to the lab where they were dissected and the proportion of ovules bearing a pollination drop was counted.

Results:

The seed cone phenology at pollination varies among sites but the pollination mechanism is similar at all sites. It involves a pollination drop mechanism in which there are erect cones with inverted ovules, saccate pollen, sticky micropylar arms that collect pollen and a pollination drop that scavenges pollen from the arms and, if large, from other nearby cone surfaces. Protandry did not occur at any of the sites in

2000 which was a cool spring. Pollination success was highest in Stage Four cones and with multiple pollinations, at stages three, four and five, and these were similar to open pollination. Pollination success (Pollen-on) was highest at PRT (12-18 pollen/ovule) and lower at KAL (5 to 10 pollen/ovule) and PGTIS (5-12 pollen/ovule). Pollination success (Pollen-in) was measured about three weeks after pollination and was about the same (~80% of ovules were pollinated) regardless of stage at pollination, multiple pollinations or open pollinations. This should have been measured about one week after pollination rather than three weeks since it appears that many cones that had fewer pollen per ovule may have aborted before these cones were collected.

Cone survival was measured about one month after pollination. Cones abort and drop if too few ovules are successfully pollinated. Cone survival was high (~80%) at KAL and PRT but lower (~50%) in PGTIS open-pollinated trees. Results from the Pollen-in study and cone survival study indicate that if about 80% or more of the ovules are pollinated the cone will not abort. The determination of the times and causes of seed loss is ongoing and requires observations for the second year as well.

A preliminary study of open-pollinated mature cones collected in the fall of 1999 and 2000 at KAL and PGTIS show low seed per cone in 1999 (~7) and higher in 2000 (~15) at KAL but both much lower than the (~25) at PGTIS in both years. The number of empty seeds with well-developed seed coats but no embryo, indicating that ovules were pollinated but aborted at or after fertilization, was five to ten at both orchards in both years but appears to be slightly higher at KAL. The number of flat (early aborted) and insect damaged seeds was low at both orchards in both years.

The effect of self-pollination and cone, ovule and seed development is being determined by comparing anatomically ovules from self-pollinated, cross-pollinated and open-pollinated cones from the same clones at KAL and PGTIS. Specimens of first year cones have been sampled, fixed and embedded in paraffin and resin (for TEM) and paraffin embedded specimens have been sectioned.

Cones were sampled, dissected and ovules observed from Stage three through five or six at the dry KAL and wet PGTIS sites to determine the phenology, size and time of pollination drop secretion. Pollination drops were small and found in few ovules of cones from KAL unless it had recently rained, whereas they were large and found in a high proportion of ovules every day in cones from PGTIS where it rained almost every morning and the humidity was usually high.

A preliminary misting trial was done at KAL in 2000. The results indicate that misting greatly increases the percentage of ovules with pollination drops compared with trees not misted. In misted cones at KAL and not misted cones at PGTIS, pollination drops were most frequent at Stages four and five. Ground misting did not increase the pollination drop frequency at KAL (Figure 48). Weather data has been obtained from the Coldstream Station near KAL and from the PGTIS. In general, the highest relative humidity at KAL is about equal to the lowest relative humidity at PGTIS during the pollination period. This aspect requires a more complete study in 2001.

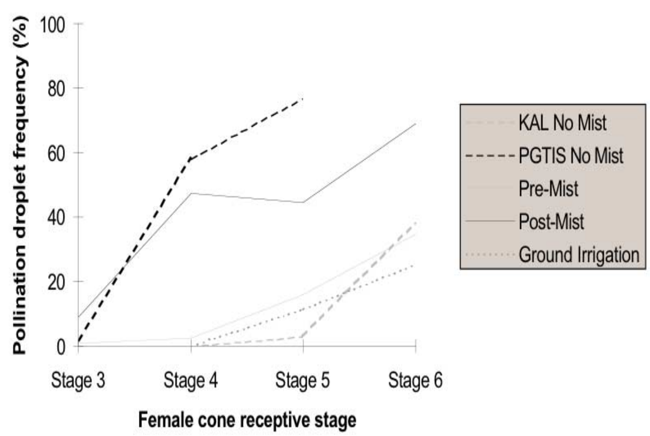


Figure 49. *Pinus contorta* var. *latifolia* pollination droplet frequency in receptive female cones by stage of cone development at KAL and PGTIS in 2000.

Summary:

The information collected so far in the preliminary work and the 2000-2001 studies indicates that the very warm and dry conditions experienced at KAL at the time of pollination may be a major factor in the low seed production at that seed orchard. Past records at KAL indicate that protandry frequently occurs which would result in low pollination success. Seed cones develop primarily in response to temperature but pollen cones and pollen release are a response to both temperature and drying. The dry conditions at KAL, as indicated by the relative humidity compared to PGTIS, also appear to reduce the size, longevity and abundance of pollination drops which would reduce the pollen taken into ovules. The 2001-2002 work will complete the second year cone collections and cone and seed analyses and set up a trial misting system before and at the time of pollination that should reduce protandry, if it is a dry spring, and increase the humidity around cones at pollination to increase the size, longevity and abundance of pollination drops. These factors should increase cone survival and filled seed for the 2003 cone crop.

2.3.45 Seedlot variation in Lodgepole pine using chloroplast DNA markers

Craig Newton

The genetic worth of seedlots derived from seed orchards is a function of a) the genetic gain of the parental clones and b) their relative contribution into the annual seed crop. Until recently only the maternal contribution could be measured (based on cone harvest volume). The paternal or pollen contribution could only be assumed from indirect measures such as pollen traps or counting the number of male strobili on different clones. Previous investments by FRBC have led to the development of DNA based diagnostic assays specific for the male pollen gamete (see OTIP SPU1408). The relative contribution of different parental clones into seedlots can then be measured directly based on seed embryo DNA haplotypes that identify the origin of the fertilising pollen. Depending on the resolution of such marker systems, these assays can be used to measure the contribution of different parental clones within an orchard (gametic balance, self-fertilisation) or the level of outside orchard sources (pollen contamination). Because wind borne pollen are highly sensitive to environmental conditions (temperature, rainfall etc), it is expected that paternal contribution will be a significant factor in variations in the genetic worth of reforestation seedlots.

The goal of SPU1004 was to determine the degree of yearly variation in seedlot composition from an operational seed orchard using the chloroplast DNA based assay developed previously (FRBC HQ96308-RE) for lodgepole pine (*Pinus contorta* var. *latifolia*). The first stage of this project was to haplotype parental clones from the three major lodgepole pine pollen sources located at the Grandview Reforestation Centre: orchard #308 (n=40), orchard #311 (n=67) and orchard #313 (n=40). Vegetative buds were collected from single ramets in the fall of 2000 and total DNAs were extracted and haplotyped as described previously (HQ96308-RE). Seedlots from orchard #308 were obtained from the Tree Seed Centre for the years 1995[seedlot #60401], 1997[#60403], 1998 [#60404], 1999 [#60405] and 2000 [#61123]. For each seed, hand dissected embryo tissues were prepared in Chelex resins and then haploptyped using the same '6 mix' as was used for the vegetative parental tissues. Figure 49 shows a typical autoradiogram for the results obtained. The six chloroplasts loci (6 mix) used in this assays are visible in bin sizes of approximately 315 bp (9.1/87R), 250 bp (L2/T1b), 178 bp (69F/R), 157 bp (10F/RR), 130 bp (I1.1/A2), and 117 bp (K2/K3). Polymorphic size variation is evident between different lanes, which each contain the assay products from different seed embryos. K2/K3 replaces an earlier site (G2.1/R1) that was difficult to multiplex in conjunction with the 5 other polymorphic loci.

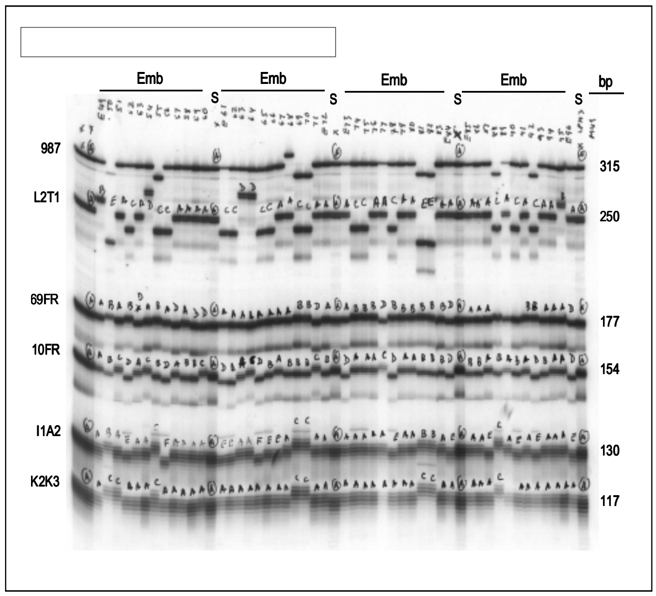


Figure 50. Lodgepole Pine Embryo Haplotyping

To provide statistical confidence, between 300 and 600 seeds were analysed per seedlot, for a total of 1800 multiplex haplotypes or approximately 10,000 individual chloroplast genotypes. In addition some 250 megagametophytes were analysed to given approximate measure of maternal contribution from seedlots 60401 and 60403. All analytical work has been completed at this time and the data analysis is currently underway. The results are expected to give the first molecular analysis of seedlot composition from a conifer operational seed orchard and will provide valuable insight into the dynamics of seedlot genetic worth.

2.3.46 Improvement of Yellow-Cedar Hedge Orchards Through Roguing of Elite Clones with Poor Nursery Performance, and Through Cultural Techniques and Rejuvenation.

Bevin Wigmore and John Russell

Background:

Elite clones identified by the Ministry of Forests are currently being established as operational hedge orchards at four sites. It is imperative that these selected clones are screened for nursery performance, 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.

Even with selection of high quality clones, production of good crops still depends on the juvenility and health of the originating hedge orchards. More information is needed on the use of serial re-propagation to rejuvenate hedges. As well, operational users have expressed a need for more information on cultural techniques to maintain existing hedges.

Objectives:

The objectives of this project (SPU1102) are to improve the production from, and quality of, Yc hedge orchards; and to rogue elite clones with poor nursery performance.

Progress to Date:

This is the second year of a four year project. The objectives are being addressed through a number of approaches. Cuttings from 22 of the elite MoF clones were taken this year from two hedge sites – WFP Saanich Forestry Centre, and the MoF Cowichan Lake Research Station. They will be evaluated at Cairnpark nursery for rooting performance and stock quality. Clones from the Weyerhaeuser hedge located at TimberWest's Mt. Newton Seed Orchards are also being screened, this time for symptoms of maturation.

One trial which has been completed this year is the assessment of cuttings from a serially-propagated experimental hedge located at the Cowichan Lake Research Station. Cuttings from selected donors within this hedge were set at Cairnpark Nursery and evaluated for rooting percentage and growth characteristics. The donors were up to seventeen years old and had been through up to four propagation cycles for any given clone. There were 24 clones in the nursery trial, and for each clone there were different types of donors; for example, an original 17 year old seedling, a 12 year old cutting taken from that seedling, an eight year old cutting taken from the first cutting, and a four year old cutting taken from the second cutting. While analysis of the data is not complete, it appears that clone contributes at least as much to rooting and growth performance as does propagation treatment.

A small hedge has been established at Cairnpark Nursery for the purpose of fertilizer trials. The fertilizer treatments applied this year did not produce a difference in foliar nutrient composition, so the cuttings were used in a time-of-year trial instead. Cuttings were taken before and after the first hard frost in the fall, as well as in January and March. Propagation boxes provided by the MoF yellow-cedar breeding program provided consistent rooting environments at different times of year.

2.3.47 Development of Pollen Management Guidelines for Yellow-Cedar

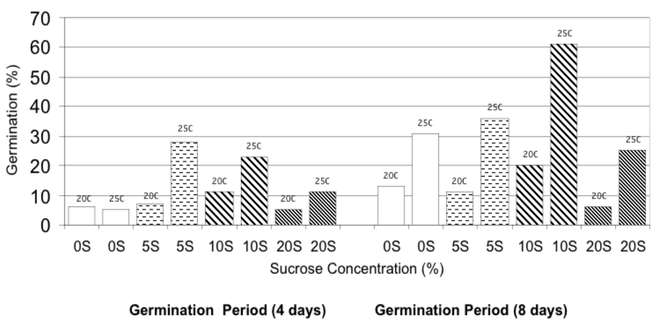
Oldrich Hak

The success of any seed production program, breeding or commercial, depends largely on the viability of pollen. Pollen viability testing, therefore, is vital to ensure that viable pollen is used for pollinations. Reliable operational method to estimate the viability of yellow-cedar pollen is currently not available.

The purpose project (SPU1106) was to develop germination media that provide the best pollen germination response. The development of the media was based solely on pollen collected from low elevation seed orchards. The project results suggest that the orchard pollen is of poor quality (i.e. low vigour and deformations of pollen tubes) and when compared to high elevation natural stand pollen, it may be considered non-viable and unsuitable for pollination. For the above reasons, the information provided in this report should be interpreted as indicative. The results should be confirmed and the methods refined using high quality viable pollen collected from natural stands.

The development of media for pollen germination was based on combinations and percentages of agar, sucrose, PEG, and Brewbaker's solution. Seventeen solid media types were tested. The medium that provided the best germination was a combination of 0.3% agar and 10% sucrose (Figure 50.). The highest germination percentage was obtained after eight days of germination (Figure 50.). Yellow-cedar pollen germination also responded positively to a higher temperature of 25°C when compared to 20°C (Figure 50.).

Pollen germination was scored at three vigour levels: A = high vigour, B = moderate vigour, C = very low vigour or deformed pollen tube. Only germination levels A and B are considered as viable pollen. None of the pollen tested in this project achieved level A or B.

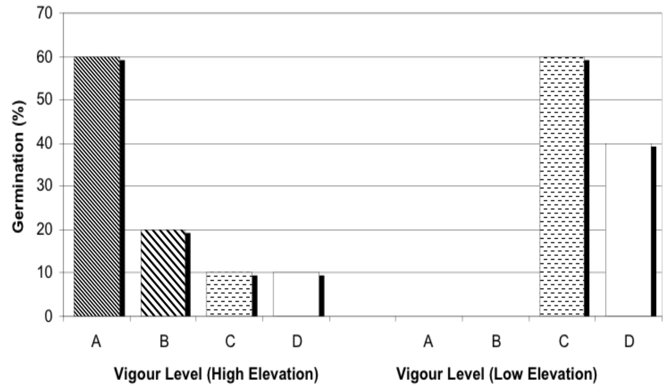


* %Germination = C/(C+D) (i.e. no A or B vigour were observed)

Figure 51. The effect of sucrose concentration, temperature and germination period on Yc pollen germination*.

All pollen collected from seed orchards had very low germination vigour (level C), with many pollen tube deformations and with high incidence of fungal infection in the germination media. In contrast, a limited sample of pollen collected from a natural stand at high elevation had high germination vigour (scoring vigour "A" and "B"), minimal pollen tube deformations, and no fungal infection (Figure 51).

Indications are that the low elevation pollen, which may complete its development early in the fall, slowly deteriorates during fall, winter, and spring, resulting in pollen of inferior quality at the time of pollination. It is possible that the low elevation pollen is subjected to prolonged respiration processes and/or is negatively effected by natural elements such as heat, UV light, and fungal infection for a longer periods than the high elevation pollen which matures later in the fall or during the following spring.



Legend:

A = high vigour (pollen tube length = or > than 3x the diameter of hydrated pollen grain)

B = moderate vigour (pollen tube length = or > than 1x diameter but < than 3x the diameter of hydrated pollen grain.

C = low vigour (pollen tube length is < than 1x the diameter of hydrated pollen grain or pollen tube is deformed -> any elongation does not resemble pollen tube)

D = non-active pollen

Figure 52. The effect of two environments on the vigour of Yc pollen

2.3.48 Operational Crown Management in an Interior Spruce "High Density" Seed Orchard and Two Western Larch Orchards

Gary Giampa and Chris Walsh

Proposed by Clare Hewson before his retirement, the project has now been taken over by Gary Giampa and Chris Walsh of the Kalamalka Seed Orchards.

Background:

Objectives of this program (SPU1301) are to determine which crown management techniques are most effective in controlling vegetative growth to allow for efficient crop collection and orchard management while maintaining or augmenting cone production.

Outline of Project:

Seven different crown management treatments were applied to ramets in the western larch orchards during the 2000 field season, following similar treatment regimes in place since 1996. Results of crop surveys were used to evaluate the effectiveness of the different treatments.

Trtmt #	Description	Prune Leader?	Prune Branches ?	Train?
1	Height control, necessary training	To 4m. height	To 4m. or if extending into rows	If extending +1.5 m. into rows
2	Moderate pruning	50% new growth, control @ 4m. height	No more than 25% to maintain hedge effect	If extending +1.5 m. into rows
3	Severe pruning	75% new growth, control @ 4m. height	No more than 25% to maintain hedge effect	If extending +1.5 m. into rows
4	Complete pruning	100% new growth, control @ 4m. height	If extending +1.5 m. into rows	None
5	Severe crown top	To 3m. if exceeding 5m. tall	If extending +1.5 m. into rows	If extending +1.5 m. into rows
C	Control	None	None	None
T	Trellised rows	To 4m. height	To 4m. or if extending into rows	If extending +1.5 m. into rows

Table 19. Treatments Applied to Ramets in Two Western Larch Seed Orchards

Five different treatments were applied to ramets in our Interior Spruce micro orchard. Each treatment was repeated in free-standing and trellised rows. Crop surveys were conducted to help evaluate the effectiveness of the different treatments.

Trtmt #	Description	Prune Leader?	Prune Branches ?	Train?
1	Height control, branch train	To 3m. if unable to train	To 3m. if unable to train	Along trellis, or to other branches
2	Freestyle	As seen fit	As seen fit	As seen fit
3	Moderate pruning, branch training	+50% new growth, control @ 3m. No leader shaping	+50% to maintain hedge effect	Along trellis, or to other branches
4	No prune, shape only	As last resort	As last resort	Along trellis, or to other branches
C	Control	None	None	None

Table 20. Treatments Applied to Ramets in the Interior Spruce Micro Orchard:

Results:

All three orchards involved in this program produced good cone crops in 2000. We were able to gather solid crop data and evaluate the different treatments

In the western larch orchards the control treatment and the severe crown topping treatment produced the highest average cones per tree (Figure 52). However, the crop on the control trees was difficult to manage due to the height of the trees. At this point severe crown topping appears to be the preferred method of crown management in the Western Larch orchards.

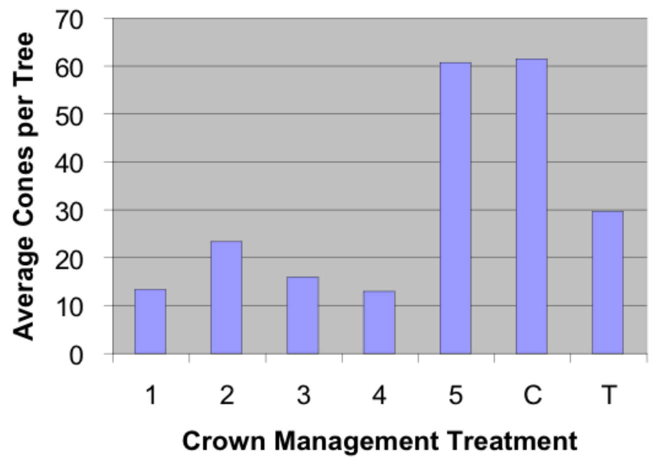


Figure 53. Larch crop by crown treatment (2000)

The results for the interior spruce micro orchard (Figure 53) are not as clearly defined. The control treatment and the moderate pruning/branch training treatment produced the lowest average cones per tree numbers. It appears that crown management in the micro orchard is beneficial in terms of cone production. Future crop data should show which treatments have the greatest effect.

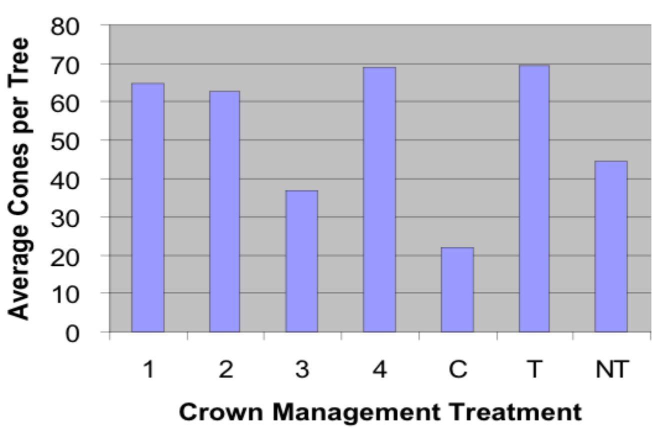


Figure 54. Sx high density crop by crown treatment (2000)

If our proposal is funded, we will continue to refine our crown management techniques during 2001, based on results to date. Another good cone crop will generate more data that will help determine with more confidence the most effective crown treatments for these types of orchards.

2.3.49 Development of Spruce Somatic Seedling Demonstration Sites in the Central Interior

Don Summers

Over the period 1995 through 1998, thirty-three ‘clonal block’ sites were each planted with a number of pure blocks of somatic seedling clones, cuttings/seedlings from seed orchard or wild seed. The sites were located throughout the Prince George Seed Planning Unit. The project (SPU1406) was designed to complement the more rigorous ‘candidacy trials’ that were installed to test the performance of somatic seedling clones for reforestation.

In 2000/01, measurements were done for those trees that were three or five years in the ground. The data is being processed to provide information on the first five years growth in the field and will be passed along to the cooperators in the project. The cooperators have also been contacted to ensure sites are documented and mapped in their records.

Local foresters were invited for a tour of three sites in October, 2000. Thirteen people, representing industry, consultants, academia and government took part in the day-long event and traveled to sites at Gregg Creek, Government Lake and North Willow. It is interesting to note that cuttings and seedlots appear to be doing quite well at most sites - by quite a margin. The results for emblings seem less consistent, however some clones are doing very well indeed. The companion candidacy trials should sort out those clones that might be used for reforestation in the future.

The ‘clonal block’ plantations will all be measured through five years in the ground. After that, only selected sites will be maintained for demonstration purposes. The rest will receive operational treatments as plantations.

Figure 55. Chris Hawkins addressing local foresters during a tour of clonal block plantations in October, 2000.

2.3.50 The Effect of Seed Orchard Environment on Progeny Performance in Interior Spruce: Seed Orchard After-Effects.

Joe Webber

Introduction:

There is a growing body of evidence suggesting that environmental factors can affect reproductive processes resulting in altered physiological (adaptive) traits. This phenomenon has been termed seed orchard after-effects and we have demonstrated its occurrence in interior spruce. However, data from this test could not be extended to all spruce parent trees nor was the design able to separate out maternal and/or paternal effects. These limitations have been addressed and controlled crosses from each of two orchard locations (Vernon and Prince George) have been completed using single parent crosses (20 males and 20 females).

Details of the experimental design and crossing scheme are given in the actual proposal (SPU1407). Pollen parents from the same genotypes were collected from the two arboreta sites in 1995 and stored at reduced pollen moisture content (6-8%) and freezer temperature (-20ϒC). The twenty female parents were randomly selected from the available flower crop at Vernon (Kalamalka) in the spring of 1996. The twenty pollen parents from the two sources were used to create progeny that only differed by the source of the pollen parent (i.e., south pollen x south female and north pollen x south female).

The Kalamalka crosses were completed in 1996. However, there was no crop at PG in 1996 and after repeated induction treatments, we finally got a crop in 1999. Only 18 of the original 20 clones used at KAL flowered. Because the seed were created three years apart, we also collected in 1999, wind pollinated (OP) cones from the same clones at Kalamalka and Prince George. While the male parents will not be similar, if the after effects work through the maternal side (which we are now beginning to think it does) then these OP comparisons may prove to be very valuable.

Temperature Effects:

We have a growing body of evidence to suggest that temperature during reproductive development may explain after-effects. We are testing a series of experiments by applying different temperature regimes during various stages of reproductive development. In the first test, we applied two temperatures (12ºC and 24ºC) during post pollination to early embryo development. We term this test GamSel (gametophytic selection) and found that progeny from the cool environment have constantly been more frost hardy in both early fall and late spring tests. We have also shown that temperature effects applied during pollen meiosis had no effect on progeny performance.

In 1999, we expanded temperature effects to include early seed cone development (FemCon) including meiosis and post pollination reproductive stages and the late stage of embryo maturation (EmCon). For FemCon and EmCon, single pollen parent crosses on six clones were treated to three levels of heat (22ºC, 18ºC and 12ºC) during two stages of reproductive development. For FemCon, treatments began prior to seed-cone bud swell (pre-meiosis) and extended to early embryo development. From past experiments, we knew early embryo development began around 50 days after pollination for the warm treatments and about 60 days for the cool. For EmCon, heat treatments began about the time of fertilization and continued through to the end of embryo maturation. Heat treatments began about 40 days after seed-cone bud swell (about 30 days after pollination) and continued until cone maturation. This was about 60 days for the heat treatment and about 85 days for the cool treatment.

Year 2000 Activities:

Objectives for 2000/01 were to grow the seedlings of aftereffects, FeCon and EmCon and prepare a plantation design. Seed derived from the after effects crosses, FemCon and EmCon were grown at Skimkin Nursery. This represents a potential of 340 families to test. Since some of the crosses were lost (mostly at PG) we ended up sowing a total of 324 families for the after-effects test. For both FemCon and EmCon, 18 seed lots each were made for a total of 36. We grew a maximum of 77 seedlings per cross in stryo-415Ds for each. The trees were lifted in the first week of December 2000. These seedlings are now in cold storage and, depending on 2001/02 funding, planted in tow sites in the Prince George region.

2.3.51 Chloroplast DNA Markers Spruce and Larch

Michael Stoehr

Chloroplast (cp) DNA markers have proven useful for assessing a range of questions regarding seed orchard efficiency and the *genetic worth* of conifer seed crops. Currently, operational cpDNA assays exists for lodgepole pine (SPU1004) and Douglas-fir The goal of SPU1408 was to develop similar assay systems other B.C. reforestation species, specifically spruce (White, Engelmann and Sitka) and western larch.

The overall approach was to screen cpDNAs from range wide or orchard populations using sets of *Pinus* based amplification primers to identify polymorphic regions that can be used to build diagnostic multiplex assays. The amplification primers used in this study comprise 51 primer pairs that cover the entire non coding region of the *Pinus* cp genome. These primers were used to amplify the corresponding regions from the test populations and polymorphic regions were identified after restriction endonuclease digestion and electrophoresis on denaturing polyacrylamide gels. In spruce a total of 12 different chloroplast sites gave between one and seven polymorphic variants in 12- 20 parental clones tested (Orchard #230 Shuswap-Adams). All but two of these sites (33.1/1819R and cp2627FR) have been localised to specific regions and corresponding primer pairs are currently being formatted into a multiplex assay. The cumulative discriminatory power from these markers is approximately 0.80. The paternal inheritance of these markers will be confirmed using controlled spruce crosses.

Preliminary screens using *Larix* have identified 5 cpDNA sites that give rise to between one and 4 variants in 12 range wide individuals tested (B. Yaquish,. MoF, Kalamalka). The current discriminatory power of the existing 5 *Larix* markers is approximately 0.5. Approximately one third of the possible non coding regions remain to be re-screened or confirmed using additional restriction endonucleases and electrophoresis conditions. If cpDNA markers alone do not provide sufficient levels of discrimination then nuclear *Larix* markers will be used.

2.3.52 Comparison of Genetic Worth Calculations using Standard Protocol and Gamete Contribution with Special Reference to SMP.

Michael Stoehr

Background:

For input variables, seedlot rating protocols require an estimate of female and male gamete contributions to an orchard seedlot. In practice, these input variables are either estimated based on reproductive bud surveys and/or estimated in the fall as volume of cones harvested (for female gamete contribution). However, the correlation between cone volume harvested per clone and the actual number of filled seed produced per clone may be weak and is generally unknown. The situation of estimating male gamete contribution is even more difficult as the identification of the pollen parent is impossible without some kind of molecular analysis. This especially applies to situations where determination of the SMP efficacy is required. Recently developed DNA techniques will make the estimates of male and female gamete contribution much more precise. In this project, chloroplast DNA (cpDNA) markers, which are paternally inherited, are used to genotype a lodgepole pine seed orchard and SMP efficacy rates determined.

Activities (SPU1603):

Genotyping of the 45 clones in Riverside Forest Products orchard #310 is being carried out with the aid of 6 cpDNA primers. The results listed in table 1 below are from three primers: L2/T1b, 9.187R and I1.1/A2. Clonal differences using primer K2/K3 at this time will probably result in 4 different bands, further increasing the separation power of this approach. However, more fine tuning with this primer is needed. Primers 10F/RR and 69FR have not proved useful to date, but will be tested on another electrophoresis system.

- Primer L2/T1b resulted in six different bands (a-f).
- Primer 9.187R resulted in three different bands (a-c)
- Primer I1.1/A2 resulted in five different bands (a-e).

As each band represents an allele, multi-locus genotypes have been assigned to each clone. Ten clones in the orchard have unique genotypes using just three primers. Further separation is expected when more primers are working.

Genotypes1	# of clones per genotype	Clone
abd	1	1083
bbd	1	803
cbd	1	1091
cbe	1	1086
dad	1	1046
db(c)or(d)	5	1031 1072 1094 1155 1161
dbd	15	829 860 861 883 1047 1048 1064 1076 1077 1088 1089 1127 1128 1134 1151
dcc	2	801 1090
ead	1	1122
eb(c)or(d)	1	1038
ebd	6	777 795 858 1126 1135 1153
ec(d)or(c)	1	824
eca	2	1021 1068
ecb	3	1000 1027 1124
ecc	2	1055 1125
ecd	1	862
fcb	1	1095

[1]The first letter refers to band for primer L2T1B, the second letter refers to band for primer 9.187r, the third letter refers to bands for primer I1.1/A2.Bracketed letters are still ambiguous and need further refinement in the methodology.

Table 21. Clonal identification using L2/T1b, 9.187R and I1.1/A2 cpDNA primers

Five cones from three ramets of 15 clones were selected for a comparison of both SMP and non SMP treated ramets. DNA was extracted from approximately 1000 seeds for both SMP and non SMP treated ramets. Approximately 800 seeds of the SMP treated ramets have been tested, to determine how often clones 1083, 803, 1086, 1091 and 1095 have been responsible for parenting that seed. Differences in male parentage between SMP-treated ramets and non-treated ramets is an indication of SMP efficacy.

2.4 SelectSeed Company Ltd.

Jack Woods – Program Manager, Forest Genetics Council of BC

Introduction

SelectSeed Company Ltd. (SCL) was created by the Forest Genetics Council of BC (FGC) to provide a mechanism for Forest Renewal BC to invest in seed orchards in a way that is responsive to FGC Business Plan needs, and supports seed markets. As SCL is owned through the FGC, it is in a unique position to also provide program management services without alignment to any single agency or company.

SelectSeed Company Ltd. is controlled by a Board of Directors that is elected through the FGC. Orchard investments are made as business investments with the objective of both meeting identified orchard expansion needs, and generating cash-flow through future seed sales. SCL will become financially self-sufficient in time, and provide the FGC with a further mechanism for program financing and delivery.

First full year completed

The first year for any new enterprise is often the most difficult. SCL faced many challenges, including negotiating long-term funding arrangements with Forest Renewal BC, providing program management services for the FGC, developing accounting and legal procedures for undertaking business, and proceeding with the orchard development work charged to it by FGC.

Other activities undertaken in 2000/01 included:

- Developing contract procedures and documents
- FGC Business Plan development
- SCL Business Plan development
- Negotiating funding arrangements with Forest Renewal BC
- Propagation (10,300) and holding (13,100) ramets for orchard development

FGC Program Management

Program management activities completed in the 2000/

01 fiscal year include:

- Development and management of the Forest Renewal BC Tree Improvement Program budget,
- Reporting to Forest Renewal BC and to the FGC on all tree improvement spending initiatives,
- Compiling species plans in conjunction with FGC Species Committees,
- Day-to-day interface with Forest Renewal BC and other groups,
- Developing issues and bringing them before Council
- Committee work and reports,
- Long-term planning

Name Change

SelectSeed Company Ltd. was formerly known as GenSeed. With increasing worldwide attention and concern over genetic engineering and genetically modified organisms, it was felt that the name GenSeed could send the wrong message regarding Company activities. A decision was made by the SCL Board of Directors and by the FGC to change the name to SelectSeed.

SCL is not involved in genetic engineering or the use of genetically modified organisms. All activities involve the production of seed or rooted cuttings using trees selected from natural stands. The name SelectSeed reflects the activities of locating, developing, producing and using select sources of seed for quality reforestation.

Future Activities

Seed orchard development to meet FGC objectives is a clear priority for SCL, and will be the primary focus during the next year. In addition planning and management of Forest Renewal BC Tree Improvement Program investments in all sub-program areas will be carried out in conjunction with Council sub-committees.

2.5 Extension and Communications:

Chris Hawkins and Don Summers

The Forest Genetics Council's Extension Technical Advisory Committee (ETAC) is completing it's first year of operation. The committee has 19 members representing forest companies, industry and government seed orchards, nurseries, seed dealers, academia, researchers, consultants and communications and extension.

In 2000, ten projects were funded, including six extension notes, three workshops, one manual and a school tour to view select material. All projects completed at the time of this report were well received. Tree Improvement workshops were held in Prince George and Smithers to provide foresters with an update on research, policy, tree breeding and seed production. There were over 100 local participants and evaluations to-date have been positive. Similarly, approximately 30 seed orchard specialists enjoyed a pollen workshop in Vernon that brought people together to discuss the latest information on pollen handling and application. Information was shared over 2 days of indoor and outdoor sessions.

ETAC welcomes ideas and proposals to increase awareness of the benefits of select material or provide tools and information for seed users on the use of select material. An ETAC 'Call for Proposals' was made in conjunction with the regular Operational Tree Improvement Program request this spring. Additional projects may be considered throughout the year depending on funding and committee priorities.

2.5.1 Project ES 0013: Lodgepole Pine Pollen Management Workshop

Dr. J. E. Webber

Lodgepole Pine is the most planted species in the province, averaging 91.1 millions seedlings annually. Currently, there are 13 producing orchards, nine of which are located in the north Okanagan. The majority of tree breeding activities that produce advanced generation material are also performed in the north Okanagan. To date, seed yields from both orchards and breeding programs have been considerably lower than planned estimates. One of the identified factors contributing to low yields has been pollen supply, including the quantity and quality of pollen. Techniques for handling and applying (pollen management) Lodgepole pine pollen are available but they have not been widely used. To ensure pollen quality is not limiting success, it is important that this information be made more widely available.

About 30 people attended a Lodgepole pine pollen management workshop held in Vernon, on March 7/8, 2001. Dr. Joe Webber led the workshop, which included a general discussion of the role of pollen in seed orchard production. Specific topics covered were storing, testing and applying pollen (SMP). The rationale for using specific pollen testing procedures (viability assays) were stressed and recommendations provided for incorporating pollen testing in both breeding and orchard programs.

The workshop was also very fortunate to have Dr. Patrick von Aderkas (Forest Biology, UVic) provide an entertaining description of the reproductive biology of pollen. Dr. Michael Stoehr giving an overview of the role that pollen plays (SMP) in seed lot rating. The workshop was closed with a general discussion from participants and a demonstration of equipment and procedures for storing, testing and applying pollen.

2.5.2 Project ES 0014 Seed Planning, Policy and Programs in British Columbia

Diane Gertzen

A pilot Tree Improvement/Forest Genetics workshop was held March 15, 2000 in Nelson with 54 people attending. With very favorable feedback, similar workshops in 2001 were held in Prince George with 62 in attendance and Smithers with 42 in attendance. Attendees represented forest regions, forest districts, and licensees in the region as well as forestry consultants.

These workshops provided a brief history and current overview of forest genetics, seed transfer guidelines, seed supply and production and gene conservation in British Columbia. Seed from selected sources is produced in seed orchards throughout the province, and represents about 38% of provincial sowing needs. This percentage is increasing each year.

The workshops were organized by Diane Gertzen and facilitated by Dave Trotter. Jack Woods gave an overview of Tree Improvement in BC. Barry Jaquish discussed his Interior Spruce, Western Larch & Interior Douglas-fir programs. Mike Carlson gave presentations on the Lodgepole Pine program, Gene Conservation/ Diversity and Genetic Worth. Ron Planden's presentation was on Tree Improvement and the Spatial Frontier, i.e. seed maps and future seed access.

Mike Madill, Anna Monetta and Gerry Pinkerton discussed their specific regional seed supply and Tim Lee gave a presentation about provincial seed orchard development and seed production. Eric Wong provided a presentation on the impact of the seed orchard program on timber flow in the Arrow TSA; provided at the Prince George workshop only.

2.5.3 Project ES 0016—Extension Note on Incorporating Genetic Gain in Timber Supply Analysis

Cortex Consultants

The purpose of this extension note was to explain how the volume gains attributed to using select seed are modelled in stand yield projections and accounted for in TSR timber supply analyses. The note briefly explains genetic gain, how it affects timber supply, and how it is modelled in timber supply analysis. The discussion draws on examples from a recent study of timber supply in the Arrow Timber Supply Area in Nelson Forest Region. The extension note was delivered as a colour PDF file that can be posted to the FGC Web site, and with instructions for colour printing. As part of this project we also designed a template for FGC Extension Notes.

2.5.4 Project ES 0017—Tree Improvement Terminology Review and Protocol on Recommended Use

Cortex Consultants

The purpose of this project was to clarify language associated with tree breeding and the development of improved reforestation materials. This project was also to identify terms that FGC cooperators feel are potentially misleading, obfuscatory, or inflammatory, and to develop a protocol on the use of such terms. The products of this project included a preliminary list of terms that might be potentially sensitive, an article for TICtalk discussing the expanded definition of "select seed" and other terms, and a report with preliminary observations about terminology usage based on this work.

2.5.5 Project: ES 0018— TI Publications Classification and Assessment

Cortex Consultants

The purpose of this project was to “take stock” of existing extension and communications materials related to forest gene resource management to provide guidance to ETAC in making funding decisions regarding the development of communication and extension materials for FGC audiences. About 60 communication and extension publications were collected from 27 agencies. Eight classification attributes (title, publisher, date, type, length, availability, scope, potential audiences) and three assessment criteria (relevance to FGC audiences and communication and extension goals, currency, sensitivity) were defined with input from a project Steering Committee. The project report discusses the assessment findings and makes recommendations regarding ETAC priorities for fiscal year 2001/02. The database and report are for the internal use of Forest Genetics Council and its ETAC and are not intended for publication or broad distribution.

2.5.6 SPU ES 0019—Communication Products on Tree Breeding vs Genetic Engineering

Cortex Consultants

The purpose of this project was to produce communication products related to clarifying the difference between traditional tree breeding and genetic engineering. The final products included an article for submission to a journal such as the Forestry Chronicle, a draft FGC extension note based on the article, and the design and layout of three new panels for the FGC display unit. The article describes the selective breeding process through which British Columbia produces high quality seed and seedlings for reforestation, the types of biotechnology that are being used or have potential for use in tree breeding and production of planting stock, the fundamental differences between genetic engineering and selective breeding, current Canadian research in genetic engineering and some of the concerns about this technology. Finally, it notes the need for Canada to develop a national policy and regulations on genetically engineered trees.

2.6 Seed Planning Information Tools

Leslie McAuley and Susan Zedel

The Seed Information Systems sub-program in the 2000/2001 fiscal year initiated the development of two web-based applications:

- SeedMap, a new web-based mapping system, will provide tree improvement clients (ministry and non-ministry) with access to seed planning maps and associated spatial and attribute data summary reports.
- SPAR (Seed Planning and Registry system) is being converted from the existing mainframe application and database to a web-based application and Oracle database.

SeedMap

SeedMap will provide tree improvement clients with the necessary tools for assessing current and projected seed needs, developing appropriate cone collection and seed supply access plans, identifying areas for orchard expansion and carrying out sound forest practices. SeedMap will also provide the ability to integrate seed planning and tree improvement information (spatially and otherwise) with other resource management initiatives such as land use planning, timber supply reviews, integrated silviculture planning, forest certification and gene conservation programs.

SeedMap will enable clients to select multiple reference map layers (e.g., seed planning zones/units, biogeoclimatic ecosystem classification (BEC), management unit (e.g., TSA, TFL1) boundaries, forest region/district boundaries, and TRIM2 data) and view them on-line or as printed 8°” x 11” maps. Clients will be able to query spatial polygon information, search locations/features, and measure distances. Non-spatial summary reports (e.g., Species Plan3 timelines, seed use, genetic gain, and inventory/production) based on current (SPAR/ISIS4) and projected (Species Plan) data will also be available through a report menu option or as a spatial query detail report.

SeedMap is being developed using ARC IMS, ESRI Canada Limited software, and client server-based technology. The SeedMap application will be accessed directly through a client’s Internet browser without the need for additional desktop software or plug-ins. Clients will be granted access to SeedMap (Figure 55) through their FSMASTER UserIDs. Non-ministry clients will access SeedMap using an Extranet User ID. A pilot of SeedMap will be available in spring 2001. A direct link to the new SPAR Web application is also planned (SPAR Web, July 2002).

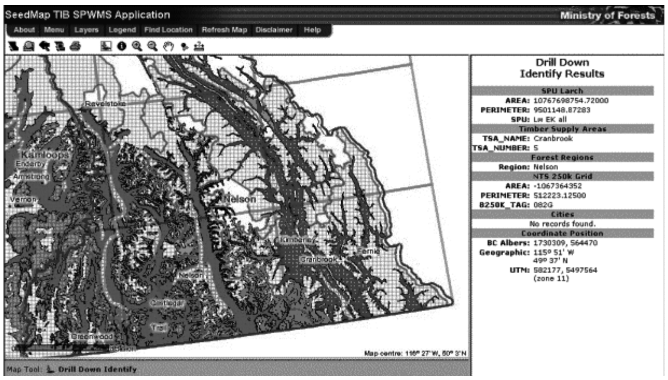


Figure 56. Example of a SeedMap screen where the spatial layers for a specific map location are identified.

The BC Forest Genetics Council and the Ministry of Forests are sponsoring the SeedMap project. Forest Renewal BC is funding Phase 1 development. The ministry project lead is Leslie McAuley, Tree Improvement Branch. GDS & Associates Limited, Victoria, B.C., is developing the application.

SPAR Web Application:

The purpose of the SPAR (Seed Planning and Registry system) web application development project is to convert the existing Ministry of Forests IBM VM mainframe application and database to a web-based application and Oracle database.

SPAR is an information management system that provides ministry and non-ministry tree-improvement clients with on-line access to current information on seed and vegetative lots and an on-line facility for entering seedling requests. SPAR incorporates the guidelines on selection of seed and vegetative lots detailed in the Forest Practices Code of B.C. Seed and Vegetative Material Guidebook (April 1995)

The new web-based application will provide a more intuitive and user-friendly interface to these SPAR functions than the existing SPAR application. SPAR users will access the system via their web browser software (e.g. Internet Explorer). The reporting capability of the new system will also be significantly improved compared to the existing VM system. SPAR users will be able to submit reports to directly receive output in various reporting formats. A direct link to the new SeedMap application is also planned. A Ministry of Forests SPAR Web Application Project Team has been established to review and prioritise any enhancements, and provide guidance on business issues regarding the redevelopment over the life of the project. Input will be sought from a range of stakeholders (Ministry of Forests and non-ministry SPAR users) at various stages throughout the project development.

The SPAR Web Application Development is a multiple phase project. The first phase, which commenced in September 2000 and is schedules for completion in spring 2001, includes:

- conversion of the SPAR data model from the existing format to an Oracle Designer format;
- conversion of the VM database to Oracle 8I;
- and conversion of all functionality related to seedlot and vegetative lot, including on-line screens and reports.

The core technology for the SPAR project will use the Java programming language, particularly Java servlets and Java Server Pages (JSP). Reporting development will use Crystal Reports, with various potential report output formats possible (e.g. Adobe Acrobat pdf files). Security will be managed by Microsoft's challenge/ response authentication process. SPAR users will continue to require a UserID and Password to access the system to ensure that access to seed owners' inventories is secure.

The second and third phases of the SPAR Web Application Development will handle conversion of the seedling request process, cone/seed service requests and all other functions until the mainframe system is completely converted. The final implementation of the project is scheduled for June 30, 2002.

The BC Forest Genetics Council and the Ministry of Forests are sponsoring the SPAR project. Forest Renewal BC is providing the funding for the contracted resources. The ministry project lead is Susan Zedel, Tree Improvement Branch, Ministry of Forests. The Information Management Group, Ministry of Forests, is providing the technical guidance required for the SPAR database conversion, the web application development, and the web security infrastructure. Pangaea Systems Inc., Victoria, B.C., is under contract for the systems development for the SPAR Web Development project.

Appendix 1

Tree Species Names and Abbreviations

CONIFERS		
western redcedar	Thuja plicata	Cw
yellow-cedar	Chamaecyparis nootkatensis	Yc
Douglas-fir	Pseudotsuga menziesii	Fdc
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 Seed 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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Back Cover Interpretations

The yellow-cedar breeding and clonal testing program has progressed rapidly over the last decade. There are over 8000 clones in tests, ranging in age from 2 to 10 years. Selected clones with 10%-25% volume gain at rotation are currently being established in hedge orchards for operational cutting production, with new selections being added annually. Nursery production and clonal forestry technical support is ensuring cutting quality from selected clonal hedges.

As we move forward to the next generation, and as clonal hedges age, orchards for both advanced generation breeding, and rejuvenation of selected clones for operational production, need to be established. Technical support projects are looking into the placement of orchards in natural yellow-cedar areas. Pollen viability and vigour, as well as seed set and germination, and their relationship to environment and climate are currently being investigated.

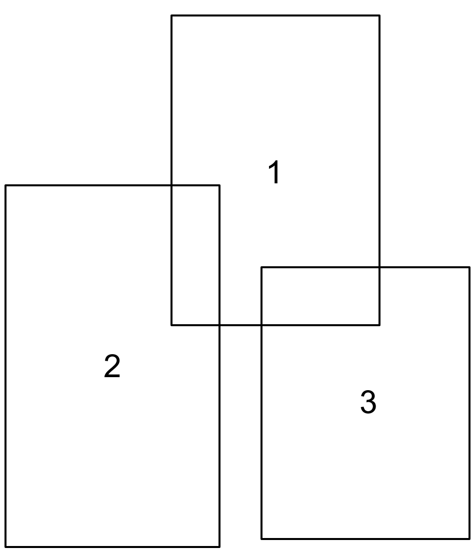

Plate 1. Yellow-cedar clonal trial. Western Forest Products has established over 2000 clones in field trials over the last decade. Dr. John Barker stands beside a seven-year-old tree from one of the top clones.

Plate 2. Yellow-cedar clonal hedge orchard. Selected clones are repropagated and pruned annually to maintain juvenility. Every clone destined for operational plantings must perform well in the nursery, as well as in the field, to be accepted in the hedge orchards.

Plate 3. High elevation pollen collections. Pollen quality is improved when originating from natural yellow-cedar environments as compared to traditional “off-site” orchard locations. The effect of pollen quality on seed set and germination is currently being investigated.

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