2003/2004

FOREST GENETICS COUNCIL OF BC

Tree Improvement Program Project Report

FGC

FOREST SERVICE BRITISH COLUMBIA

Front Cover

Andy Bower looking at white pine blister rust on whitebark pine (*Pinus albicaulis*).

Andy Bower collecting buds from whitebark pine at Granite Butte for isozyme analysis of variation and inbreeding level.

Staff and students with the Centre for Forest Gene Conservation at the University of British Columbia.

A common garden experiment at UBC containing whitebark pine populations collected rangewide. The results will be used to determine the degree of local adaptation in this high-elevation species.

FOREST GENETICS COUNCIL OF BC

Tree Improvement Program Project Report

Coordinated and compiled by:
Beacon Hill Communications Group Inc.

and

Roger Painter
Tree Improvement Branch
British Columbia Ministry of Forests

Acknowledgements

It is a great pleasure to present this report for yet another year. This program is now seven years old and continues to grow. What started out as a potentially short-term funding source to augment current budgets and increase annual production has expanded into a complex and progressive, successful public-private partnership that encompasses all aspects of tree improvement. The program has not been content to sit back, but continues to take on more challenges. In the past year we have added yet another sub-program to target a specific need within tree improvement. The newest effort is specifically geared to answer problems about seed pest management by investing in longer-term research and problem solving in that vital area. We look forward to results from seed pest research to provide us with valuable tools for protecting our orchards and crops.

We enjoy strong support from the Forest Investment Council because it recognizes the value of investing in tree improvement. There is little doubt that this support provides us with the resources to continue with a vibrant and robust long-term program. Yet it is our management of the program that continues to guarantee success. Our use of proper business planning and performance management, coupled with long-term strategic planning, has come to the attention of other organizations that wish to harness the energies and advantages associated with multi-stakeholder groups. Other organizations look upon our program as a successful model for developing investment programs, and the Forest Genetics Council (FGC) is now considered a model for co-operative partnerships.

My sincere thanks once again this year to the project leaders for their contributions to this report. This publication is well received by numerous people in the forest industry and provides a method of not only reporting on the work done but also showing the successes of Tree Improvement. My congratulations to you all, and I hope that you enjoy this seventh annual report. I would like to acknowledge the hard work of our editorial review team for taking the time to look over our submissions. They include Diane Gertzen, Joe Webber, Jill Peterson, and David Kolotelo.

Our sincere thanks to Dr. Sally Aitken and the Centre for Gene Conservation for their contributions to the front and back covers of this year's report. The Centre has grown considerably in the past few years, and it is a pleasure to highlight and bring attention to all of their good work.

My thanks to all those who have worked on this program in the past year, including the review committees, species committees, and various TACs. You provide sound direction on the technical details of our program. To all the project leaders, I hope 2004/2005 is very successful.

Roger A. Painter
Tree Improvement Co-ordinator
Forest Genetics Council

Introduction

First and foremost we would like to recognize and sincerely thank the many industry and government staff who contribute to the provincial gene resource management program for their cooperation and dedication over the past year. Although forestry in BC is changing quickly, there is a consistent and solid base of support, and a well established business planning process in place.

During the 2003/04 fiscal year, substantial progress was made in several important areas:

- Chief Forester Standards for Seed Use, in support of the new Forest and Range Practices Act are nearly technically complete. The Standards consolidate existing policy, guidelines and practices, and will result in efficiencies for both industry and government stakeholders when implemented. Many members of Council and affiliated committees contributed to and improved the Standards during the past year.
- The FGC completed a new Strategic Plan for the period 2004 to 2008. This plan sets out objectives and organizational structure for the continued cooperative delivery of gene resource management.
- Council membership changes were completed, resulting in greater industry representation, and the addition of a member from the Canadian ForestService.
- The lodgepole pine breeding program, under the leadership of Dr. Michael Carlson of the Ministry of Forests, continues to meet the challenge of selecting parents and producing sufficient scion to allow the large new orchard development led by SelectSeed Co. to proceed. These orchards are now nearing completion, marking a substantial milestone in British Columbia tree improvement programs.
- The Centre for Forest Gene Conservation at the University of BC embarked on a project to predict native tree species range shifts under various climate-change scenarios. This work draws upon past genecology research and combines it with state-of-the-art climate-change modeling. Our ability to evaluate risk associated with various seed transfers will be improved.
- The FIA – Tree Improvement Program continues to support the long term goals of Council for increased seed quality and seed production in seed orchards.

The coming year will continue to present challenges for Council. As programs mature, and industry continues to feel pressure to increase competitiveness in global commodity markets, the need to realize value from all silviculture investments will increase. At the same time, public expectations regarding stewardship of the genetic resource on public lands will require careful coordination among aspects of the program directed toward conservation and those concerned with value. We are confident, however, that Council and affiliated committees will meet these challenges.

Forest Genetics Council Co-Chairs

Shane Browne-Dayton, Industry Co-Chair

Dale Draper, Ministry of Forests, Co-Chair

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:

TIP Program Administrator
Ministry of Forests
Tree Improvement Branch
PO Box 9518 Stn Prov Govt
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Further Tree Improvement information can be found at our Web sites:

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

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Tree Improvement in British Columbia

Ministry of Forests Program Overview

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: the Ministry of Forests (MoF), Canadian Forest Service (CFS), and universities.

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

The FIA BC Tree Improvement Program is guided by strategic and annual business plans prepared by the FGC.

Forest Genetics Council of B.C.

The Forest Genetics Council of British Columbia (FGC) is a multi-stakeholder group representing the forest industry: the Ministry of Forests (MoF), Canadian Forest Service (CFS), 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.

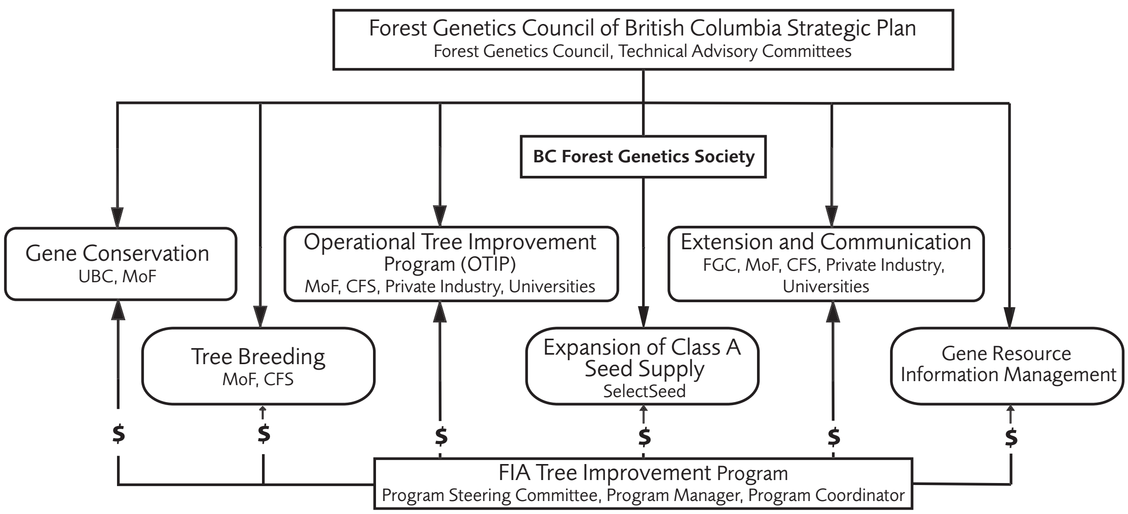
Forest gene resource management is a co-operative effort. In broad terms, the MoF leads tree breeding activities and private industry leads operational production of reforestation materials. The Canadian Forest Service, MoF Research Branch, and universities undertake research supporting tree improvement, 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.

FIA – Tree Improvement Subprograms

The Forest Investment Account, (FIA), Tree Improvement Program 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 six subprograms (Figure 1).

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



Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest gene resource management areas

1.0 Expansion of Orchard Seed Supply Subprogram (SelectSeed Company Ltd.)

Jack Woods

The Subprogram for the Expansion of Orchard Seed Supply was initiated by the Forest Genetics Council (FGC) to ensure sufficient orchard capacity to meet objectives. The coastal and interior technical advisory committees of the FGC estimate total seed orchard capacity needs for each seed planning unit (SPU) through the process of developing species plans. This process previously identified substantial gaps that will be met through this subprogram.

SelectSeed Company Ltd. (SelectSeed) was initiated by the council to expand orchard capacity on behalf of all stakeholders. Figure 1 shows the relationship between the council and SelectSeed. SelectSeed also provides program management services to the FGC. Funding is through a Multi-Year Agreement (MYA) originally set up with Forest Renewal BC and now transferred to the Ministry of Forests. FIA funding is used by the provincial government to meet its obligations under the MYA. As SelectSeed-developed orchards begin production, seed sales will displace funding provided under the MYA.

All SelectSeed orchards are developed through long-term contracts with private seed orchard companies. During the fiscal year ending March 31, 2004, activities focused on the propagation and planting of 14 orchards. Progress is summarized in Figure 2.

All orchard developments mandated to SelectSeed are well underway to full development. In total, 31,812 ramets have been planted of a planned total of 35,320 (90%). Thanks to the hard work and careful stock treatment of contracted orchardists, the survival and condition of stock is generally very high. The support of the MoF lodgepole pine breeding team (Mike Carlson, John Murphy, and Vicki Berger) through their efforts to complete selections and supply scion for the large propagation program is gratefully acknowledged.
This fiscal year completes the majority of orchard development. Future years will see the completion of planting and a shift of focus to site management and crop production. Of note is the first small crop produced in a SelectSeed orchard (321 Douglas-fir Nelson low elevation).

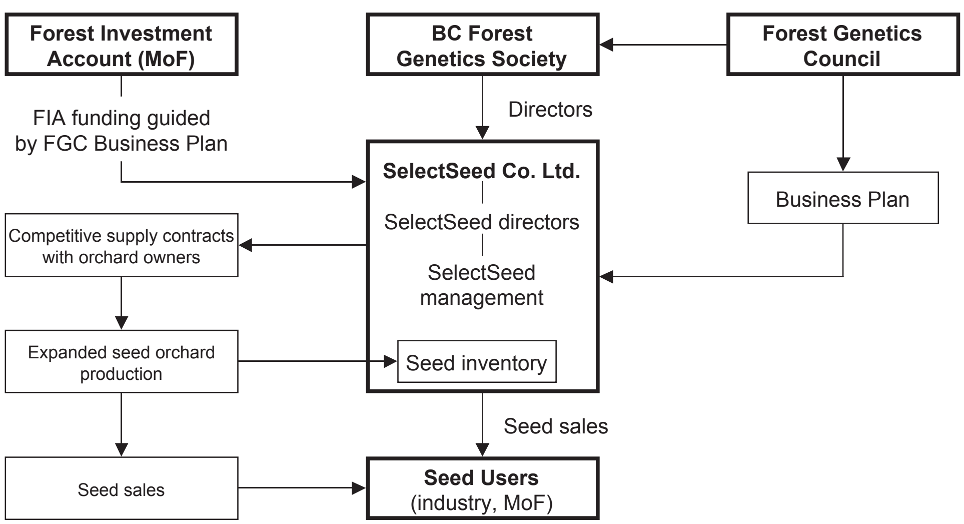


Figure 1. Schematic of organizational relationships among FGC, FIA, SelectSeed and seed users

SPU #	Spp.	SPZ	Elev	Orch #	Orch final size	Grafting (# grafts)	Planting (# ramets)	# ramets established	% Orch completion
7	Pli	NE	< 1400	337	1000	27	34	902	90%
10	Pli	TO	< 1400	338	4780	1,048	91	3,374	71%
12	Pli	PG	<1200	236	4500	1,233	1,256	4,011	89%
12	Pli	PG	<1200	237	4900	2,540	1,987	4,436	91%
16	Pli	TO	> 1400	339	3473	830	679	3,176	91%
17	Pli	BV	1200	234	3000	653	693	2,849	95%
17	Pli	BV	1200	240	3100	1,203	3,082	3,084	99%
18	Pli	CP	<1000	238	3100	286	901	2,997	97%
18	Pli	CP	<1000	241	2000	385	1,810	1,934	97%
21	Fdi	NE	< 1000	321	2200	215	164	1,930	88%
28	Sx	TO	1300-1850	343	1052	118	53	1,042	99%
30	Sx	TO	< 1300	342	454	103	75	445	98%
37	Fdi	QL	all	232	975	0	104	886	91%
41	Fdi	PG	all	233	786	0	94	746	95%
					35,320	8,641	11,023	31,812	

Figure 2. Summary of SelectSeed orchard developments, and progress in propagation and planting during 2003

2.0 Gene Resource Information Management

Leslie McAuley

Gene resource information management (GRIM) forms a critical link to the long-term stewardship and sustainable resource management of the province's forest-tree gene resources over future generations. GRIM has the following key objectives.

- Develop a provincial GRIM framework to support land use and forest development/stewardship plans, forest regeneration (planting) programs, forest tree genetics research, and GRM (gene conservation/seed deployment) strategies.
- Support and maintain GRM registries and data repositories.
- Provide access to tree improvement program products (seed and vegetative material for operational use).
- Build an effectiveness GRM monitoring program integrated with broader forestry (criteria and indicators) and land-based resource management initiatives.
- Develop a means to incorporate genetic gain into timber supply analyses through forest inventory update procedures, forest simulator modelling tools, and the use of GIS-ready spatial and attribute GRM datasets.

GRIM project accomplishments in 2003/04 included the following.

- Full implementation of the new web-based Seed Planning and Registry system (SPAR) in support of future on-line seed registration; annual testing, storage, withdrawal, and transfer; and seedling-ordering activities.
- Migration and implementation of the new web-based SeedMap map viewer and summary reporting tool with direct links to the provincial Land Resource Data Warehouse (LRDW).
- Identification of business requirements and development of design specifications to support a new web-based parent tree registry within the SPAR corporate database.
- Development of GRM results-based information reporting requirements under the new *Forest and Range Practices Act* (on-going).
- Development of new spatial GRM datasets (natural stand seed planning zones).
- Development of web-based training modules, tutorials, and on-line Help documentation (on-going)
- Integration of GRM within other forestry analyses (Mountain Pine Beetle, Timber Supply). See Figure 3.

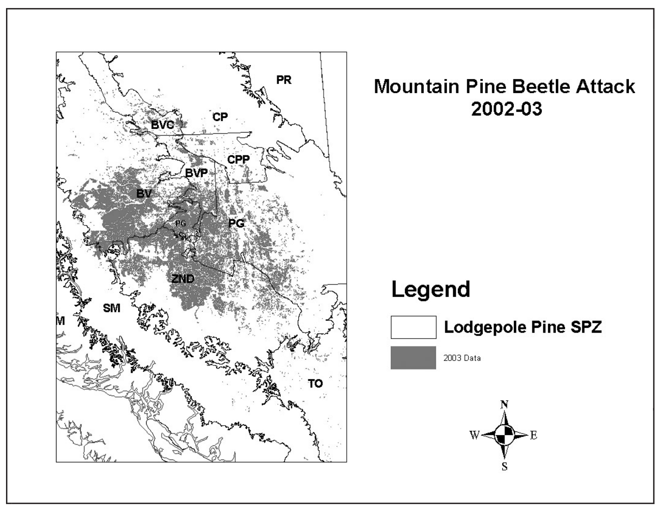


Figure 3. Example of GRM integration with other forestry analyses

3.0 Centre for Forest Gene Conservation

Sally Aitken

Protecting the forest genetic resources of British Columbia requires an understanding: 1) the current extent of forest genetic resources, including species distributions, and the amount and distribution of genetic variation within species; 2) the degree to which species are conserved *in situ* in protected areas throughout their ranges or portions thereof; 3) patterns of climatic or ecological variation that are likely to coincide with adaptive patterns of genetic variation and species ranges; 4) the extent of *ex situ* genetic resources, in seed storage, for example; and 5) optimal sampling strategies for conserving genetic diversity through *in situ* and *ex situ* protection, particularly given the challenge of a rapidly changing climate. The Centre for Forest Gene Conservation (CFGC) at the University of British Columbia addresses these needs to meet the objectives of the Forest Genetics Council, with guidance from the Gene Conservation Technical Advisory Committee of the FGC. With the completion of the CFGC's fourth year of existence, a number of projects have come to fruition, others have made significant advances, and we have initiated new projects. Here we highlight progress in some of these projects.

We continue to catalogue the degree of protection of both commercially important and minor tree species in protected areas. Using Geographic Information Systems methodology in conjunction with the provincial botanical-plot database, Andreas Hamann has produced detailed range maps for all forty-nine tree species in British Columbia. The degree of *in situ* protection of genetic resources was evaluated for eleven commercially important conifers in a total of fifty-one seed planning units (SPUs) that are currently delineated. In addition, preliminary SPUs were evaluated for three important hardwood species. This year for the first time, the species plans within the FGC Business Plan include updated information on the degree of protection. In a second analysis, also covering minor tree species and populations of commercial conifers outside SPUs, Andreas Hamann and Pia Smets estimated the degree of representation in protected areas by Biogeoclimatic Ecological Classification (BEC). This analysis is taken to a new level by applying advanced statistical methods to estimate population sizes and utilizing information from the seamless forest cover database for threat analysis. Data on genetic resources conserved *ex situ* and *inter situ* are also being added to the gene conservation status of commercially important conifers. Additional information is available on the CFGC website (genetics.forestry.ubc.ca/cfgc).

A project was completed this year on optimal sampling strategies for capturing allelic diversity in *ex situ* conservation collections. For his PhD research, Washington Gapare assessed micro- and macro-geographic patterns of genetic variation in Sitka spruce by using DNA-based sequence tagged site markers to genotype 200 spatially mapped individuals in each of eight populations spread across the species range. Populations were classified according to the ecological niche of the species as to core or peripheral and whether they were continuous or disjunct based on degree of isolation from the nearest populations. The findings indicate that the optimal sampling strategy varies substantially with population classification. Disjunct populations, whether core or peripheral, are more likely to harbour rare, localized alleles than continuous populations. However, peripheral populations, whether continuous or disjunct, are likely to have much stronger micro-geographic genetic structure than core populations. These results indicate that optimizing the spatial distribution of sampling effort (i.e., by increasing the distance among samples) is not essential for the capture of genetic diversity in core populations (Figure 4). However, in peripheral populations, it is important to distribute sampling effort across a larger area within a stand or a population because individuals within smaller areas are more likely to be genetically similar, and lower frequency alleles are more likely to be missed.

We continue to explore the genetics of whitebark pine (*Pinus albicaulis*) to inform restoration strategies for this high-elevation native species under attack by the introduced pathogen *Cronartium ribicola* that causes white pine blister rust. Andy Bower's PhD research includes a large seedling common garden experiment that is entering its third growth season. He is also using isozyme markers to study the relationships between inbreeding and rust infection levels in natural stands. A completed study of *ex situ* seed storage indicates that seed of this species can maintain viability in storage for at least 10 years, although to achieve good germination rates, it may need a long pretreatment period that includes both warm and cold stratification.

Adapting gene conservation and genetic resource management to a changing climate has become a major focus for us in the past year. Tongli Wang and Andreas Hamann have developed a high resolution baseline model of climatic normals for nine important climate variables. This model, in conjunction with future climate predictions obtained from the Hadley Centre, UK, and the Canadian Centre for Climate Modelling and Analysis, facilitated the prediction of future spatial distributions of climatic envelopes for our native tree species, biogeoclimatic zones, and currently delineated seed planning zones. Our preliminary results indicate that rapid climate change may be the biggest challenge facing gene conservation and other aspects of genetic management this century. We need to be able to anticipate this challenge and develop strategies to mitigate the effects. A strategic grant supported jointly by NSERC and the BIOCAP Canada Foundation is funding the majority of this research.

We continue to extend our findings to the forest genetics, forestry, and conservation communities through presentations at workshops, on field trips, and at conferences. We hosted the Western Forest Genetics Association annual meeting at Whistler in 2003 and addressed gene conservation issues on the meeting field trip. The CFGC website is updated periodically to include recent findings and reports, and it receives a fairly high level of traffic. People affiliated with the CFGC have been asked to give presentations within B.C., in other provinces, and in Oregon and California in the past year. This has allowed us to develop an identity for the Centre outside as well as within the province of B.C. to help us play a role in broader gene conservation.

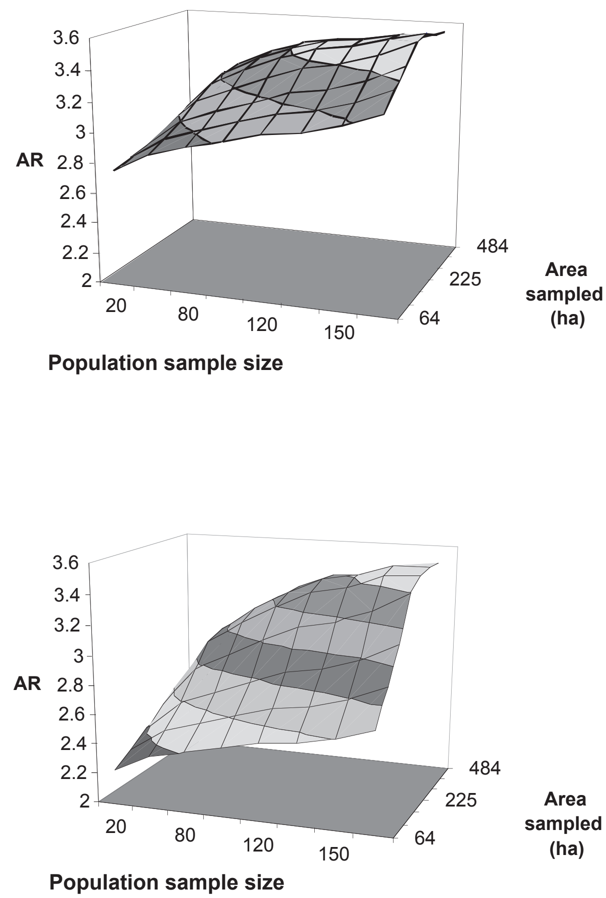


Figure 4. Genetic diversity as measured by allelic richness (AR) captured in *ex situ* collections as a function of the number of trees sampled and the area those trees are distributed across, in A) core; and B) peripheral populations of Sitka spruce

4.0 Tree Breeding

4.1 Coastal Douglas-fir

Michael Stoehr, Keith Bird, Clint Hollefreund

Low-elevation coastal Douglas-fir (SPU 01)
Control pollinations for advanced-generation breeding for general combining ability (GCA) and full-sib testing progressed well, with over 200 crosses completed this year. Series 1 subline tests (Figure 5), planted in 1999 for third-generation seed-orchard selections, were maintained and measured (height at five years). Series 2 subline tests (planted in 2003), also containing eight sublines, were weeded and fertilized. Realized gain trials, planted in 1996, were brushed.

High-elevation Douglas-fir (SPU 31)
The high-elevation Canfor Douglas-fir seed orchard (>700 m) at Sechelt is progeny tested at two test sites on northern Vancouver Island (Mt. Cain and Sutton Creek). These polycross tests were established in 1997 to rogue and backward select parent trees in Orchard 116. Age-five heights were used to rogue ramets with BV<20. Breeding values calculated based on year-seven heights will also be used for roguing. Final selections will be made based on age-twelve heights. This year, trees were measured and assessed and analyzed on both sites.

Breeding values adjusted for selection at age seven and forecast to rotation age sixty for the top thirty clones range from two to ten, based on best linear prediction (BLP) calculations. As the age-age correlation increases, these values will increase correspondingly.

Sub-Maritime (transition zone) Douglas-fir
The newly established clonal seed orchard 181 at Puckle Road (Central Saanich) will be progeny tested using a polycross (GCA) test. For this purpose, all clones in the orchard were control pollinated in the spring of 2003 using a polymix made of submaritime pollen (and some high-elevation coastal pollen). Of ninety-four parent trees in the orchard, seed was obtained from ninety-one and sowed for the production of test stock at Cowichan Lake. Progeny tests will be established in the spring of 2005 at three sites in the transition zone at elevations above 800 m. (Figure 6)

Test Site	N	Test means (cm)	Std. Dev.	Single-tree Heritability	Family Heritability
Buckley Bay	2674	187.5	48.9	0.18	0.56
Canoe	2540	312.3	71.3	0.17	0.54
Noomas	2413	251.7	51.3	0.16	0.50
Snowdon	2685	213.2	51.8	0.26	0.65

Figure 5. Test information for Series 1 GCA tests using eight sublines of advanced generation coastal Douglas-fir

Test Site	N	Test means (cm)	Std. Dev.	Single-tree Heritability	Family Heritability
Mt. Cain	1829	171.7	32.7	0.12	0.49
Sutton Creek	1773	353.2	56.7	0.30	0.71

Figure 6. High-elevation test results based on two test sites located on Northern Vancouver Island

4.2 Sitka Spruce

John King, René Alfaro, Charlie Cartwright, Dave Ponsford

Activities this year included the establishment of the first phase of the F[1] breeding program. Parents were designated by their phenotypic resistance to the weevil and their source (mainly Haney or Big Qualicum). Some susceptible parents were also used. The trials have been established in the Adam's River drainage, north Vancouver Island, and at Jordan River, south Vancouver Island. We have held over another site that we hope to establish on the Queen Charlotte Islands next spring (2005). The breeding to establish future series is continuing. The F[1]s will replace the clones and families in our research efforts to understand the mechanisms behind this resistance.

Parent trees have been screened for a more detailed investigation of resistance mechanisms. All of these have been field assessed for resistance to weevil attack after weevil augmentation, but a more detailed microscopic evaluation is being attempted in order to classify according to putative mechanism. This is particularly valuable for "constitutive" type of mechanisms such as sclereid cells or constitutive resin cells, and we are working to extend these techniques to look at some of the "inducible" mechanisms, particularly traumatic resin cell production.

Ongoing trial assessments for weevil attack have continued; these have included some of the hazard assessment trials. The hazard assessments were a series of trials established to test resistance over a variety of ecological and potential weevil-hazard areas. The main objective is to aid in determining deployment guidelines. Some of these guidelines were assessed in previous years to investigate elevational and latitudinal transfer of weevil-resistant sources. To further this objective, we have sowed a small series of high-elevation selections in 2003/4, along with some resistant-sib lots to be established in 2004/5.

Good progress has been made in the first draft of a report outlining the weevil resistance program. This report will present many of the details of the program, an outline of our scoring system for resistance, and a ranking of all of our parents to date. The report will also present deployment guidelines for resistant material. In addition to last year's book chapters, we have just published an article in the Journal of Forestry entitled: "Genetic resistance of Sitka spruce (*Picea sitchensis*) populations to the white pine weevil (*Pissodes strobi*): distribution of resistance."

4.3 Western Hemlock

Charlie Cartwright

Low-elevation maritime hemlock (SPU 3)

The primary focus of the program at this point is advanced-generation breeding. Data for age-five heights have been collected from eleven trials, and preliminary analysis has been performed. A full-scale formal report is awaiting further results from nine trials established by American co-operators that are due in Fall 2004. Over 100 forward selections have been made and propagated, but they are being used for studies of methodologies for breeding juvenile material while the later round of testing is completed. Early results suggest that, to a large degree, the area encompassing the whole co-operative can be treated as one breeding zone, with some Oregon parents performing well on harsher test sites.

A secondary aspect of the hemlock forest genetics program involves provenance studies. Although tested parents from the breeding program are generally deployed in areas where they have been tested, smaller trials with a wider representation of plants from across the species' range are valuable for establishing the limits of safe seed transfer. As well, areas not warranting investment in a breeding program still need rules for transferring wild stand-collected seed. Age-five height data were collected from three sites in the autumn of 2003, with a further five to be measured this year. Age-ten results from eight earlier tests were reported to a Western Forest Genetics Association meeting in Whistler, B.C. in July 2003. At the same meeting, research was reported that supported hemlock's resistance to dwarf mistletoe. Trees from ten provenances were infected with the parasitic plant (Figure 7). No variation by provenance or family was noted, although one provenance clearly had half as many successful attacks as the others. Similarly, there was a wide range of responses by family, but analysis suggests that these results might not be repeatable. Too few replications were used to detect the effect, and so it could not be confirmed. However, a further round of inoculations is planned with more plants per family to be infected in the belief that there are indeed genetic differences.

The inoculations and scoring of the progress of infection was in the hands of forest health specialist Dr. Simon Shamoun of the Canadian Forest Service Pacific Forestry Centre and two of his grad students, Sue Askew and Lea Reitman pictured in Plate 1.

High-elevation maritime hemlock (SPU 24)

The high-elevation breeding program covers maritime hemlock regeneration from 600 m elevation to the transition to mountain hemlock. A last round of first-generation testing has just been sown, which will bring the number of high-elevation selections tested to about 325. Ten-year-old data for height and diameters are expected for 91 parents, with revised breeding values for these to follow by April 2004. Projected volume gains of selected available seed lots should rise from around 6% currently to over 10%.

Plate 1. Forest health personnel assisting in mistletoe screening

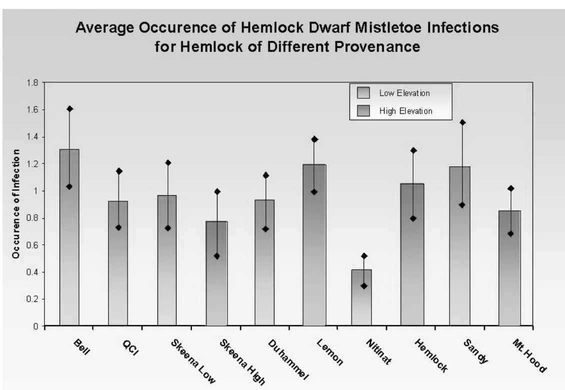


Figure 7. Provenance variability in hemlock susceptibility to mistletoe

4.4 Western Redcedar

John Russell, Craig Ferguson

Breeding for first-generation polycross testing involving just under 1,000 parents for the maritime low SPU is complete. To-date, six annual series of tests have been established totalling thirty-nine sites (Figure 8). The last series will be established in Spring 2005. Breeding values for volume at rotation are currently available for Series 1 based on seven-year heights (150 parents), and Series 2 and 3 based on five-year heights (248 parents). Approximately fifty parents from the first three series have been selected for advanced generation testing and established into breeding orchards. Information on the durability of the parents in the first three series is currently underway.

Sixty within-family selections for high needle monoterpene concentration/deer resistance were made at the Holt Creek, South Vancouver Island (SVI) family/population study. These selections will be bred using a combination of selfing and outcrossing, and resultant progeny will be screened for monoterpene concentration and deer resistance. Both backward and forward selections can then be incorporated into a deer-resistant production population.

Plate 2. Spraying selected western redcedar deer-resistant trees with GA3 at Holt Creek

			# of test sites/SPU[1]						
Series	Year	# parents	ML	MH	QCI	NM	SM	INT	Total
1	1998	150	3	1	-	-	-	-	4
2	1999	138	4	-	-	-	2	-	6
3	2000	110	3	-	1	1	1	-	6
4	2001	57	4	1	1	-	-	-	6
5	2003	160	3	2	1	1	1	-	8
6	2004	168	2	3	-	1	1	2	9
7	2005	157[2]	3[2]	-	-	-	-	-	3[2]
Total									42[2]

1. ML= Maritime low (under 600 m); MH=Maritime high (>600m); QCI=Queen Charlotte Islands; NM=North Maritime; SM=Submaritime; INT=Interior.
2. projected.

Figure 8. Summary of western redcedar polycross tests

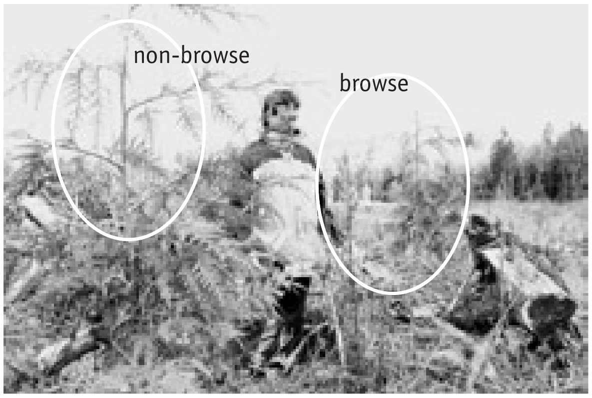


Plate 3. Deer browse on western redcedar at Holt Creek

4.5 Coastal White Pine

John King, Rich Hunt, Dave Ponsford

This year we sowed and grew the first phase of the F[1] breeding program. Parents for this effort came from the CFS screening program and were designated as either Slow Canker Growth (SCG) or Difficult to Infect (DI). SCG or "slow-rusting" trees occur more frequently than DI. Also included, as parents were some of the best of the Texada trees and some Idaho, Interior, and Dorena trees. We are currently lining up several sites to establish these trials and are looking at sites on Texada Island and near Sechelt.

We collected several more scions from the CFS screening list — two from Texada Island and a few from Vancouver Island — and several of the major gene resistance (MGR) trees. Much of this was to make up for the grafts made in 2002/3 that did not survive. Grafting this year was done for us at Kalamalka, and grafts will be established in the North Arm clonal archive, seed orchards and a newly established breeding orchard at Puckle Road.

We had a very good trip last September. The three of us met Mike Carlson and Hadrian Merler and toured the Interior provenance trials established by Rich Hunt (Root Rot Series) and Mike Meagher (Provenance Series) in the 1980's. We looked particularly at the Dorena MGR seedlots to see how well they held up in the Interior, and overall they did not appear too bad. We are now in the process of measuring all these trials. These measurements will help us to evaluate the resistance of these various sources and assess their transferability across the province. We are also currently doing a first assessment of the full-sib block trial initiated by Patti Brown. This trial allows the comparison in field conditions of various CFS selections such as "low spotters", and "slow rusting" against Dorena and wild unselected lots. Although the data are still being gathered, some preliminary results are very encouraging: some of the wild unselected blocks are 90% infected, whereas some of the Dorena x Dorena and Dorena x SCG are only 5% infected.

Our paper entitled "The Five Needle Pines in British Columbia, Canada: Past, Present and Future" by J. King and R. Hunt has been published as a special USDA Forest Service Research Report, and a chapter for a special edition of the Journal of Forest Ecology and Management entitled "Genetic Approaches to the Management of Blister Rust in White Pines" is well underway.

4.6 Yellow-cedar

John Russell, Craig Ferguson

First-generation cloned progeny tests have been established, and the focus is currently on maintenance and measurements. The first two series of trials were measured at five years in the field, and clonal values from 3,000 clones were released. The third series will be measured in 2005. Advanced-generation selections from the Wester Forest Products (WFP) clonal program and from Ministry of Forests genetic trials have been established in three breeding orchards, including one high-elevation site. Maintenance continued this year in these orchards, as well as monitoring of the performance and production of pollen for collection for advanced-generation breeding.

Various technical support projects were maintained and measured. These include clonal maturation, clonal competition, pollen viability, and deer resistance studies. Provenance trials were also maintained. Analyses of 10-year data from interior population test sites (Figure 9) revealed responses similar to those on coastal sites: significant population variation for growth with no discernable adaptive responses. Survival was high, with little evidence of cold-related damage for all populations except northern California. Breeding continued for a deer resistance heritability study.

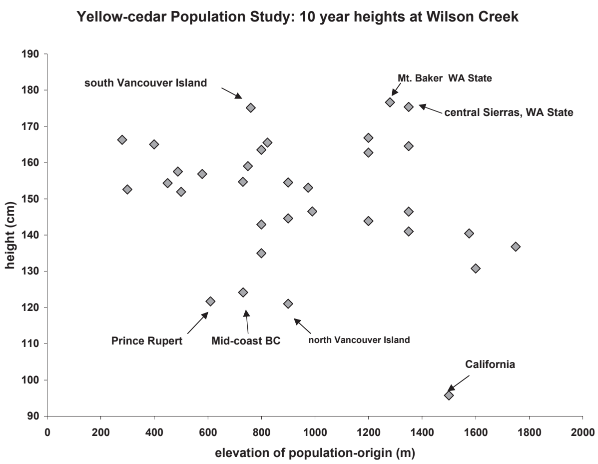


Figure 9. Population means for ten-year heights at Wilson Creek, southern interior

Plate 4. Yellow-cedar population study near Mica dam (12 years in the field)

Plate 5. Breeding for the yellow-cedar deer resistance heritability study

4.7 Queen Charlotte and Coast/ Interior Transition Spruce

John King

The Queen Charlotte Island program allows us to assess Sitka spruce growth free from weevil attack and supports the Seed Orchard program (SO 142 and its replacement). Our major difficulty has been in getting "free-to-grow" conditions, in this case not free from weevil or brush but from deer browse, and a good deal of our maintenance effort is on browse protection. This year we spent a good deal of time cleaning up, tagging, and removing browse protection from the trials we have established there. This fall we hope to do a major measurement of our QCI sites.

The transition program is designed mainly to test seed transferability in a very environmentally heterogeneous area with pressures from both frost and weevil. In the past year most of the activities for this program have concentrated on routine site maintenance, although a small weevil-resistance plot has been established in the Bish River area near Kitimat. A series of measurements and assessments are planned this summer.

4.8 Interior Douglas-fir

Barry Jaquish, Val Ashley, Gisele Phillips, Bonnie Hooge, Dave Wallden

Crossing: Controlled crossing in the Interior Douglas-fir program is focusing on the low-elevation Nelson SPU. This new zone is largely the result of merging the old Shuswap Adams, Mica, and West Kootenay low-elevation zones. In 2003, a total of 171 crosses were completed in the Nelson zone, and 188 were completed in lower priority zones. Approximately 200 pollen lots were collected, processed, and stored for future breeding.
Progeny Testing: Five fifteen-year-old sites and two twenty-year-old sites in the old Mica and Cariboo Transition zones, respectively, were maintained and measured. Data analyses for these sites are on-going. Wood relative density determination was completed for the Mica Revelstoke dam site.
Research: Three ten-year-old sites from the Douglas-fir elevation transect study were maintained and measured.

The pilot *Armillaria* root disease resistance screening project is now three years old and is near completion. This joint Canadian Forest Service/BC Ministry of Forests project used artificial inoculation (Plate 6) to screen 88 open-pollinated families of Interior Douglas-fir. To date, family mortality attributed to *Armillaria* ranges from 0 to 82% (Figure 10).

Plate 6. *Armillaria* inoculated birch block and oak dowel used for inoculating potted interior Douglas-fir seedling

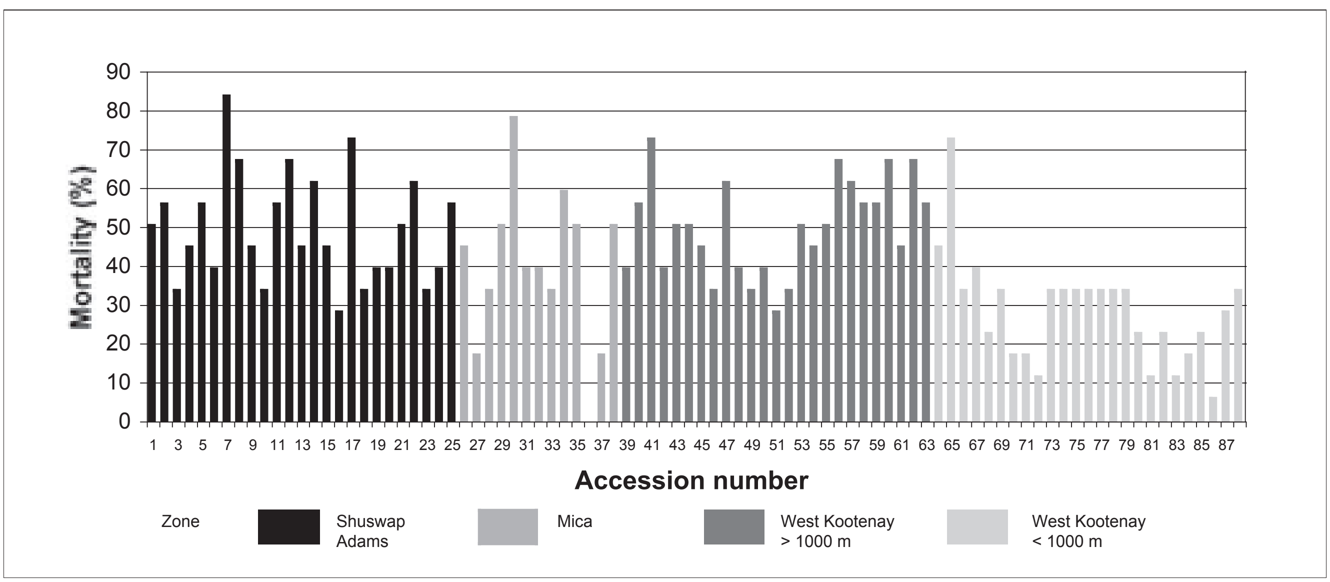


Figure 10. Interior Douglas-fir family mortality attributed to *Armillaria* root disease (data as of February 19, 2004)

4.9 Interior Spruce

Barry Jaquish, Val Ashley, Gisele Phillips, Bonnie Hooge, Dave Wallden

Interior spruce tree improvement began in the mid-1960s and has progressed to the point where much of the current spruce planting stock (over 75 million seedlings per year) originates from rogued first-generation seed orchards. Second-generation full-sib progeny tests are also in place for three seed planning units (SPUs). Over the years, refinement of interior spruce SPUs continued as relevant new information became available from genetic tests. Today, six large SPUs are in place, and selection, breeding, and testing activities are on-going in each unit.

Progress over the last fiscal year

Breeding: Thirty-three (thirty Thompson Okanagan, three Prince George) pollen lots were collected, processed, and stored for future crossing. Thirty-five crosses were completed in the new expanded PG zone. Controlled crossing for the new PG zone is now 98% complete and we look to establish new 2nd generation progeny tests in 2006.

Progeny Testing: Six twenty-year-old sites in the old Quesnel Lake, Finlay, and Bulkley Valley (BV) seed zones were maintained and measured, and four five-year-old sites in the Fort Nelson zone were maintained. Eight second-generation sites in the PG, BV, and East Kootenay SPUs were maintained.

The Shuswap Adams polycross test at the Skimikin Seed Orchard, which was augmented with cage-reared spruce weevils in fall 2002, was evaluated for leader damage. When evaluation was completed, the site was clear-felled and wood disks were collected from each family to determine the relative density of the wood. In June 2003, spruce leaders containing weevil eggs were collected near Vernon, and more than 10,000 weevils were reared in cages at Canadian Forest Service, Pacific Forestry Centre, Victoria. In early fall, adult weevils were released in the Thompson Okanagan Series I polycross test at Skimikin. Plantation damage assessment will commence in summer 2004.

Research: Three spruce provenance tests (Quick, Verdun, and Bowes Ck) that were established in the mid-1960s were maintained, pruned, and relabeled. These tests represent the oldest interior spruce plantings with genetic structure in B.C. Two ten-year-old realized-gain tests in the old Hudson Hope zone were maintained and measured. In these tests, the superior seed lots were 17% taller and had 15% greater survival than the composite wild-stand seed lot. Six field plantings of somatic emblings were maintained and measured.

A new genecology study was established in the new Prince George SPU to: 1) further refine seed zone boundaries and seed transfer rules, 2) characterize growth and physiological differences between PG class A and wild-stand seed-lots, and 3) confirm weighting coefficients used for estimating breeding value. One raised bed site was established for intensive study at the Kalamalka Forestry Centre, and three wild sites were established in the Prince George area.

4.10 Second Generation Family Testing of Lodgepole Pine

Mike Carlson, Vicky Berger, John Murphy

The intercrossing of tested/selected first-generation lodgepole pine parent trees for second-generation family testing is complete for all five seed planning units (low-elevs. PG, BV, TO, NE, and CP). Factorial crossing sets comprise subpopulations bred for stem volume growth rate and wood relative density for each SPU (130 FS families per SPU). In 2002, the PG test series was planted. In 2004, the BV series will be planted, and the TO and NE series will be sown/grown for planting in 2005. The last test series, the CP, will be planted in 2006.

In addition to the BV SPU test series grown, lifted, and packaged in 2003, research trial planting stocks for three Forest Investment Account (FIA)-funded trials were grown, lifted, and packaged for 2004 planting. These included the Comandra Rust Screening Trial for the Vernon Seed Orchard Company and two provenance screening trials, one each by Weyerhaeuser Co. and West Fraser Ltd. The fall 2003 lift and tagging for these four trials set a record for the pine team (and likely for the Research Branch, too) in that 83,000 test seedlings were lifted, of which 63,000 were individually tagged. The job was well done by Future Forest Services Ltd. of Vernon.

Plate 7. Future Forest Services Ltd. crew lifting the 2003 Bulkley Valley second-generation family test series in Vernon

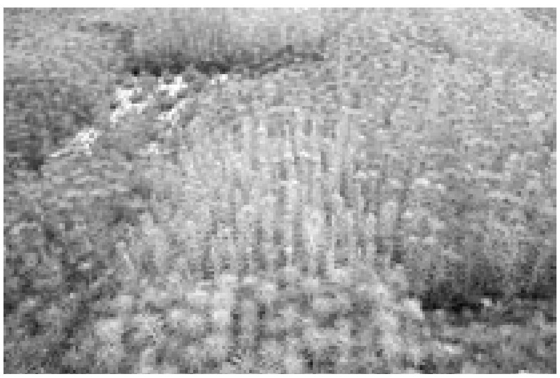


Plate 8. Seedling phenotypic and genotypic variation for various seedling traits: red fall pigmentation display (chlorophyll prod stops, anthocyonins show), seedling needle/crown forms, terminal bud farms, seedling heights/calipers, ratios of ht/cal, germ rates, etc. This was a "selected" spot within the BV 2nd gen crop (Landing Nursery, Nov 2003) which contains full-sib families for increased growth potential, maintenance of wood relative density, and wild operational control seedlots. Thsi view contains more seedling phenotypic/genotypic variation than has been observed by the breeder in any one progeny crop in 21 years of selective breeding of Lodgepole pine. Viva les differences!

4.11 Lodgepole Pine "Forward" Selections for Expanding Seed Orchard Production

Mike Carlson, John Murphy, Vicky Berger, Dr. Chang-Yi Xie

The planting of lodgepole pine throughout the B.C. interior has greatly increased beginning in the early 1990s. Today, 90 million seedlings are planted annually. Our first-generation tested seed orchards were designed to meet earlier seedling needs. Regrafting to expand orchard seed production capacity began in 1996. Since then, more than 60,000 grafts have been made, and several new orchards have been planted to meet approximately two-thirds of the total seed needs for the species. The majority of parents grafted in this expansion effort have come from first-generation progeny test family arrays aged 15-18 years from seed, so called "forward" selections. These superior trees were identified using a two-step process. First, Dr. Chang-Yi Xie from the Ministry of Forersts Research Branch in Victoria took the ten-year measurement data sets and developed a selection index score for every tree in each particular test series (30,000 trees per test series). Each tree's final score or breeding value (BV) depends on the relative superiority of its family compared to other test families and its own superiority within the family (compared to its sibs). Site means, block means, and plot means are also estimated and are used to adjust individual tree scores (BVs).

The analysis product is a listing of the top 500 BV-ranked trees across the sites in a particular test series. The second step is to visit one or more sites with the ranking list and examine trees in descending rank order. Tree height at age ten years is only one criterion used for tree selection. Height and diameter growth rates sometimes change with competitive interactions after age ten. Also, stem form and branching habits have significant impacts on log/wood values and can be assessed at ages 15-18 yrs. So, in addition to current tree height, stem diameter, and form, branching characteristics, including branch numbers, diameters, lengths, and stem growth cyclicity (monocyclic vs polycyclic internodes) are all considered in selecting seed orchard parent trees. With this, the final year of forward selecting, over 400 progeny test trees will have been selected and grafted (60-80 ramets each).

Overall organization and direction of seed orchard expansion projects has been the responsibility of Select Seed Company Ltd.

Plate 9. Excellent stem form and a fine branching habit are part of the "forward" selection criteria

Plate 10. John Murphy at the Bowron Lakes progeny test site (planted 1986) with a "forward" selected parent tree, 2003

4.12 Western Larch

Barry Jaquish, Val Ashley, Gisele Phillips, Bonnie Hooge, Dave Wallden

This program was initiated in 1987 and has advanced very rapidly. To date, 609 parent trees have been selected, and wind-pollinated families of 607 have been established in progeny tests across 14 sites. The oldest of these progeny tests is 13 years old. Two grafted seed orchards were established in 1990 and are now in full production. Presently, over 70% of the 6.5 million western larch seedlings planted annually in BC originates from seed orchards. Second-generation controlled crossing is over 40% complete, and three realized-gain field tests will be planted in spring 2004.

In 2003, 82 controlled crosses were completed, and about 160 pollen lots were collected, processed, and stored for future crossing. One progeny test site (EK Semlin Ck) was thinned and wood disks were collected for wood relative density determination.

5.0 Operational Tree Improvement – The Seventh Year in Review

Roger Painter

In 1997-1998 our provincial Tree Improvement Program consisted of the Operational Tree Improvement Program, or OTIP. All funding was approved through a large call for proposals and a broad review process. Over the past seven years, the program has matured in both planning and delivery. The 2003-4 business year includes an added sub-program dealing with seed pest issues. This continued definition of focus and planning procedures is allowing our program to continue to expand despite reductions in funding in the past two fiscal years. The continual review of program goals has allowed us to set priorities for the distribution of limited resources and move ahead. Most orchards had good crops in 2003-4. SelectSeed now has all of its orchards in the ground, and the first crop from those orchards has been harvested. The Forest Investment Account continues to show strong support for our program. Available seed supplies from seed orchards continue to increase, and the genetic quality of seed crops continues to improve. Seed use in 2003-4 is now at 48% of provincial use, and seed quality is now at 10.5% GW (genetic worth). The long-term benefits for our province will be in providing excellent wood products and, a healthy resource, leading to a more stable long-term economy for our forest industry.

After seven years of effort, our program is progressing towards its long-term goals. The program continues to identify and develop specific elements that require resources. Currently, the Forest Genetics Council (FGC) is developing a new strategic plan to incorporate program progress and changes that have occurred since the last version. The overall program is complex and maintains a robust yearly planning process to meet the needs of its various programs. The Tree Improvement Program now contains six sub-programs to direct the operational side of tree improvement. They include Operational Production (OTIP), Tree Breeding, Extension and Communication, Gene Conservation, Gene Resource Information Management (GRIM), and the newest, Seed Pest Management. The Forest Genetics Council has six working committees that provide technical direction for these sub-programs. These committees develop goals and priorities specific to those areas. The performance management system developed by the FGC is a key tool in ensuring that programs stay on track and overall program goals are met. Species committees review progress and provide priorities for future investment.

In 2003-4, the two technical review committees reviewed a total of 84 requests for funding in OTIP. The total amount of proposals received was approximately $1 million. The Coastal and Interior technical committees recommended approval of only $861,000. The breakdown of investment by region for all of OTIP is shown in Figure 11.

Council relies on the various species committees to review and develop annual projects and priorities. Both the Tree Breeding and the Operational Tree Improvement Program receive their direction from these reviews. Similarly the Extension and Gene Conservation TAC's have developed their own priority review procedures, with a steering committee providing oversight for the GRIM sub-program. Tree Breeding, is a Ministry of Forests responsibility and is therefore not part of the original Operational Tree Improvement Program "Call for Proposals" process. The species sub-committees develop priorities for the Tree Breeding sub-program, 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 it will continue to receive strong levels of funding to ensure that development of new production stock is achieved for new orchards. 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 genetic material to establish these new

Interior projects	45	$554,605
Coastal projects	26	$306,941
Overall Total	71	$861,000

Figure 11. Number of projects and funding by region

orchards. The development of a long-term investment program through SelectSeed Ltd. has so far produced over 31,000 grafts for establishing new orchards.

Although Technical Support is not a specific sub-program, it is an integral part of tree improvement in general and has provided an excellent avenue for operational problem-solving through the OTIP process. The Lodgepole Pine seed-set issue has been an excellent example of focussed investigations to solve serious problems affecting tree improvement. A project breakdown by areas of investment is shown in Figure 12.

The tree improvement industry represents a broad base of partners. This includes forest companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies, and individuals. In 2003/2004, the Tree Improvement Program involved thirty-nine separate contributors from all aspects of the industry. With the current structures that include sub-programs and the focus-driven TAC's, the Forest Genetics Council continues to provide the direction necessary for making sound investments and the guidance needed for selecting acceptable proposals. The use of performance planning also helps ensure that approved submissions reflect the direction that the Council has set for meeting its goals through centralized planning and review.

Tree Breeding	33
Gene Conservation	7
Operational Production	57
Technical Support	14
Seed Pest Management	4
Extension and Communication	4
Seed Planning and Information Tools	2

Figure 12. Number of projects by areas of investment

5.1 Orchard Projects

5.1.1 Saanich Forestry Centre

Annette Van Niejenhuis

Western Forest Products Limited manages western redcedar, coastal Douglas-fir, western hemlock, and Sitka spruce seed orchards and orchards of yellow cypress hedges for the production of high-quality regeneration stock for coastal reforestation programs. To support the Forest Genetics Council's objectives for quality and quantity of orchard production, Western Forest Products incorporated high-gain clones from the breeding programs as part of its ongoing development process. Enhanced orchard and crop management from our program have delivered high-gain seed and stecklings to reforestation programs.

Western Forest Products maintained more than 2,400 western redcedar seedlings in test (OTIP 0206) in the holding bed. This project is aimed at a quick start for high-quality seed production as test results become available. Various means of ensuring out-crossing in this species continue to be tested in the orchard. In-breeding is a significant problem for western redcedar. In-breeding leads to successful seed production and nursery performance, but it reduces the plantation's productivity to below site potential. The 2002 crop yielded a lot of GW_5 estimated to produce 30,000 plantables. Cone induction and pollen management, which are now underway, will promote a high-gain crop in 2004.

Orchard 166, our Douglas-fir orchard, saw the addition of eight ramets to improve the quality of seed produced (OTIP 0107). Because available seed yield in this seed-planning unit is still below needs, aggressive roguing will be postponed until production surpluses exist or ramets are available for replacement. Enhanced crop management, including pollen harvesting and application, resulted in 27.5 kg of seed with a genetic worth of 10 or greater.

Pollen management in the low-elevation western hemlock Orchard 170 resulted in the production of 0.6 kg of seed with a genetic worth of 13 (OTIP 0304). Roguing of eighty-three ramets and replacement of forty-nine ramets is underway in response to the latest breeding values published; this will result in an orchard with average genetic worth of 13.8. The high-elevation western hemlock Orchard 187 did not show enough crop potential to justify pollen management in 2003 (OTIP 2401). Roguing removed 123 ramets from Orchard 187, and 186 ramets will be added. This orchard will then have an average breeding value of 6.7, including those clones for which test results are anticipated, presently scored at 2.

Grafting, maintaining holding-bed stock, and replacing Sitka spruce clones have continued to improve the quality of Orchard 172 (OTIP 0601). An additional 109 ramets were planted. This orchard is oversized temporarily; it includes all clones in test for weevil resistance and volume. Upon receipt of test results, aggressive roguing for weevil resistance combined with volume gain will maximize the production of the best quality seed. OTIP funds have supported the bulking-up program in Sitka spruce that has resulted in the early deployment of highly weevil-resistant stock to plantations for the last few years. The stored seed supply from the last three years of controlled pollination under OTIP funding will supply the bulking-up program until orchard production can meet demand. Western Forest Products' 2003 nursery crop included 56,000 weevil-resistant Sitka spruce stecklings.

Rooting stecklings and maintaining holding bed stock have continued to improve the yellow cypress hedge orchards (OTIP 1104). Managing the hedges included pruning and fertilization. This resulted in production cuttings for more than 185,000 plantables with a genetic worth of 19 or greater for Western Forest Products and one external order. Cuttings for an additional 100,000 plantables at genetic worth 19 remained surplus on SPAR from mid-October of 2003 and are now being harvested and destroyed. According to the latest clonal test scores, roguing 1,690 ramets and replacing 1,010 ramets in the hedge orchards will accelerate the delivery of gain.

Plate 11. Coastal Douglas-fir seedlot 61214 is cured in the cone racks prior to shipping and extraction

Plate 12. Cathy Cook measures extracted Douglas-fir pollen for supplemental mass pollination to off-set the effects of contaminant pollen and to ensure adequate pollination for receptive flowers at the tail ends of the pollination period

Plate 13. Pollination bags are applied to the western redcedar field grafts to maintain higher humidity and to prevent bird damage while the grafts "take"

Plate 14. Controlled pollination for the Sitka spruce bulking up program and the breeding program is implemented in the weevil-resistant orchard at Saanich Forestry Centre

Plate 15. Paul Bertorelli monitors root weevil presence in the holding bed

Plate 16. Retired Douglas-fir breeder Chris Heaman discusses a trial near Campbell River

5.1.2 Sechelt Seed Orchard

Patti Brown

Douglas-fir (SPU 0101)
SPU 0101 provided funding for the induction of Orchard 177 to produce its first quantity crop. Approximately half of the 330 ramets that were induced in June of 2003 produced female flowers for pollinating in 2004.

Western redcedar (SPU 0201)
The goal of SPU 0201 was to increase the yield of the 2003 crop by treating the crop for midge with dimethoate in April and to monitor and treat local *Lygus* infestations in July. The result was high yields of 1.0 kg/hl for the hooded crop (total of 550,000 plantables) and 1.2kg/hl for the SMP crop (total of 650,000 plantables). In addition, the ramets in the holding beds were rogued from 2050 to 1250, fertilized monthly with 20-20-20, and pruned twice to increase the surface area.

Western hemlock (SPU 0301)
SPU 0301 was for Orchard 133 and Orchard 179. Fifty-eight ramets were removed from Orchard 133, leaving twelve clones and approximately eighty ramets with

an average BV of 14 and the potential to produce one million plantables annually.

In December 2003, 146 ramets held in holding beds for the past two years to replace mortality in Orchard 179 were outplanted.

The planned flower induction treatment of Orchards 179 and 133 had to be postponed due to a naturally produced stress crop in 2003. Therefore, only twenty trees were induced in Orchard 179 with good results.

Western white pine (SPU 0801)

The goal of SPU 0801 was to increase the resistance of Orchard 174 to slow canker growth in the long term and to produce a crop with 50% resistance (MGR) in the short term.

For the last two to three years, 450 slow canker ramets from the CFS screening program were kept in holding beds and were incorporated into Orchard 174 in December 2003.

This year's MGR crop (> 50% resistance) was monitored closely and spot treated for *Leptoglossus* from May to August. The high yield crop that resulted has the potential to produce 350,000 plantables. The 2004 crop was also hand pollinated with MGR pollen collected from the Roberts Creek plantation.

Yellow-cedar (SPU 1101)

SPU 1101 continues with the goal of producing 300,000 stecklings with a GW of > 12% annually for our coastal operations. To achieve this, donors are grown and cultured at both Cairnpark and Sechelt orchards. The funds for this project were used to maintain high-quality donors to maximize steckling production. Only a small portion of the funds was used to upgrade the donor materials because test results and original donor availability was limited in 2003. The Ministry of Forests Series 2 tests resulted in 750 new donors. Therefore, the funds were returned, and the work is now planned for 2004.

5.1.3 Mount Newton Seed Orchard

Tim Crowder

Five Operational Tree Improvement Projects (OTIP) were carried out at Mount Newton Seed Orchard this year

Management of coastal Douglas-fir orchards (SPU 01)

Two hundred and forty-eight (248) grafts of high-breeding-value clones were made to replace those that failed in the last two years. Three hundred and twenty (320) surviving grafts from 2002 were maintained in a holding bed, while those from 2001 were planted in empty spots in the orchards.

SMP was carried out on early- and late-flowering clones. Following the harvest of the 2003 crop, 248 ramets with low BV were rogued from the three orchards.

Western redcedar orchard management and holding bed maintenance (SPU 02)

Genetic gain was improved in Orchards 140 and 152 by roguing thirty-six trees and replanting with 198 small trees with higher breeding values. A crop was induced in Orchard 140 for 2004.

In order to reduce self-pollinated seed, the orchards have been divided into two age classes of ramets, with the large trees to be used as the pollen source and the cone crop to be collected only from the young smaller trees.

Thirty-three hundred (3,300) small grafted trees were maintained in holding beds until test data are available.

Management of western white pine Orchard 403 (SPU 08)

Three hundred (300) trees were grafted for specific clones that failed to take or were not available in the past. One hundred and fifty (150) existing grafts, representing the most resistant material available, were planted in empty spots in Orchard 403.

MGR pollen was collected from the test site at Ladysmith and applied to 150 ramets in Orchard 403 with female flowers.

Insect control, including monitoring and treating for *Leptoglossus* and *Dioryctria* damage, was carried out. 18.5 hectolitres of cones were collected.

Maintenance of *Abies amabilis* Orchard 129

Eleven hundred and fifteen (1,115) orchard trees were maintained by fertilizing, irrigating, and pruning and by controlling insects and competing vegetation.

Five litres of pollen was collected and re-applied to the existing flowers. 14.5 hl of cones were collected, yielding 31.9 kg of seed.

Management of high-elevation western hemlock Orchard 130

Fifty trees were rogued that either have low breeding values or have not yet been tested.

The crop on the remaining 66 ramets was managed by applying supplemental mass pollination, fertilization, and irrigation.

8.3 kg of seed was produced, enough for 1.7 million plantables.

Plate 17. Cw flowers in 2003

Plate 18. Cw pollen crop in 2003

Plate 19. Fdc breeding at Mt. Newton

5.1.4 Bowser Seed Orchards

Dan Rudolph

Genetic upgrading and enhancing seed yields and quality from second-generation Douglas-fir seed orchards (SPU 0110)

This project is a multi-year effort being conducted in two second-generation seed Orchards, 149 and 162, at the Ministry of Forests site at Bowser. There are two main objectives:

1. To upgrade the genetic composition of the orchards by roguing the lowest-ranked clones and replacing them with higher-ranked parents.
2. To enhance the seed yield and genetic worth of the seedlots produced by:

- applying cone-induction techniques to all suitable candidates in each orchard.
- using controlled-pollination techniques in both orchards in order to produce elite seedlots, and
- using orchard management techniques to maximize yields and optimize growing stock vigour and crop health.

Results

Upgrading

In Orchard 162, 647 ramets from twenty clones with breeding values of less than 10 were removed. At Cowichan Lake Research Station, 120 grafts from each of seventeen clones (2,040 total ramets) with breeding values ranging from 18 to 26 have been propagated.

They will be transplanted into a holding area at the Bowser site in the second year of this project.

Enhancing seed yield and genetic worth

Controlled crossing: From seventeen of the highest-ranked parents in each orchard, 73 ramets were identified, and isolation bags were put on 953 branches of these ramets. Controlled crosses using pollen mixes with high genetic worth were made. Pollination bags were replaced with insect bags after orchard receptivity had passed.

Induction: Suitable candidates for induction were identified in each orchard. Criteria used to establish a candidate list included: negligible crop in the current year, no crop from last year, no induction treatment last year, sufficient vigour, and an adequate number of cone-bearing sites. Induction treatments consisted of a double overlapping girdle and $GA_{4/7}$ injection. Irrigation was withheld until mid-July in order to increase drought stress on the trees.

Orchard management: All orchard trees were maintained through appropriate cultural practices.

Insect management and control: Surveys were conducted for *Contarinia oregonensis* and *Leptoglossus occidentalis*.

Output and deliverables

Upgrading

The removal of the lower-ranked clones in Orchard 162 raised the overall genetic worth of the orchard from 12.5% to 15%. When the new clones are established in the orchard, the overall genetic worth of the orchard will rise to 20%.

Enhancing seed yield and genetic worth

Controlled crossing: Two controlled-cross seedlots, one from each orchard, were produced. Seedlot #60687 from Orchard 149 produced a collection of 4.25 hectolitres, or about 9000 cones, with a yield of 1.237 kg of seed and a genetic worth of 14. Seedlot #60689 from Orchard 162 produced a collection of 1.0 hectolitre, or about 2000 cones, with a yield of .358 kg of seed and a genetic worth of 20.

Induction: A total of 275 trees were induced: 181 from Orchard 162 and 94 from Orchard 149. In late March, bud surveys will rate the efficacy of the treatments.

Orchard management: Foliar nutrient samples were taken, fertilizer was applied for both growing stock and crop maintenance, irrigation was applied when necessary, trees were basal and top-pruned, and identity tags were upgraded before cone collection.

Insect monitoring/control: *Contarinia* levels were within the acceptable threshold, so no control measures were necessary. *Leptoglossus* levels were also low, so no control measures were undertaken.

5.1.5 Kalamalka Seed Orchards

Chris Walsh

Ten OTIP projects were approved under the operational production sub-program for 2003/2004 at Kalamalka Seed Orchards (Figure 13). The funding supported a significant enhancement of 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, planting rootstock for future grafting, 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 from clone banks and the application of Supplemental Mass Pollination (Figure 14).
- improving orchard productivity through pest management and other management activities.

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 that damage orchard tree stems.
- baiting for control of rodents that feed on tree roots.
- sanitation picking of cones in orchards with non-collectible crops to reduce pest populations.
- dormant oil application to control larch adelgids.
- sprays to control *Cydia* and *Strobilomyia* in Sx cones.
- sprays to control *Leptoglossus*.
- sprays to control spittle bugs and *Zelleria* in lodgepole pine orchards.

Other funded management activities to boost productivity and gain included:

- foliar analysis to determine the nutrient status of orchard trees.
- crown management of orchard trees.

The OTIP funding was instrumental in increasing both the quantity and quality of seed produced. At Kalamalka in 2003 we produced approximately 330 kg of interior spruce, western larch, lodgepole pine, and western white pine seed, equivalent to over 45 million seedlings with an average GW of +17. Kalamalka seed is being used over large areas of the interior of the province.

Project	Species	SPZ	Orchard	Roguing	Grafts Made	Maintained	Rootstock
SPU0401	Sx	NE	305		113	481	
SPU0502	Sx	NE	306		136	401	
SPU0701	Pli	NE	307			202	
SPU1302	Lw	NE	332	59	200	518	200
SPU1501	Pw	KQ	335		50	141	
SPU2201	Fdi	NE	324		120	25	50
SPU2501	Sx	EK	304	26		49	
SPU3201	Pli	EK	340		200	135	200
SPU3401	Lw	EK	333	119	100	423	100
SPU3501	Sx	BV	620		61	268	
Totals				204	980	2643	550

Figure 13. Orchard composition activities by project

Project	Species	SPZ	Orchard	Pollen Collected (litres, dry)	Trees Pollinated
SPU0401	Sx	NE	305	4.0	495
SPU0502	Sx	NE	306	4.0	443
SPU0701	Pli	NE	307	5.0	825
SPU1302	Lw	NE	332	1.5	691
SPU1501	Pw	KQ	335	1.0	1,500
SPU2201	Fdi	NE	324	1.0	
SPU2501	Sx	EK	304	4.0	1,719
SPU3501	Sx	BV	620	2.0	583
Totals				22.5	6,256

Figure 14. Pollen management activities by project

5.1.6 Vernon Seed Orchard Company (VSOC)

VSOC

Tim Lee

The nine funded projects approved for this year (Figure 15) are an important part of our programs. With this funding, we are able to undertake projects that allow for the improvement of all 1.5-generation production orchards on site. With the young age of many of our orchards, additional activities are required to keep orchard seed production at as high a level as possible for this stage of development. Most of our orchards require added pollen management to achieve the pollen uptake needed for expected seed set in each orchard. Other mature orchards require funding for roguing of lower breeding-value families and then to upgrade graft replacements for the benefit of the Seed Planning Unit. Our other spruce orchard continues its upgrading to achieve both improved growth and weevil resistance to cover off a recognized SPU need.

VSOC manages eight orchards for production each year. These orchards were part of the first phase of our site development. The second phase included the addition of five more orchards. These orchards are not expected to be a part of the seed supply for eight to ten more years.

Individual Items

- **Pollen work –** Young orchards often have a supply of frozen pollen from previous years that can be applied to early or late flowers. The families that fall into these categories are often left alone without a natural pollen supply available. On occasion, young orchards will have no pollen available but may have many females present. For example, in 1999 the Prince George Spruce 214 had no pollen available for the many flowers present, but VSOC was able to

Plate 20. Entrance to Vernon Seed Orchard Company

produce 275 kg of seed because of our stored pollen. Throughout our history, VSOC has picked, applied, stored, and frozen many litres of pollen from all our managed orchards.

- **SMP treatments –** Most orchards use Supplemental Mass Pollination. The timely application of pollen can make the difference in ensuring the production of seed. Helicopters have proved to be the key in large, widespread young orchards that have only the start of a detectable pollen cloud. Through our monitoring efforts we are getting the pollen into the receptive female flowers, whereas beforehand with only the orchard's natural pollen cloud, we were receiving marginal pollen into pollen tubes. There is always more than one way to accomplish a task, and each species requires slight changes to ensure the success of each treatment.
- **Roguing –** Lower breeding values for parents within each orchard require monitoring because the supply and quantity of seed builds. The breeding values of orchard parents are adjusted from time to time, and our handling of the information will affect the quality of seed for an SPU. Each year the species committee deals with the information as it is brought forward for future orchard planning.
- **Grafting –** Timely ramet replacement is dependent on an active, well-planned program that is aware of the needs of each SPU. Rootstock holding beds are managed with a projected need of continued improvement of each orchard in mind. Information on family rankings and the advancement of the next generation selections are always in the back of the minds of each orchard management team. Orchards should evolve as the breeder and the orchard management team see the inclusion of the next generation ramets into the orchard and determine how to lessen the transition period's effect on seed supply.
- **Ramet replacement –** Replacement of rogued positions within an orchard are for the benefit of all involved in tree improvement for that SPU.
- **Insect and disease control –** Controlling insects is an important part of seed production. *Leptoglossus occidentalis*, European pine shoot moth, pine pitch moth, and adelgids are a few of the insects that are monitored and controlled for the protection of our orchards' health and production.

Activities undertaken each year affect the quantity and quality of seed produced for this province. All involved believe that the funding made available has had a positive effect on moving towards the Forest Genetics Council's goals of 12% gain and 75% use of Class A seed for our province.

Vernon Seed Orchard Company **OTIP- 2003**

SPU Project#	Species	Orchard	Pollen Litres	SMP - Treatments	Insect & Disease	Grafts Made	Holding beds	Planted
1201	All	Site	Nutrient Analysis for all Production Orchards					
1202	Pli	222	15	2000	4389	1614	1850	1614
1403	Sx	211			4000	388	1000	1250
1404	Sx	214			4345	310	119	429
1701	Pli	219	25	5000	5850	233	650	233
1801	Pli	218	12	3000	4300	351	450	351
3702	Fdi	226	8	300	351			
4102	Fdi	225	4	200	540			
4301	Fdi	231	10	600	1050			
		Totals	74	11100	24825	2896	4069	3877

Figure 15. Break-down of projects

5.1.7 Grandview Seed Orchards

Hilary Graham

Grandview seed orchards are located on Grandview Bench, about 20 km southwest of Armstrong, B.C. At this site, three lodgepole pine orchards and one Douglas-fir orchard have received OTIP funding for activities to increase the yield and genetic gain of seed produced. Orchards 308 and 311 provide seed for the Pli Thompson-Okanagan low-elevation seed planning unit (SPU), Orchard 313 provides seed for Pli Nelson low-elevation SPU, and Orchard 321 provides seed for Fdi Nelson low-elevation SPU.

Pli Orchard 308 is a provenance-based orchard with an estimated genetic worth of 6%. Pli orchards 311 and 313 are 1.5 generation orchards each with an estimated genetic worth of about 16%. Fdi Orchard 321 is a 1.5 generation orchard with an estimated genetic gain of 26%.

In 2003, OTIP funded a number of activities in these orchards. OTIP projects 0702, 1001, 1002, and 2101 covered activities in orchards 313, 311, 308, and 321 respectively. These activities included planting grafts, pollen and cone surveys, pollen monitoring, insect and disease control, rodent control, crown management, foliar analyses, pollen collection, cone harvest, and supplemental mass pollination (SMP).

Pli orchards – 2003 activities

In early spring 2003, grafts were planted to fill vacant positions in all three Pli orchards. At the same time, the first foliar samples were taken to determine the appropriate fertilizer mix for spring application. Foliar samples were taken again later in the season for fall fertilization. These foliar analyses helped direct fertilizer applications to ensure optimal nutrition.

Pollen monitoring began in May with monitors set up within all three Pli orchards and between orchards. Pollen monitoring indicated that there was a substantial pollen supply in Orchard 308, and therefore SMP was not conducted in this orchard. However, orchards 311 and 313 both required SMP because the natural pollen cloud was relatively small for adequate pollination.

No protandry was observed in any of the Pli orchards; the shedding of pollen and flower receptivity coincided well. As the volume of pollen being shed increased, an air-blast sprayer (blowing a very fine water mist) was used on calm days to ensure good distribution of pollen in the orchards.

Warm and dry conditions during the pollination period (mid- to late May) allowed for four well-timed applications of pollen (SMP) in Orchards 311 and 313 (SMP was not necessary in Orchard 308). These orchards were pollinated in 2003 with stored pollen from a 2002 collection (previous OTIP project). Surveys were conducted before each application to indicate the trees with receptive seed cones. These trees were tagged so that the pollen applicator crew could move quickly from tree to tree and apply the pollen only to receptive seed-cones. It is expected that SMP will improve seed set by providing pollen in the absence of an adequate natural pollen cloud.

During the pollen flight period, pollen was collected from orchards 311 and 313 for future use. Whole pollen buds were manually collected by clone and brought into the laboratory for drying and processing. Over five litres of pollen with an average BV of 23.4 was put into storage.

In all three Pli orchards, the amount of pollen and number of cones produced per tree was assessed and recorded. This data will be used to calculate the genetic worth of seed produced in the orchards in 2003/2004. Data collection and handling was much more efficient this season with the use of a Palm Pilot purchased with OTIP funding.

Throughout the season, monitoring for insect and disease problems ensured ramet health and seed quality in the three Pli orchards. Pesticide sprays were applied to control *Leptoglossus* seed bug and Pine Needle Cast disease. Poison was set out to control rodents feeding on tree roots, and pitch moths were removed by hand.

A small amount of crown pruning in each orchard encouraged branching and maintained the trees at a manageable height without compromising flower production.

Finally, cones that had SMP applications in 2002 were collected in orchards 311 and 313.

Fdi Orchard – 2003 activities

Pollen monitoring began at the first flight of pollen in the orchard. Pollen monitors were erected in a number of locations within the orchard, and they were monitored daily until the pollen flight was completed. At the same time, phenological surveys were conducted every second day on a sample set of ramets of each clone in the orchard. Pollen shed and female receptivity were monitored throughout the pollination period. Phenological surveys and pollen monitoring provide baseline data for pollen management in this Fdi orchard. They also indicated the timing for SMP applications.

Pollen was applied three times at the end of April with stored pollen from a 2002 collection (previous OTIP project). Pollen for future use was also collected by a PRT crew at the Kalamalka Forestry Centre. Thanks to Barry Jaquish and Valerie Ashley for providing pollen for our use and assisting the PRT crew. The pollen was processed and dried at PRT and put into freezer storage. This pollen is now available for SMP efforts in 2004.

The volume of pollen and the number of cones on each clone were also assessed. These pollen and cone surveys not only provide baseline data for this young orchard, but they were also used to calculate the genetic worth of the seedlot produced in 2003. Cones were harvested in August, and 675 grams of seed was produced.

Summary

With the early confirmation of OTIP funding and an inventory of pollen from 2002/3 OTIP work, all projects were completed as planned. The Pli Thompson Okanagan Low produced 17.7 kg of seed in 2003, which has the potential to generate 2.9 million seedlings. In the Pli Nelson Low, 8.75 kg of seed was collected, which has the potential to produce 1.4 million seedlings. The Fdi Nelson Low orchard produced a small crop of 675 grams of seed with the potential to produce approximately 28,000 seedlings.

The activities conducted in 2003 with the assistance of OTIP funding ultimately move us closer towards our goal of increasing the amount and quality of A-class seed for the Pli NE low, Pli TO low, and Fdi NE low seed planning units.

5.1.8 Riverside Seed Orchards

Greg Pieper and George Nicholson

Lodgepole pine (SPU 2801)

- The 2003 crop year produced another record cone crop for Orchard 303. A total of 113 hectolitres generated 102 kg of seed and 19 million potential seedlings. Cone induction was not used this year.
- A routine pesticide control program was initiated to control ahpids, *Leptoglossus*, and cone worm.
- Soil and foliar samples were taken, and analyses of nutrient status were completed in the fall.
- Pollen collection for a second-generation crossing program was completed; the pollen was extracted and stored at Kalamalka Research Station.

Interior spruce (SPU 1601)

- In 2003, Orchard 310 produced 19.4 hectolitres of cones that yielded 1.9 kg of seed. Productivity continues to be an issue for this orchard. The installation of micro sprinklers has improved the uniformity of irrigation around the root system.
- The orchard grass was not mowed until the pollination period was completed; this allowed higher humidity to build within the orchard.
- Control of *Leptoglossus* was a high priority, and five applications of pesticide were required this crop year. Sequoia pitch moth larvae were controlled by manually removing the larvae twice during the season.
- Branches infected with Western gall rust were removed from the orchard and destroyed.
- Soil and foliar samples were taken for analysis of nutrient status in the fall.

5.1.9 Prince George Tree Improvement Station (PGTIS)

Rita Wagner

Lodgepole pine (SPU 1203, 1802, 1702)

Activities are aimed at increasing the quantity and quality of lodgepole pine seed from Orchard 220 (Prince

George low planning zone), Orchard 223 (Central Plateau low planning zone), and Orchard 228 (Bulkley Valley low planning zone).

Three Operational Tree Improvement projects (SPU 1203, 1802, and 1702) were conducted at the Prince George Tree Improvement Station in 2003-2004. Emphasis was placed on the application of high-gain pollen to early and late flowering clones as well as to areas in orchards containing younger grafts to increase seed production in seed orchards 220, 223, and 228. Non-orchard pollen was also collected from other high-gain trees on site for application in future years. Approximately 20 litres of pollen with an average breeding value of 11% are now in storage. The fall 2003 cone harvest from the three orchards yielded 19.241 kg of seed. The seed has a genetic worth of 6%. Some strategies to increase flowering, including crown pruning and hormone application, were carried out. Trees in all orchards were surveyed for western gall rust and lophodermium needle cast.

Interior spruce (SPU 1412)

Management of interior spruce clone banks at the Prince George Tree Improvement Station is designed to ensure the availability of scion to replace existing orchard ramets or develop new orchards to boost productivity and gain.

The Interior Spruce Clone Banks at the Prince George Tree Improvement Station provide vital support to the orchard and tree breeding programs in B.C. The clone banks are a centralized source of scion material for the grafting of new and improved seed orchards. They contain the only copy of many of the interior spruce parent tree selections found in seed orchards and breed arboreta. Transplantation of 250 ramets (grafted in 2001) into the clone banks in the summer of 2003 filled empty positions. In 2003, 500 grafts were made, and they will be held in the holding area until 2005. These grafts were weeded, watered, fertilized, pruned and monitored, and treated for insects and disease. Similar management activities were carried out in the 12,000-tree clone bank.

Lodgepole pine (SPU 1704)

Activities are aimed at determining the efficacy of supplemental mass pollination (SMP) in lodgepole pine seed Orchard 228 and its contribution to seed production.

Supplemental mass pollination is recognized as an operational tool to improve seed production and genetic gain within seed orchards of some species of conifers. To determine the efficacy of SMP in lodgepole pine seed orchards, pollen with unique DNA markers was applied to select trees in Orchard 228 in the spring of 2000. However, cool and wet weather prevented the application of pollen as outlined in SPU 0708, and this resulted in the collection of insufficient seed for analysis. The trial was successfully repeated in 2001 following the procedures identified in SPU 1703. Cones were collected in fall 2002. Seed was extracted in fall 2003, and at time of this report DNA analysis is in progress at Vizon Scitec Ltd.

Re-tagging of the lodgepole pine provenance trial (EP 699.04) (SPU 1207)

The lodgepole pine provenance trials in B.C. are the most comprehensive of the Ministry's provenance studies; they comprise a range-wide collection of more than 150 population samples tested in various combinations at over 60 locations throughout the province. The plantation at PGTIS is the largest of these installations. The trial facilitates the development of a breeding strategy for lodgepole pine by providing valuable information on variation and its components. The trial is also a continuing source of material for research. Re-tagging of the most important provenances maintains the identity of these trees and facilitates further research, measurements, etc.

Plate 21. Planting spruce grafts in the Prince George Tree Improvement Station clone banks

Plate 22. Pollen cloud at the Prince George Tree Improvement Station

5.1.10 Skimikin Seed Orchard

Keith Cox

Funding supported work in the research plantations and four of the seed orchards at Skimikin in 2003.

In the West Kootenay (Nelson mid- and high) spruce orchards, 319 replacement grafts were made in the spring and planted in the holding area in the fall. The orchards were surveyed for insects and disease, and conelet samples were taken to monitor for the spruce cone maggot. A total of fifty-four rust brooms (*Chrysomyxa arctostaphyli*) were removed. Both orchards were sprayed twice to control the conifer seed bug, *Leptoglossus occidentalis*. Orchard 302 yielded a small crop of 3.23 kilograms.

The white pine crop in Orchard 609 was sprayed twice for the white pine cone moth (*Eucosma recissoriana*) and four times for the conifer seed bug (*Leptoglossus occidentalis*). The 2003 crop of 68.6 hectolitres yielded 19.4 kilograms of seed. Sixteen trees were rogued in the spring. Repairs were made in the spruce orchard for the Peace River mid-elevation zone (212) where 349 lower ranked trees had been removed the previous fall. The 2,101 trees in the orchard were monitored for insects, disease, and rodents. The orchard was sprayed once to control both spider mites and grasshoppers. Maintenance of replacement grafts in the holding area included spraying for spider mites. Seventeen mis-identified trees were removed in the fall.

The on-site research plantations were monitored for insects and disease and baited for rodents, and two young plantations were irrigated. Weevils were collected from the spruce plantations and orchards in June. They were reared in Victoria, along with weevils collected from other sites, then brought back in October and placed on the trees in the west end of the Shuswap-Adams spruce progeny test and the Thompson-Okanagan test to provide weevil resistance data. A trial of coastal Douglas-fir and a demonstration of realized gain in interior lodgepole pine were planted in the spring. Approximately 5,000 white pine seedlings were also planted as part of a rust resistance screening trial, and a site was prepared for 3,500 more to be planted in the spring of 2004. The *Ribes* garden was maintained, and white pine seedlings were inoculated in September. A total of 12,998 trees were removed from plantations no longer required, and about 80 loaves of the fungus *Hypholoma* were dug into one of the spruce plantations where *Armillaria* root rot has occurred. This fungus out-competes *Armillaria* and therefore will reduce loss.

Plate 23. In April 2003, 5040 white pine seedlings were planted to screen for blister rust resistance

Plate 24. In April the 3850 spruce trees in this trial were mulched in preparation for planting a coastal Douglas-fir trial

Plate 25. In the spring a portion of the Thompson-Okanagan spruce progeny test was cut down and mulched

Plate 26. In November, approximately 7,000 trees were removed from the Shuswap-Adams spruce progeny test after being screened for weevil resistance and sampled for wood density

5.2 Technical Support Projects

5.2.1 Cone and Seed Pest Management – Interior Operations

Robb Bennett

SPU 0405

During 2003/04 the Interior Seed Pest Management Biologist (Dr. Ward Strong) continued to provide the exceptional extension, research, and training services to which we have become accustomed. During this period he provided the following services to the Interior cone and seed production community and others:

- 325 seed-orchard site visits, pest surveys and identifications, and damage predictions and assessments.
- 58 written pest-survey reports to orchard managers and other seed production personnel.
- over 100 other pest-identification services to Ministry of Forests personnel and others.
- over a dozen extension presentations to secondary school, college, and university students.
- various professional presentations to the BC Seed Orchard Staff Group, Forest Genetics Council, and others.
- numerous “tail-gate” extension presentations to operational seed production personnel.

- initiated, continued, or completed six in-house seed-orchard pest-management research projects.
- collaborated on five other research projects in cooperation with university, research institution, and other personnel.

The following publications resulted from these activities:

Bates, S. L., W. B. Strong, and J. H. Borden. 2003. Abortion and seed set in lodgepole and western white pine conelets following feeding by *Leptoglossus occidentalis* (Heteroptera: Coreidae). Environmental Entomology 31(6): 1023-1029.

Morewood, P., D. Morewood, R. G. Bennett, W. B. Strong, and G. Gries. Submitted for review. Last Call®: A tactic for control of *Contarinia oregonensis*? The Canadian Entomologist.

Heeley, T., R. Alfaro, L. Humble, and W. B. Strong. 2003. Distribution and life cycle of *Rhyacionia buoliana* (Lepidoptera: Tortricidae) in the interior of British Columbia. Journal of the Entomological Society of British Columbia 100: 17-23.

Strong, W.B. 2003. Seed Orchard Pest Management and Insecticide Deregistration. Canadian Tree Improvement Association Tree Seed Working Group News Bulletin 38: 9-11.

5.2.2 Damage Potential of Field Densities of *Leptoglossus occidentalis*

Ward Strong

The Western Conifer Seed Bug, *Leptoglossus occidentalis*, is the most serious pest in conifer seed orchards in the interior of B.C. Tests over the past six years have shown that it routinely reduces seed set by 10 to 50% and is capable of reducing seed set by up to 80%. The problem of low seed set in lodgepole pine orchards in the southern interior has largely been attributed to *Leptoglossus*. It also feeds on white pine, Douglas-fir, spruce, and larch, though the problem is less well characterized in these tree species.

Management of the seed bug is dependant on the use of broad-spectrum insecticides. Despite years of study, no other control methods, such as biological controls, trapping methods, or cultural techniques, have come to light. Appropriate use of insecticides requires two techniques: a method of estimating field densities of *Leptoglossus* (monitoring technique) and a method of relating these densities to damage potential (density-damage relationship). A visual-sample monitoring technique is under development concurrently with this project. This project is designed to develop a density-damage relationship so that the damage potential of monitored densities of *Leptoglossus* can be estimated.

Methods

Leptoglossus densities were monitored weekly or more frequently from early May through early August, 2003, at each pine orchard in the southern interior of BC. Large pine orchards were divided in half, and each half was monitored separately. In total there were 15 orchards and half-orchards (“replicates”). Monitoring consisted of half-hour transects through the orchard on foot, visually examining cones and counting *Leptoglossus*. This monitoring method has been in use for several years. The effects of temperature, cloud cover, time of day, wind, and season on monitoring results were explored in 2003 and will continue to be investigated in 2004.

For each replicate, accumulated *Leptoglossus* days (LDs) were computed to estimate feeding pressure in that replicate. LDs were computed by taking the average of the current day’s count and the previous day’s count and multiplying by the number of days between counts. For example, if the count on June 10 was 12 *Leptoglossus*, and the count on June 17 was six *Leptoglossus*, LDs accumulated in that period was (12 + 6) / 2 x (17 - 10) = 63 LDs.

In each replicate, feeding damage was assessed with insect exclusion bags. On April 28, exclusion bags were placed over second-year cones to protect them from *Leptoglossus* feeding. On July 30, bagged cones and nearby unbagged cones (exposed to *Leptoglossus* feeding) were collected. Seeds were extracted by the boil, bake, and shake method, and for each sample seed set (filled seeds per cone) was computed. The difference between exposed and bagged cones was a measure of feeding damage.

Feeding damage was then graphed against LDs to indicate the relationship between monitored densities of *Leptoglossus* and feeding damage. A regression line was generated to describe the relationship mathematically. A close relationship is indicated by a high r^2 value of the regression. The closer the relationship between LDs and damage, the more reliably we can estimate damage from monitored densities.

Results

We conducted 173 thirty-minute monitoring events for this study, or over eleven per orchard replicate. Another 78 events were conducted to evaluate the environmental variables that might influence the monitoring system itself. From these results, the feeding pressure, expressed as LDs, has been calculated for each orchard replicate. Data on the influence of environmental variables have not yet been analyzed.

The exclusion bag treatments have been harvested, and the seeds extracted and X-rayed. The filled and empty seeds were counted. Seed loss due to *Leptoglossus* for each orchard replicate was then calculated. Graphs of reduced seed set (decrease in Filled Seeds per Cone) as a function of *Leptoglossus*-days were generated. Figure 16 shows graphs from 2002 data; Figure 17 shows graphs for 2003 data; and Figure 18 shows combined data from 2002 and 2003. LDs were calculated based on counts of all ("Total LDs," Figures 16A, 17A, and 18A), counts of female *Leptoglossus* only ("Female LDs," Figures 16B, 17B, and 18B), counts of male *Leptoglossus* only ("Male LDs," Figures 16C and 17C), and a weighted count ("Low-male LDs," Figures 16D, and 17D,). Low-male LDs were calculated based on the results of Sarah Bates's work showing that females consume about three times as many seeds as males or nymphs. Therefore "Low-male" LDs were calculated by counting each female as one lepto and each male or nymph as 0.3 lepto.

Each point on these graphs represents one orchard replicate. Although a nice regression line is shown on each, the r^2 value is generally low, indicating a poor relationship between LDs and subsequent damage. This poor relationship is not surprising in view of the variability in the monitoring method; differences in cultural techniques, orchard age, microclimate, and other site-specific factors; and experimental error in sample collection. As we learn the influence of environmental variables and time of year, we will be able to account for these in our calculation of lepto-days, which will improve the regression. Even without analyzing the environmental variable data, it's clear that ambient temperature plays a key role in observed numbers of *Leptoglossus*. Eventually we will be able to incorporate a temperature-adjustment factor, and possibly adjustment factors for other environmental variables or time of year, to make our predictions of seed set loss very accurate.

In the regressions LDs calculated on male counts alone showed no relationship at all to subsequent seed reduction (Figures 16C and 17C). Nymphs alone also showed no relationship (not shown). However, when males and nymphs were included in the "low-male" LDs, the regression gave the most consistent r^2-value between the two years. Theoretically, this method of calculating LDs should give the best relationship with subsequent seed loss because it reflects the relative amount of feeding by the females, males, and nymphs. Time will tell whether this theory pans out.

Regressions are expected to tighten up as data rolls in over the next few years, and as the analysis becomes more refined. The more data points (replicates) on the graph, the stronger the overall regression will be. Even more important, as more data comes in we will be able to account for factors that contribute to variability. We will be able to take orchard age into account, cone crop size, weather, *Leptoglossus* stage and sex, and time of year. Currently there are not enough data to make meaningful regressions with these refinements. Ultimately, however, this multi-year project will provide enough data to make a highly refined analysis that will lead to an accurate density-damage relationship.

Once an accurate density-damage relationship has been described, we will be able to make well-informed decisions about managing *Leptoglossus*. Pesticide spray thresholds will be the main decision-making tool. We might be able to say, for example, that "x number of *Leptoglossus* found in our half-hour search indicates a potential seed loss of y%, and therefore a spray is not warranted." In this way, pesticide applications will be minimized and will be used only when and where necessary.

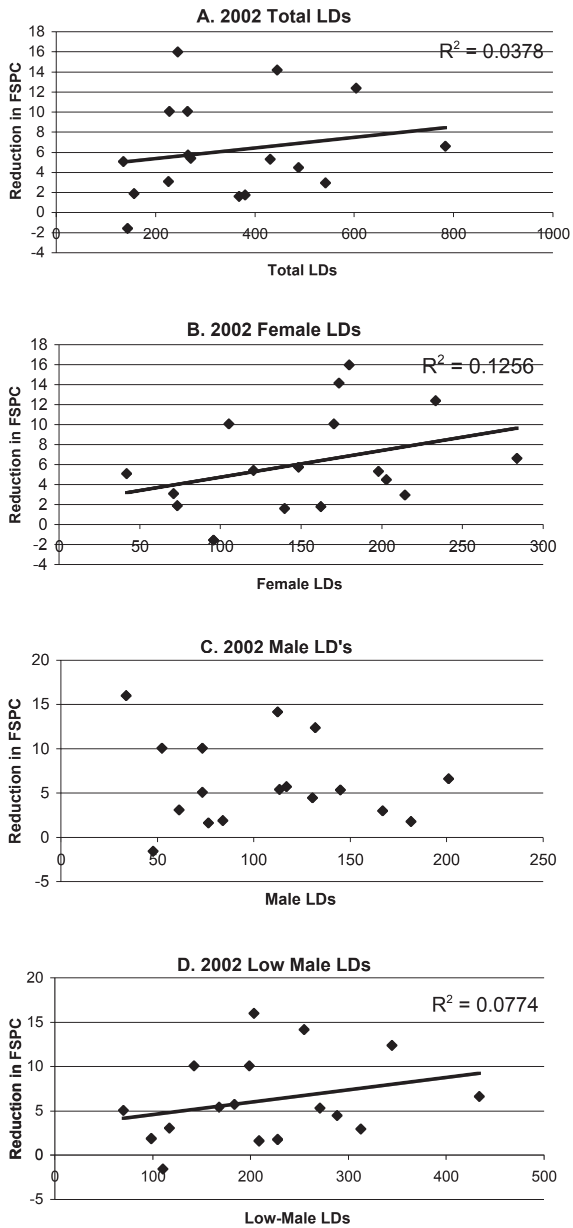


Figure 16. 2002 data comparing *Leptoglossus* days with seedset loss

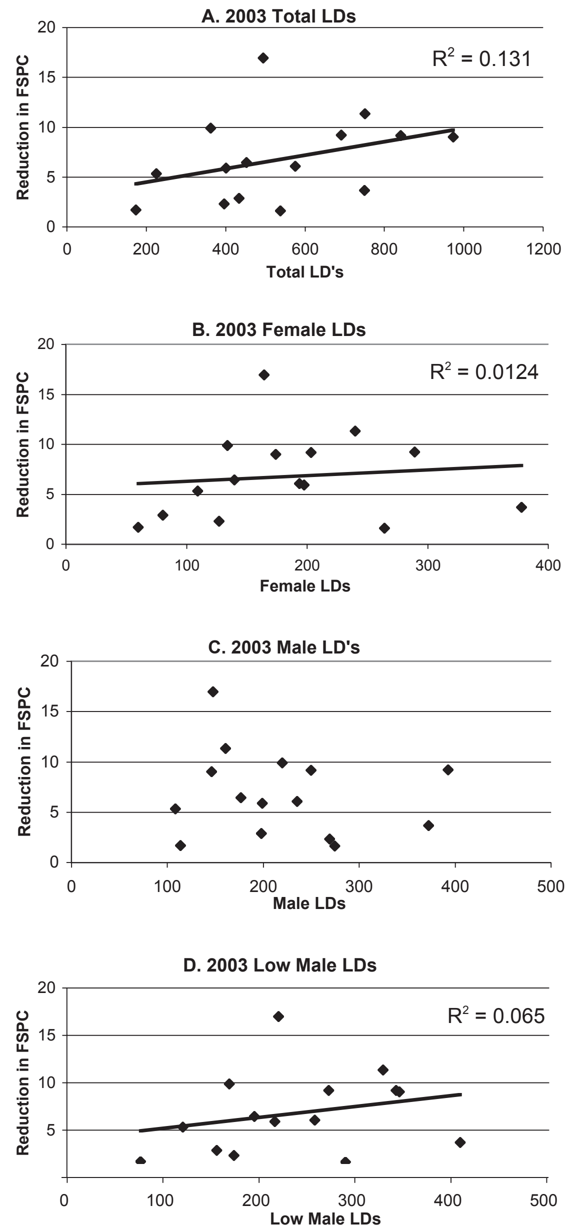


Figure 17. 2003 data comparing *Leptoglossus* days with seedset loss

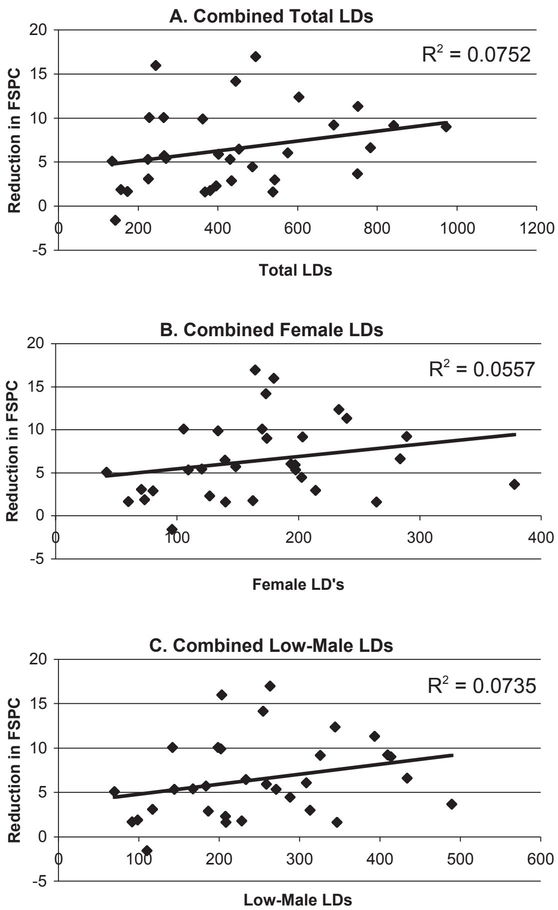


Figure 18. Combined 2002 and 2003 data comparing *Leptoglossus* days with seedset loss

5.2.3 Identification of Communication Signals Produced by Male Western Conifer Seed Bugs, *Leptoglossus occidentalis*

Robb Bennett (compiled from report submitted by Gerhard Gries)

SPM 0001

In the first year of this project, the following objectives were addressed:

- identify the major candidate pheromone component of the western conifer seed bug (WCSB).
- test whether male WCSB produce substrate-borne vibrations.
- test in laboratory or field experiments whether the blend of all candidate pheromone components attracts female WCSB.

Major candidate pheromone component

Earlier work had suggested that the major candidate pheromone component (CPC) of WCSB is a sesquiterpenoid. Of 183 essential oils screened by coupled gas chromatography-mass spectrometry for the presence of CPC, only one yielded any positive results. An abundant component in Valarian root-oil has physical characteristics very similar to those of CPC, suggesting that this compound might be useful for the identification of CPC (work proposed to be done in the second year of this project will pursue this further).

Substrate-borne vibrations

Lab bioassays demonstrated that male WCSB produce sonic signals 20 decibels above the threshold of human hearing with two dominate frequencies of 115 +/-10 Hz and 175 +/-15 Hz (Figure 19) in a distinct temporal pattern. There was no evidence that females produce sound to attract males and no evidence for ultrasonic sound production by either sex. Whether nymphs also produce sound has not yet been determined.

Pheromone experiments in attracting females

Based on difficulties encountered during work on the first objective and the positive results derived from work on the second objective, the third objective was revised as follows:

- test whether male WCSB-produced signals are attractive to other WCSB.

In lab bioassays, male WCSB (Figure 20; Exp. 1) and female WCSB (Figure 20; Exp. 2) preferred played-back sonic signals from males to silent control stimuli, whereas nymphal WCSB (Figure 20; Exp. 3) failed to respond. Groups of WCSB strongly preferred male-produced sonic signals to the silent control (Figure 20; Exp. 4). Visual observations during Exp. 4 suggest that nymphs actively track males.

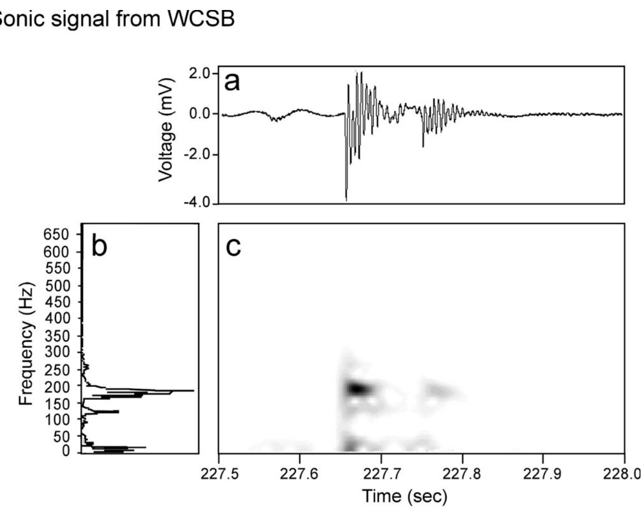


Figure 19. Analysis of waveform (a), frequency (b), and time-frequency sound intensity (c) of a substrate-borne sonic signal recorded from a male *Leptoglossus occidentalis*. The more intense the shading in diagram c, the more intense the frequency component of the signal. WCSB = Western Conifer Seed Bug

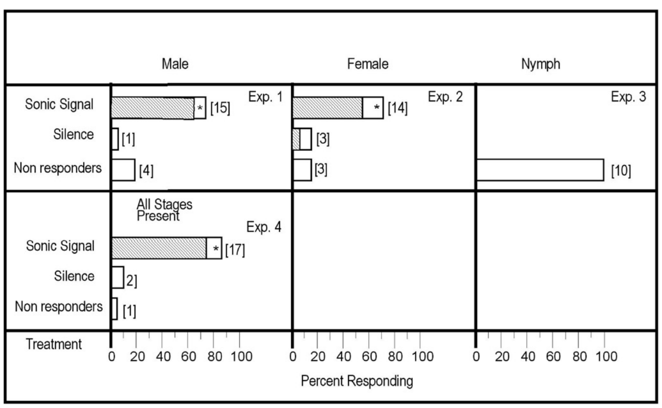


Figure 20. Responses of male (Exp. 1), female (Exp. 2), 3rd instar nymph (Exp. 3) and of mixed groups of male, female, and nymph WCSB (Exp. 4) to test stimuli in arena experiments. Bars represent percent of WCSB responding to a particular stimulus; numbers in parenthesis beside bars indicate number responding to test stimuli. For each experiment, an asterisk indicates a significant preference for a particular stimulus [Fisher Exact test (Exp. 1-3; $P < 0.05$)]. Note: 1. Cross-hatching on bars represents the number of insects on the loudspeaker; 2. females responded to test stimuli only during the scotophase; 3. nymphs were tested during the photophase and need to be retested during the scotophase (taking results of Experiment 2 into account)

5.2.4 Operational Assay Program for Fungi Attacking Conifer Seed in B.C.

Robb Bennett (compiled from report submitted by Dave Kolotelo)

SPM 0004

In the first year of funding for this project, a combination of in-house and Forest Genetics Council (FGC) funding enabled fulfilment of the immediate high-priority project objectives. These were:

- to perform fungal assays on new seedlots from conifer species known to be at high risk of infection by a particular pathogen and
- to reduce the backlog of assays of high-priority seedlots.

A long-term goal of this project is to test new and backlog seedlots during the summer of each year and have the results posted on the on-line Seed Planning and Registry System (SPAR) before current year sowing requests are placed through SPAR.

The Forest Genetics Council funding was used to perform the following assays:

- *Caloscypha fulgens* – 27 seedlots
- *Fusarium spp*. – 78 seedlots
- *Sirococcus spp*. – 24 seedlots.

The results of these assays were posted on SPAR in preparation for the 2004 seedlot sowing request system.

5.2.5 Identification of an Effective Sex Pheromone Lure for the Fir Cone Worm, *Dioryctria abietivorella*, and Demonstration of its Efficacy in Seed Orchards

Robb Bennett (compiled from reports submitted by Gary Grant and Jocelyn Millar)

SPM 0002

Canadian Forest Service and University of California (Riverside) researchers led work on this project, with collaboration from the B.C. Ministry of Forests. The broad objectives of this work are to:

- determine the components of the fir coneworm pheromone.
- synthesize and purify pheromone components for field testing.
- conduct trapping experiments in seed orchards in B.C., California, and Quebec.
- perform behavioural bioassays on live moths in the lab.

From moths reared from Douglas-fir cones, pheromone extracts were prepared and then tested through standard coupled gas chromatograph/electroantennogram detection (GC-EAD) procedures. The EAD detected only two compounds in the extracts: Z9,E11-14:Ac, and trace amounts of either Z9- or E9-14:Ac. Although the GC detected a number of other compounds in the various extracts, none of them elicited antennal responses. Thus the evidence indicates that the pheromone consists of one or possibly two components. Final resolution awaits further work planned for 2004/05.

Purification of pheromone components has been focused on the major component, Z9,E11-14:Ac. The use of custom-made chromatography columns and associated equipment achieved 99% chemical and isomeric purity, but this method proved costly and provided only tiny amounts of purified pheromone. An industrial process based on low-temperature recrystallization of derivatives was also used, but none of four different derivatives methodologies produced satisfactory results. Despite this, continuation of this work is planned in the hope that this general technical and financial bottleneck can be eliminated.

Field tests of synthetic pheromone blends were conducted at Chico, CA, Vernon, BC, and in Quebec during 2003. Trap catches were low in Chico and Vernon and zero in Quebec. The poor catches were not likely due to pheromone degradation or impurity. A key pheromone component may be missing, or perhaps one of the physical parameters (e.g., traps design) needs to be manipulated.

A laboratory colony of cone worms has been established in Sault Ste. Marie, ON to provide insects for the behavioural bioassays (and further GC-EAD analysis). Continuation of this aspect of the work is expected in spring 2004.

5.2.6 Identification of Seed Chalcids Infesting Seeds of B.C. Conifers (SPM 0003)

Robb Bennett (compiled from reports submitted by Jean Turgeon and Alain Roques)

SPM 0003

This collaborative B.C. Ministry of Forests/Canadian Forest Service/Institut National de Recherche Agronomique (France) project has been trickling along for several years. 2003/04 was its first year of Forest Genetics Council funding. The long-term objectives are to:

- clarify the identity and host range of the North American species of seed chalcids in general, and of those exploiting conifer seed in B.C. in particular.
- determine the identity of, and attack timing data for, parasitoid insects attacking seed wasps.

In 2003/04 the following work was accomplished. Seed samples from approximately 50 natural stand and orchard seedlots (predominantly *Pinus monticola*, *Pseudotsuga menziesii, Abies amabilis* and *Picea* sp.) collected in fall 2003 were shipped to the Canadian Forest Service Sault Ste. Marie lab in early 2004. Cones were also collected from natural stands of *Larix laricina, Tsuga canadensis, Albies balsamea, Pinus strobus, Picea rubens, Picea glauca* and *Picea mariana* in northern Ontario (funded by Canadian Forest Service). All seedlots were X-rayed during Winter 2004 to determine the presence of insect larvae within seeds. *BC Picea* spp., *Abies amabilis* and *Pseudotsuga menziesii* and *ONT Albies balsamea*, *Tsuga canadensis* and *Pinus strobus* hosted large numbers of *Megastigmus* spp. seed chalcids. Currently, a proportion of infested seed from all seedlots are being stored at 2^0 C until Spring 2004, when they will be put in an outdoor insectary and checked daily for adult seed chalcid or parasitoid emergence. Half or more of the seeds from each infested sample have been shipped to France for genetic analysis of emerging specimens.

To determine identity and attack timing of parasitoids, cones from several B.C. natural stands (*Picea, Pseudotsuga, Abies*) with known high numbers of *Megastigmus* and associated parasitoids were collected in late Fall 2003. The seeds were extracted and then sent to Sault Ste. Marie. Winter conditions allowed for only one late season collection of cones from these sites. Cone samples from two heavily infested *Pseudotsuga menzesii* orchards were collected monthly between October and December 2003. In December, all remaining cones were collected from these orchards; seed was extracted in early 2004 and subsequently sent to Sault Ste. Marie for analysis and insect rearing. Similar work was done at *Tsuga canadensis, Albies balsamea* and *Larix laricina* sites in Northern Ontario (CFS funding): three collections of cones were made at each site, approximately one month apart. As above, insects from all these samples are being reared at Sault Ste. Marie and in France for morphological and genetic analysis of emergent adult chalcids and parasitoids.

5.2.7 Estimation of the Deleterious Effects of Different Levels of Inbreeding on Production in Western Hemlock Seed Orchards

Oldrich Hak

When SMP is used in forward-selected advanced-generation seed orchards and even in first-generation orchards, there is likely to be some reduced seed set due to inbreeding. The size of these effects for western hemlock is unknown, except for selfing. It is therefore advisable to investigate even the low levels of selfing for a species before designing and establishing advanced-generation orchards.

The objective of this project is to determine the effect of lower-level inbreeding on 16 western hemlock parent trees and their progeny to estimate the impact on seed production. Back–crosses, full-sibs, half-sibs, and out-crosses will be made to determine the percentage of seed production relative to the out-crossed seed. The trees were induced with a hormone in the spring of 2003 to ensure adequate male and female cone production, and the crossings will be done in the spring of 2004.

5.2.8 Determination of Selfing Rates in a Clonal-row Spruce Orchard (SPU 3503)

Michael Stoehr and Helga Mehl

Background

In the past, seed orchards needed to be licensed to ensure that orchard-management plans and orchard composition were up to standards. A seed orchard license was a pre-requisite for seedlot registration. This licensing requirement no longer exists, and more emphasis is placed on the protocol for rating seedlots. However, in an orchard with a new and innovative design, mating dynamics should be checked to find out if they conform to expectations. One type of orchard with a new and innovative design is a clonal-row orchard in which many ramets of the same clone are planted in a row and spaced relatively close together. This type of orchard will make orchard management more efficient because all ramets of a single clone are in close proximity for surveys, pollinations, cone harvesting, and other orchard-management activities. However, this arrangement may also increase selfing levels because many “closest-neighbour” trees are genetically identical and will have very similar flowering phenologies (receptivity and pollen shed). Clearly, before seedlots from this type of orchard are registered, it is prudent to evaluate selfing because increased levels of selfing in a seedlot large enough to raise 2.2 million seedlings per year may have serious implications. Not only will seed set be lowered, but also the vigour of the resulting seedlings is compromised.

Activity

Paternal analyses of seed from ten easily identifiable clones were conducted. For this purpose, all thirty clones of Orchard 620 were genotyped using polymorphic chloroplast DNA (cpDNA) markers. For genotyping, vegetative buds were used to extract the total DNA from all clones. Potentially polymorphic sections of cpDNA were amplified using PCR and compared among the thirty clones. Ten clones with unique multi-locus genotype patterns were chosen for further analysis. From the ten selected clones, a clonal bulk sample of seeds was collected, and their embryos were analyzed individually to see if they had the same cpDNA pattern as their maternal parent (seed trees). The identical pattern in the embryo indicates a selfed seed because cpDNA is carried by the male gamete only. A total of fifty seeds per clone were assayed for a total of 500 seeds.

Results

There was no evidence, based on the ten sample clones, that there is an overall increased level of selfing in this particular clonal-row orchard. Individual selfing on a clonal basis ranged from 0% to 14%, with an average of 4.4%. Results for the sample clones are listed in Figure 21. It is important to realize that these selfing levels are unambiguous because only unique orchard clones were selected for this study.

Clone	Selfed Seed	Total Seed	%Percentage
311	5	50	10
381	4	50	8
339	0	50	0
386	7	50	14
408	3	50	6
447	0	50	0
422	0	50	0
377	0	50	0
410	0	50	0
419	3	50	6
Average			4.4

Figure 21. Levels of natural selfing in ten clones of a clonal-row spruce orchard (620) at Kalamalka seed orchards

5.2.9 Determination of Selfing Rates in a Top-pruned Interior Spruce Seed Orchard (SPU 410)

Michael Stoehr and Helga Mehl

Background

In the past, seed orchards have routinely been top-pruned to facilitate easier and safer orchard management. This practice, however, brings the zone of male and female reproductive cones closer together, thus potentially increasing the chance of selfing. The problems associated with selfing are reduced seed set and reduced vigour in the progeny. DNA markers are available to test for increased selfing in these top-pruned orchard ramets.

Activities

In an orchard, clones must be genotyped before they can be identified as candidates for study. For this purpose, total DNA was extracted from vegetative buds of each producing clone (78 clones in total) in interior spruce orchard 305. Using the PCR technique, several chloroplast DNA (cpDNA) markers were applied to screen for unique clones, ones that are unambiguously identifiable among all orchard clones. These easy-to-score clones have been chosen for further study in 2004.

Results

The results of the genotyping revealed that, with only two primer pairs, 12 out of the 78 trees in the orchard can be identified unambiguously (Figure 22). Marker S2spF/R especially is extremely variable, yielding 14 alleles (different bands) alone. However, because some of the clones in orchard 305 are too small for pollination or because they have been subsequently culled, genotyping was intensified by using all five available polymorphic markers. The separation power increased, so that 18 clones can be identified by using five primer pairs (Figure 23). This array of available clones will be used to make final selections for further study based on the expected cone crop of these clones in year 2004.

Primer Pairs			
S2spF/R	89F/62R	# of clones	clone id
a	b	1	575
b	b	1	3079
c	c	1	3180
e	d	1	1289
f	b	1	692
g	d	1	3243
h	d	1	3146
j	d	1	1299
k	a	1	3004
l	c	1	661
n	d	1	3254
o	d	1	2005

Figure 22. Unique genotypes of interior spruce clones growing in Kalamaka Orchard 305 identifiable using two genetic markers

S2spF/R	89F/62R	84.1F/R	8F/8R3	7RR/7F3	# of clones	clone
a	b	d	b	b	1	575
b	b	d	d		1	3079
c	c	d	b		1	3180
d	c	d		b	1	3173
e	c	d	b	a	1	3263
e	d	d	b	b	1	1289
f	b	d	b	b	1	692
g	d	d	b	b	1	3243
h	b	d	c	b	1	1364
h	b		b	b	1	2008
h	d		b		1	3146
j	c	d			1	2702
j	c	e	b	a	1	3324
j	d	d	b	c	1	1299
k	a	d	c		1	3004
l	c	c	c	a	1	661
n	d	d	b		1	3254
o	d		b		1	2005

Figure 23. Unique genotypes of interior spruce clones growing in Kalamaka Orchard 305 identifiable using five genetic markers

5.2.10 Estimation of Selfing Rates in Western Larch using DNA Markers

Craig Newton and Chris Walsh

SPU 3402

Orchard haplotyping to identify pollen donors

In this study, 114 parental clones in two western larch (*Larix occidentalis Nutt.*) seed orchards (332 and 333, Kalamalka Forestry Centre) were haplotyped using a set of three polymorphic chloroplast DNA markers. The haplotypes will be used to identity parental clones whose pollen is unique and can be distinguished unambiguously. For example, if a clone has a unique chloroplast haploytype, then any seed carrying this haplotype could only have been sired from that pollen source. Haplotype analysis using cpDNA therefore provides a means to measure selfing rates — for example, seed that carries the same haplotype as its parent — and other questions such as the amount of pollen flow between orchards. The ability to measure pollen flow is a useful tool for detecting whether orchard design or management practices — for example, crown topping — have an impact on selfing levels and overall seedlot genetic health.

Results

Total genomic DNA were prepared from vegetative samples from one ramet of 133 different clones (Figure 24). The genomic DNAs were then amplified using the three larch chloroplast markers, G_2.1/R1, 59A, and 10FRR, and the products were analysed by electrophoresis and autoradiography. Complete three-loci haplotypes were obtained for 114 of these clones, or 86% of the total. A total of twenty-five (22%) different haplotypes were found in these 114 samples. Of these, fifteen were unique to single clones, while the remaining ten haplotypes were shared between two and twenty-three different clones from either orchard. The number of unique haplotypes per orchard was seven and eight, respectively.

Conclusions

Although the total haplotype diversity is low in these western larch orchards (22%) compared to lodgepole pine or spruce chloroplast markers (~75%), at least fifteen clones or approximately 10% of the total were identified as unambiguous sources of pollen haplotype. The low level of haplotype diversity may be a consequence of having only three polymorphic markers, compared to the five or six used in spruce and pinus species. For Orchard 332, the eight unique haplotype clones comprise 161 out of 1,412 potential ramets in this orchard and therefore are still a significant sampling (11%) of the total theoretical orchard pollen cloud.

It will now be possible to analyze seed collected from these fifteen clones to determine selfing rates and pollen migration between orchards with little or no ambiguous background.

Haplotypes / clone	Parental Clones		
	Orchard 332	Orchard 333	Total
Number of parental clones	70	66	136
Number of complete 3 locus haplotypes	62	52	114
Number of different haplotypes	16	18	25
Number of unique haplotypes	8	7	15

Figure 24. Chloroplast haplotype diversity in *Larix* spp.

5.2.11 Controlling Selfing Rates in Seed Orchard Populations of Western Redcedar

Kermit Ritland, Patti Brown, Bev Wigmore, John Russell

SPU 0209

For the past four years, we have been conducting experiments to determine factors influencing selfing rates in redcedar seed orchards. Since western redcedar has a very low isozyme heterozygosity, with only one useful isozyme locus for genotyping , we are using highly informative microsatellite loci, developed at UBC, for estimating the mating system in these studies. In the current year, we conducted three studies.

1. We examined the effect of crown position on selfing in the TimberWest Mt. Newton Seed Orchard. In 2002, 20 seeds from each of twenty trees, half sampled from the lower crown and half sampled from the upper crown, were genotyped for four microsatellite loci. As expected, outcrossing rates were higher in the upper crown (mean 0.835 ± 0.024 SE), compared to the lower (mean 0.793 ± 0.024 SE), but only marginally so. These differences were not as great as in two earlier studies, and a third study conducted last year actually found that the outcrossing rate was higher in the lower parts of the tree.
2. We examined the effect of "hooding," a treatment used to avoid unwanted pollination in Canfor's Sechelt seed orchard: in hooding, loose bags are put over female branches and pollen is applied a few times under these hoods when females are receptive. We compared this method with supplemental mass pollination (SMP) and an undisturbed control, and we also looked at the influence of north-facing vs. south-facing exposure. In 2003, these treatments were applied to 10 trees, and 30 seeds per tree were assayed, with five seeds for each combination of (north, south) x (hooding, SMP, control). Unexpectedly, hooding had little detectable effect on outcrossing (0.864 ± 0.027 SE), compared to SMP (0.829 ± 0.032) and the control (0.897 ± 0.023). At least, hooding increased the tendency of trees to produce full-sibs in response to controlled pollination, as indicated by a significant correlation of paternity within families of 0.113 ± 0.054 SE, compared to the control which showed no significant correlation of paternity. Also as expected, the outcrossing rate on the north side (0.844 ± 0.024 SE) was lower than that on the south side (0.882 ± 0.021 SE). These results and those of earlier years show that selfing rates in redcedar are variable and not easily predicted.
3. The above findings of rather unpredictable patterns of selfing would suggest conducting routine assays of seedlot quality, independent of seed orchard practices, and perhaps using such assays in seedlot quality ratings. As a "proof of concept" that levels of selfing in production seedlots can be economically characterized via molecular assays, data were simulated with outcrossing rates of 0.70, using the same gene frequencies as this year's Sechelt seed orchard study. A model of outcrossing was fitted to "bulk" data (not families) and evaluated for statistical properties in relation to numbers of individuals and loci assayed. We found that using only the two most polymorphic loci was almost as efficient (within 5%) as using all four loci. While there is considerable bias with smaller samples (see Figure 25), it seems that samples of around fifty seeds are needed for reasonably reliable estimates, where the SEs are ca. 0.1, when there is also little bias. A reduction of the SE to ca. 0.06 can be attained by doubling the sample size to 100, but it may be better to focus on the assay of more seedlots to identify those with conspicuously high levels of inbreeding.

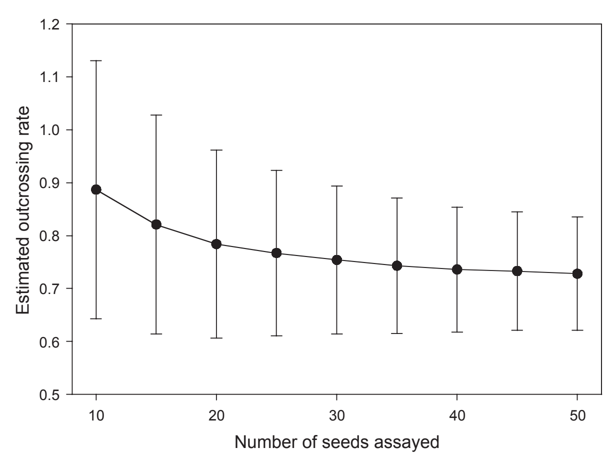


Figure 25. Simulations of the power of inferring outcrossing rate in bulk seed lots, as indicated by the bars for standard errors. The true outcrossing rate was 70%, and two microsatellite marker loci were used. Significant bias occurs with samples less than about 20

5.2.12 Development of Pollen Management Guidelines for Yellow-cedar.

Oldrich Hak

Poor pollen quality at pollination time may be one of the principal factors responsible for the failure of low-elevation orchards to produce sufficient quantities of viable seed. To date, all assessments of pollen quality were based entirely on *in vitro* testing using pollen germination. These assessments should be interpreted as only an indication of pollen fertility.

In this project, the actual fertility of low-elevation males is being confirmed through control pollination of females in natural stands. Similarly, the level of fertility of low-elevation females is not known and is being examined through control pollinations using high-quality pollen collected from natural stands.

Control pollinations at a low-elevation seed orchard (Mt. Newton) using stored high-elevation pollen and orchard pollen as control, and control pollinations in natural stands at high elevations (Mt. Washington and Jordan River high elevation) using low-elevation pollen (Mt. Newton) and high-elevation pollen as control have been completed during the spring of 2002. During the fall of 2003, mature cones at each of the above locations were collected, and the seed was extracted and blown to separate full seeds from empty seeds.

Since the use of air agitation to separate full seeds from empty ones provides only a rough estimate of the number of full seeds, a sample of 100 blown "full" seeds from each control pollination was x-rayed this winter and will be examined for the presence or absence of embryos. The same sample of 100 seeds is being stratified and will be germinated to determine the percentage of germination. Results will be available in the fall of 2004.

This was the first attempt to carry out control pollinations in natural stands of yellow-cedar at high elevations. Difficulties with environmental conditions and with bears were encountered. For example, trees were almost completely covered by a heavy snow load during the winter. In the spring, during a gradual snowmelt, branches with female flowers were not freed and exposed to pollination uniformly. This resulted in inconsistent pollination within and between trees: pollen for some pollinations had to be held in the fridge for up to three weeks longer than pollen used for the first pollination. Furthermore, physical damage to the trial branches by bears at a high-elevation site reduced the number of testing samples. Bears were curious about mesh bags placed on the pollinated branches and ripped them and the developing cones down. This damage occurred entirely at the Jordan River high-elevation site, while the Mt. Washington site remained untouched. These problems can be dealt with in the future and can be overcome.

Given the important consequences of locating and managing yellow-cedar breeding and seed orchards, recommendations for their establishment should be based on data from more than one year. Furthermore, difficulties with environmental conditions and bears that were encountered during this project introduced several factors that may influence the results of the trial to a certain degree.

A follow-up project at Mt. Newton seed orchard (low elevation) and Mt. Washington (high elevation) was therefore established in 2003 to deal with the above problems and to confirm the results in the first project through re-testing. An additional low-elevation site at Jordan River was included in the new project since it has produced good quality pollen in the past trials and has a good potential to produce viable seed. Control pollinations at all the above sites will be completed in the spring of 2004, and cones will be collected in the fall of 2005.

5.2.13 Improving Seed Production in Yellow-cedar Seed and Breeding Orchards

Oldrich Hak

Sexual reproduction of yellow-cedar, adapted to cold temperatures and short growing seasons, may be negatively affected when trees are grown in low-elevation seed orchards and subjected to a warmer climate and a longer growing season. Previous results indicate that at the time of pollination, pollen produced at high elevations is superior to pollen produced at low elevations (see SPU 1107 "Project Report 2002/2003"). If this proves to be true, yellow-cedar pollen could be produced at high elevations, stored, and used for pollinations in low-elevation or high-elevation orchards.

Recently, a high-elevation seed orchard has been established on Vancouver Island. A seed production area is being developed, and new breeding orchards will be established in the near future.

Pollen and seed production at high elevations are sporadic. Techniques to enhance male and female cone production have been developed for low-elevation orchards only. Because of environmental differences between low- and high-elevation sites, the optimum periods of time and optimum GA_3 concentrations for effective cone induction treatments differ at these elevations, and the techniques developed for low-elevation sites need to be refined and adapted to high-elevation sites. The objective of this project is to develop protocols for operational cone induction treatments in natural yellow-cedar environments at high elevations.

To date, trials testing the effects of the timing and concentration of GA_3 on male and female flower production at high elevations have been completed. The results show that the best response for male-cone production is at 200 mg or 400 mg/l GA_3 one month after pollen shed (Figure 26). Concentrations of 100 mg/l during the same period resulted in moderate male-cone production. The effectiveness of the treatment decreased with increased time from pollen shed. Treatments after two months from pollen shed resulted in very low male-cone production

The results also show that the effects of timing and concentration on female-cone production are very significant (Figure 27). The best response was with 400 mg/I GA_3 one month after pollen shed. GA_3 concentrations of 200 mg/l during the same period produced a moderate number of female cones. Production decreased drastically with higher concentrations and increased time from pollen shed. Production after two months from pollen shed was almost zero.

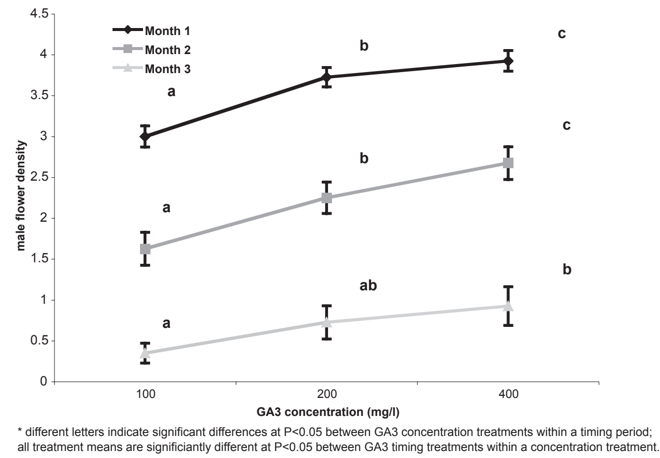


Figure 26. Cy male flower: effect of timing and concentration of GA3*

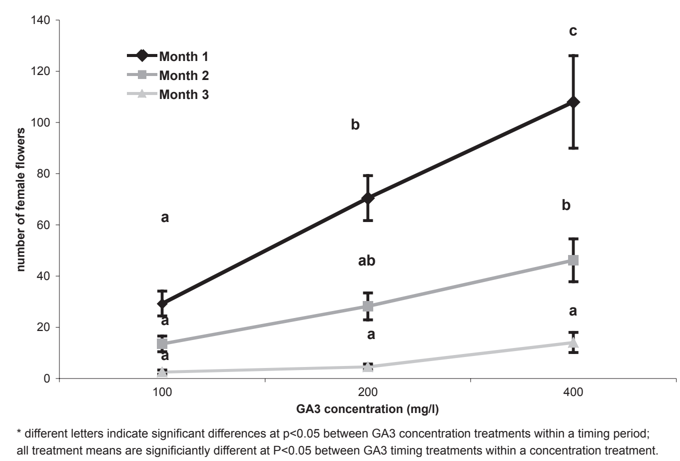


Figure 27. Cy female flower: effect of timing and concentration of GA3*

5.2.14 Promotion of cone production in *Abies amabilis* (Ba) seed orchards.

Oldrich Hak

Seed orchards established in dryer and warmer environments with the intention of increasing seed production have failed to produce sufficient quantities of female cones in *Amabilis* seed orchards. Cone induction treatments using $GA_{4/7}$ either as stem injections or foliar sprays have not been promising. Possible reasons for the lack of response may be that the method of application was not optimum, or the timing and concentrations were imprecise. Dr. J. N. Owens (personal conversation) suggests that early treatments (i.e., at vegetative bud burst) may be more effective and supports the idea of foliar spray alone or in a combination with stem injection using $GA_{4/7}$.

The objective of this trial is to test this suggestion, and if indications are positive, additional trials to fine-tune the timing and the $GA_{4/7}$ concentration will be proposed in the future. To date, 14 clones at Mt. Newton Seed Orchard in Saanichton were treated with $GA_{4/7}$ using foliar spray in the spring of 2003. Three $GA_{4/7}$ concentrations and three time periods were used to treat each clone. Each clone was initially scored for size and later for vegetative bud/shoot developmental stages at each treatment period. Male and female cone production will be assessed and analyzed in June 2004.

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

Gary Giampa

Background

The objectives of this project (funded as OTIP SPU 1301) are to determine which crown management techniques are most effective in controlling vegetative growth to allow for safe crop collection and efficient orchard management. In addition, we are trying to determine the effects of various treatments on crop production.

Outline of project

As we gain confidence in our crown management techniques, we have shifted our emphasis towards developing and testing practical, economical applications that are useful operationally. Beginning in 2001 we streamlined our approach to three pruning treatments applied to trees in the western larch orchards and four treatments in the spruce micro orchard. 2003 was the third year that these treatments were repeated. Crop surveys were conducted to help evaluate the effectiveness of the different treatments. Please note that the results shown in Figures 28 and 29 reflect the year 2002 pruning regime. Cone and pollen surveys were conducted in the spring of 2003 before any treatments were applied. The actual crown management treatments are applied in the fall after the cone crop has been harvested.

Crown management in the western larch orchards results

Figure 30 indicates that the control treatment produces the best cone crop. Unfortunately it is impractical to manage a crop on the control trees. Leaving the trees free to grow is not a viable option.

The other two treatments deliver very similar results. Height control with moderate pruning produces slightly more pollen than the other treatments, and the operational style pruning technique yields a marginally better cone crop. However, the operational style pruning treatment is the least labour intensive treatment.

Crown management in the spruce micro orchard

Currently, four different treatments are being applied to ramets in our interior spruce micro orchard. It is worth noting that the flower crop in this orchard was rather light in 2003. The data presented is not necessarily conclusive.

Results

As Figure 31 illustrates, the control group clearly yields a much greater cone and pollen crop than the other methods. Leaving the trees unmanaged is definitely not an option in a micro orchard setting. Because space is limited, it is essential to manage the growth of each ramet to prevent it from expanding out of its allotted area.

The three crown management methods deliver reasonably similar results. Operational style pruning seems to yield the most consistent crop. This treatment is also the most efficient to implement because it does not require labour-intensive branch training.

Conclusion

We have been testing our current crown management techniques for three field seasons. Because our survey results are based on two years worth of inconsistent flower crop data, we are reluctant to make any firm recommendations.

At this point, it appears that operational style crown pruning is the preferred crown management technique for crop production in our western larch seed orchards. Operational style pruning also seems to be the most effective method to apply to the interior spruce micro orchard.

In 2004 we will continue to refine our techniques and collect additional crop data.

Trtmt #	Description	Leader Pruning	Branch Pruning	Crown Training
1	Control	None	None	None
2	Operational Style Pruning	To 3m. if exceeding 5m. tall	If extending +1.5 m. into rows	If extending +1.5 m. into rows
3	Height Control and Moderate Pruning	To 4m. height	No more than 25% to maintain hedge effect	If extending +1.5 m. into rows

Figure 28. Treatments applied to ramets in two western larch seed orchards, 2003

Trtmt #	Description	Leader Pruning	Branch Pruning	Crown Training
1	Control	None	None	None
2	Freestyle	As seen fit	As seen fit	As seen fit
3	Height Control, Branch Train	To 3m. if unable to train	Only if extending past 0.5 m. into row	To other branches on same tree.
4	Operational Style Pruning	Prune 75% current leader growth. Not to exceed 3 m.	Remove 75% current growth to promote hedge effect	Prune or remove branches extending >0.5 m. into rows

Figure 29. Treatments applied to ramets in the interior spruce micro orchard, 2003

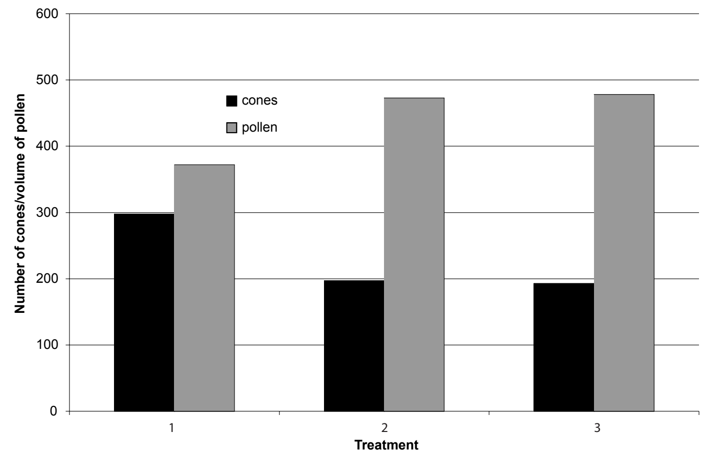


Figure 30 Larch Crown Management effect on crop

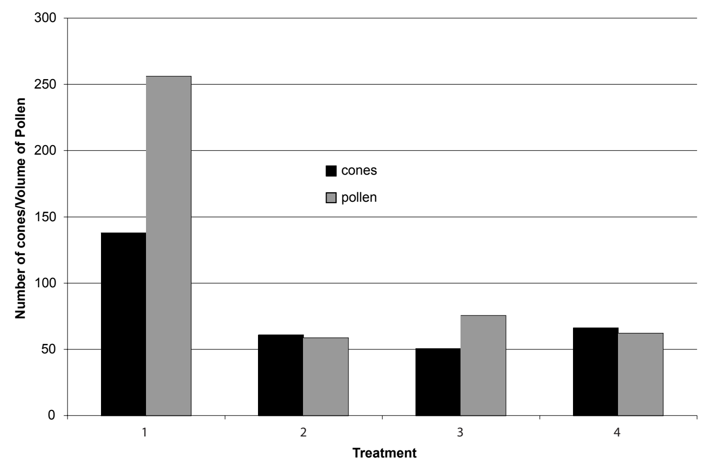


Figure 31. Sx Crown Management effect on crop

5.2.16 Upgrade of the Irrigation Delivery Systems in Two North Okanagan Seed Orchards.

Gary Giampa

Introduction

This report is a summary of two separate OTIP-funded projects (OTIP SPU 0412 and SPU 0718) with the same objectives. We propose to improve tree vigour and maximize seed yield in two Kalamalka seed orchards by converting a portion of each orchard's drip irrigation system to broadcast delivery.

SPU 0412 funded the irrigation conversion in our Nelson Mid Sx Orchard 305. SPU 0718 allowed us to upgrade the irrigation system in Nelson Low Pli Orchard 307.

Background

Orchard 305 was established at Kalamalka in 1981. Orchard 307 was planted in 1984. Since their inception, these orchards have been watered with a drip irrigation system. The trickle system seemed to work well enough when the orchards were young, but as the trees matured we began to question the efficiency of this type of irrigation delivery. Delivering water to the base of each tree limits root growth to the zone wetted by the emitter. As the tree grows larger, this limited zone may constrict root volume expansion to the point where the roots cannot service the developing crown. This imbalance has a negative effect on ramet health and ultimately can lead to decreased seed production.

Our objective was to deliver water to a larger area around each tree to give the roots a chance to expand. A portion of the drip delivery system in each orchard was converted to under-tree micro-sprinkler delivery.

Activities

A sprinkler delivery system requires a higher volume of water than a trickle set up. In order to provide enough water to service the broadcast system, a larger capacity mainline was required for each orchard. Staff at Kalamalka constructed the new mainlines in the spring of 2003. Over the summer, 948 TORO Ag Micro-Sprinklers were installed in the orchards and tested.

Results

A portion of each orchard has had its irrigation system converted to broadcast delivery as planned. The systems have been tested, but are not in operation yet .

We will be watering with the converted system starting in the 2004 field season. The portion of the orchards serviced by the broadcast delivery system will be compared to the portion of the orchards irrigated with the drip system. These observations will allow us to determine how the different irrigation delivery systems affect ramet performance. The results of our studies will be made available to orchard managers.

5.2.17 Seedlot Rating in Interior Spruce

Craig Newton

SPU 1420

Seedlot quality or genetic worth is maximal when panmixis (random mating) is high and pollen contamination is low. The main variable in estimating seedlot quality is the windborne (OP seedlots) male pollen contribution, which until recently depended on indirect assays such as male strobili surveys and pollen traps. The development of chloroplast DNA markers, which in conifers detect pollen contribution in fertilized seed, has provided an alternative approach that promises to increase the accuracy of seedlot genetic worth evaluations. As part of a wider program to better understand seed orchard pollen dynamics, this study analysed half-sib cone collections from Interior spruce Orchard 305 to assess pollen contributions between parental clones, inter-orchard pollen migration, and selfing levels. The chloroplast haplotypes for the twenty-two maternal clones are shown in Figure 32.

A set of five polymorphic interior spruce chloroplast markers (89F/62R2, 84.1F/R3, 8F3/R3, 7F3/R2, S2F2/R3) were used to haplotype seed in cones collected from twenty-two maternal parental clones in Orchard 305 (Kalamalka Forestry Centre, Vernon, B.C.). An average of forty-five seeds were analysed from each of the twenty-two maternal clones, for a total of approximately 1,000 seeds, or 5,000 polymorphic loci. Individual seeds were dissected and the embryo DNAs were prepared using Chelex resins. Following amplification with the spruce chloroplast five-loci multiplex, the products were analysed on polyacrylamide gels and visualised by autoradiography. A sample gel is shown in Figure 33. The haplotype of one embryo (lane) is indicated (AAAAA). The preliminary seed data for all twenty-two maternal clones from Orchard 305 have been scored and sorted manually. Complete haplotype files for this and other orchard studies (304, SPU 1414) are available on request.

Chloroplast haplotypes					
Clone	89F/62R	8F3/R3	7F3/R2	84.1F/R3	S2SpF2/R3
574	D	J	A	B	H
575	A	J	A	A	Q
1284	B	A	A	B	A
1285	D	J	A	B	H
1289	F	J	A	A	M
1290	D	J	A	B	**X**
1295	D	J	E	B	L
1299	F	J	A	A	F
1352	D	L	C	B	H
1364	A	C	A	B	G
2719	D	J	A	B	L
3001	B	A	A	A	A
3015	D	E	A	C	G
3042	D	J	E	B	G
3137	D	K	A	B	N
3146	F	J	D	B	G
3180	D	J	A	B	**U**
3260	A	A	A	A	G
3261	D	J	A	G	H
3262	B	A	C	A	A
3318	D	J	A	A	G
3184X	D	J	A	B	L

Figure 32. Parental cpDNA haplotypes from Orchard 305

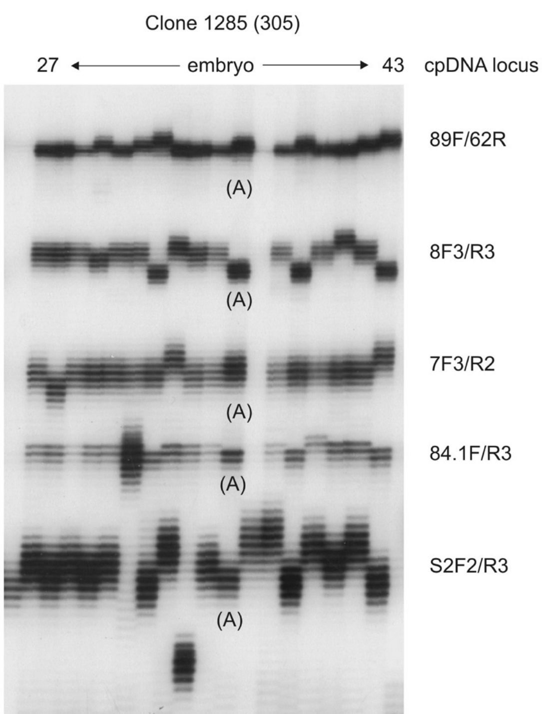


Figure 33. Chloroplast analysis of embryo DNA

5.2.18 Lodgepole Pine Seed Set Issues

Chris Walsh and Joe Webber

Project OTIP SPU 0719

This report summarizes the fourth-year results of a project studying the effect of improved irrigation and crown cooling (misting) on seed set in the Kalamalka Pli Orchard 307. Treatment effects were measured on seed yields (total seed per cone, filled seed per cone, and seed weight), cone mass (first- and second-year cone dry weights), cone numbers, pollen supply (pollen cloud density), and phenology (seed cone receptivity and pollen shed). Meteorological data (temperature, relative humidity) were also recorded and expressed as heat sums and vapour pressure deficit to explain variations in climate data from year to year and in response to treatment effects (in particular, the crown cooling effects of misting).

For years 2000-2002, dramatic effects on seed yields were not observed because spring temperatures were cool in each of these three years and soil moisture was not limiting. However, the effect of a hot dry spring during either the pollination period (principally via effects on pollination drop formation and pollen uptake) or early embryo development (which follows pollination) has not been tested. The specific objectives for 2003 thus became a test of the irrigation/misting systems during a hot dry April/May. Because, operationally, the irrigation system would always be activated, the test for a hot dry spring would be limited to the effect on seed set of misting before and during the pollination period.

Meteorological conditions over the past four years have been consistent. April and May have been typically cool through pollination (end of May), followed by increasing summer heat and drought, through fertilization (early June) and embryo development (mid-June to mid-July). Under these conditions, soil moisture was adequate. As *Leptoglossus* was controlled, seed yields rose from an average of about nine to eleven filled seed per cone (FSPC) in 2000 to 15-18 FSPC in the subsequent three years (See Figure 34). It is now apparent from this study that operational levels of seed yields can be obtained from north Okanagan lodgepole pine seed orchards if *Leptoglossus* is controlled and soil moisture is managed during periods of unusually hot and dry weather. Although irrigation did not substantially improve seed set under the conditions experienced, it is prudent to install systems that can supply adequate water to maturing trees. Misting effects did not affect seed yields, other than making the feeding environment for *Leptoglossus* less favourable.

The greater capacity irrigation system did improve first- and second-year cone mass and seed weights (Figures 35 and 36), but we did not see dramatic increases. Again, this was attributed to the adequate soil moisture that was present early in the season and that was not affected by the cool weather during April and May.

Cultural effects on cone numbers were also observed. There is concern that increasing the volume of water added over a large area of the orchard may reduce the number of cones initiated and differentiated in August (pollen cones) and September (seed cones). Figure 37 shows the counts for pollen cone clusters and first- and second-year cones for each of four years. Increased irrigation and mist treatments did not affect first-year cone numbers, but a slight reduction in pollen cone clusters was observed. Apparently, when treatments were concluded (end of July), the drying of soil moisture was sufficient to induce a seed cone crop naturally for the next year. It is possible that the increased soil moisture (from both irrigation and mist treatments) did have a negative effect on pollen cone initiation. It is not possible to determine if soil moisture affected the naturally inductive effect on pollen cone initiation or whether the cultural effects increased the vigour potential of the mid crown shoots thereby decreasing the number of pollen cone clusters (and alternatively increasing the number of seed cones initiated).

The sampling points for determining cone numbers have remained on the same major whorl branches for the last four years. It is reasonable to expect a reduction in seed cone numbers because the principal seed-cone-bearing part of the crown moves higher with increasing tree height.

The supply of orchard pollen (pollen cloud density), seed cone receptivity, and pollen shed (synchrony) were monitored in each of the four blocks for each of the four years. In all four years, pollen cloud density was among the highest recorded for any conifer orchard and exceeded by several hundred times the pollen load required to pollinate the orchard naturally. Irrigation and misting treatment had no effect on pollen cloud densities recorded for each of the four treatment blocks, but there were differences in both the absolute numbers of pollen grains captured by block and the days when maximum pollen shed and seed cone receptivity occurred. Synchrony between seed cone receptivity and pollen shed for all trees within each of the four blocks was adequate.

Our conclusions for last four years remain the same. Controlling *Leptoglossus* is the single most important management activity for the lodgepole pine seed orchards in the north Okanagan. Cultural treatments (irrigation) provided a modest increase to seed yields and cone size, but the beneficial effect of misting has yet to be determined. Misting effects during a very hot and dry pre-pollination and pollination period must still be verified. It is very clear that soil must be fully moist in April when irrigation waters are turned back on. While the increased irrigation capacity provided only a slight improvement to seed yields and cone size (relative to the previous drip system), it seems prudent to maintain these systems, knowing that the root volume for the mature trees is larger and the trees have a better chance of surviving extreme temperatures and drought.

Plate 27. Pollinating Sx Orchard 306

A. Total Seed per Cone

		Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags					
2000		22.4 (2.4)	23.3 (2.2)	23.3 (1.9)	25.1 (2.5)
2001		30.6 (na)	28.9 (na)	29.1 (na)	30.6 (na)
2002		27.5 (2.9)	32.3 (1.7)	32.6 (1.9)	29.0 (1.6)
2003		31.1 (1.9)	32.2 (1.6)	31.6 (2.1)	27.6 (1.6)
Means		**27.9**	**29.2**	**29.2**	**28.1**
Open Pollinated - Insect Bagged					
2000		na	na	na	na
2001		36.9 (2.6)	38.4 (3.3)	37.4 (3.8)	37.4 (3.0)
2002		33.3 (2.9)	36.4 (1.9)	38.4 (2.7)	35.0 (1.9)
2003		31.0 (2.0)	32.6 (1.6)	34.2 (2.3)	31.2 (1.8)
Means		**33.7**	**35.8**	**36.7**	**34.5**

B. Filled Seed per Cone

		Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags					
2000		9.7 (1.6)	13.0 (1.5)	11.9 (1.4)	15.9 (1.9)
2001		18.8 (na)	19.5 (na)	18.5 (na)	21.9 (na)
2002		16.7 (1.9)	22.5 (1.6)	17.6 (1.6)	20.6 (1.6)
2003		19.8 (1.7)	19.4 (1.6)	20.4 (1.9)	19.3 (1.4)
Means		**16.2**	**18.6**	**17.1**	**19.4**
Open Pollinated - Insect Bagged					
2000		na	na	na	na
2001		25.5 (2.9)	26.8 (2.8)	23.7 (3.5)	26.9 (3.0)
2002		24.3 (2.5)	25.8 (1.6)	28.0 (2.6)	24.9 (1.9)
2003		21.4 (1.6)	21.9 (1.7)	24.4 (2.2)	23.0 (1.8)
Means		**23.7**	**24.8**	**25.7**	**24.9**

Figure 34. Mean total and filled seed yields (+/- standard errors) for open pollinated cones in Orchard 307 for cones bagged and unbagged in each of the four treatment blocks for each of the four years

		Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags					
2000		4.1 (0.14)	4.2 (0.16)	4.6 (0.24)	4.4 (0.10)
2001		3.0 (0.71)	3.9 (0.72)	3.6 (1.04)	3.5 (0.72)
2002		4.1 (0.13)	4.8 (0.13)	4.8 (0.13)	4.1 (0.11)
2003		4.2 (0.14)	4.9 (0.18)	4.8 (0.16)	4.1 (0.14)
Means		**3.8**	**4.4**	**4.4**	**4.0**
Open Pollinated - Insect Bagged					
2000		na	na	na	na
2001		3.2 (0.18)	3.9 (0.25)	3.6 (0.27)	3.5 (0.21)
2002		4.2 (0.16)	5.0 (0.16)	5.1 (0.16)	4.3 (0.13)
2003		4.3 (0.14)	4.9 (0.16)	4.9 (0.16)	4.3 (0.15)
Means		**3.9**	**4.9**	**4.5**	**4.0**

Figure 35. Mean seed weight in milligrams (+/- standard errors) for open pollinated cones in Orchard 307 for each of the four years

	Control	Mist/Irrigation	Irrigation	Mist
Yr1 Seed Cones				
2000	0.229 (.015)	0.272 (.017)	0.223 (.013)	0.319 (.039)
2001	0.195 (.008)	0.276 (.021)	0.242 (.021)	0.245 (.023)
2002	0.182 (.011)	0.217 (.009)	0.192 (.007)	0.203 (.007)
2003	0.188 (.007)	0.185 (.007)	0.189 (.007)	0.174 (.007)
Means	**0.199**	**0.238**	**0.212**	**0.235**
Yr2 Seed Cones				
2000	6.54 (.445)	6.19 (.899)	5.46 (.624)	6.16 (.956)
2001	6.86 (.408)	6.95 (.658)	6.67 (.498)	6.64 (.308)
2002	6.19 (.278)	6.93 (.276)	6.83 (.303)	5.98 (.254)
2003	6.93 (.342)	6.65 (.256)	7.11 (.321)	5.60 (.260)
Means	**6.63**	**6.68**	**6.52**	**6.10**

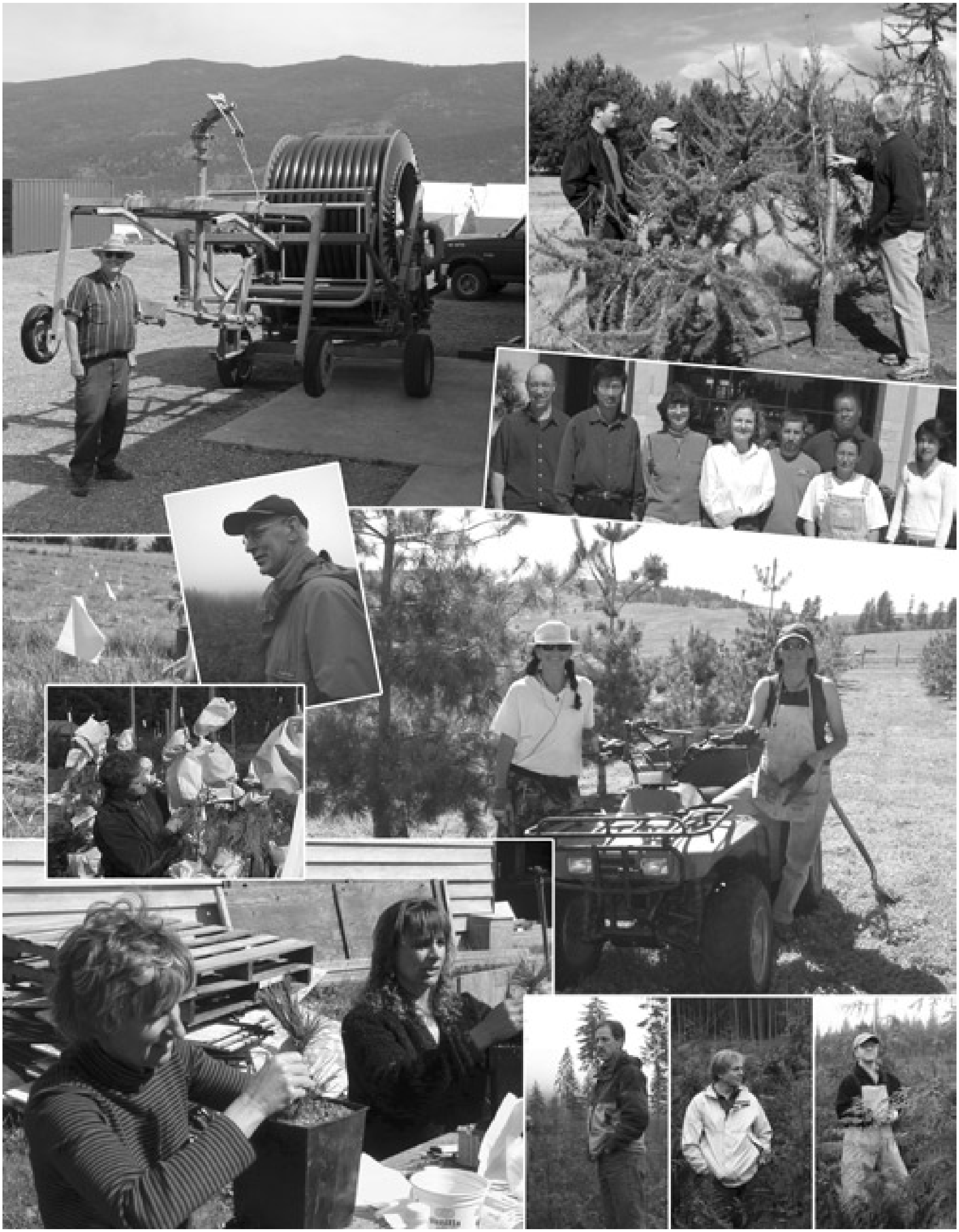
Figure 36. Mean cone dry weight in grams (+/- standard errors) for first and second year cones in Orchard 307 by treatment block and year

	Control	Mist/Irrigation	Irrigation	Mist
Pollen Bud Clusters				
2000	37.6 (2.0)	34.1 (2.1)	35.6 (1.7)	30.7 (1.9)
2001	46.7 (2.9)	34.7 (3.0)	36.0 (4.4)	32.8 (2.5)
2002	61.1 (3.8)	30.4 (2.7)	38.8 (3.1)	43.8 (3.2)
2003	70.6 (5.0)	46.6 (4.7)	61.2 (4.9)	55.6 (3.9)
Means	**54.0**	**36.4**	**42.9**	**40.7**
First-Year Cones				
2000	16.8 (1.2)	13.4 (2.1)	12.8 (1.7)	13.7 (1.9)
2001	16.7 (1.7)	17.2 (1.8)	15.2 (1.5)	13.1 (1.3)
2002	12.7 (1.7)	14.3 (1.9)	15.1 (2.0)	12.2 (1.4)
2003	8.8 (1.3)	10.0 (1.8)	9.2 (1.4)	8.4 (1.2)
Means	**13.8**	**13.7**	**13.1**	**11.9**
Second-Year Cones				
2000	7.9 (0.9)	8.3 (0.9)	7.1 (0.7)	5.2 (0.4)
2001	15.4 (1.1)	12.2 (1.0)	11.5 (0.9)	12.2 (0.9)
2002	13.4 (1.5)	15.2 (1.7)	13.5 (1.4)	11.6 (1.3)
2003	10.5 (1.2)	12.4 (1.8)	11.7 (1.8)	10.1 (1.2)
Means	**11.8**	**12.0**	**11.0**	**9.8**

Figure 37. Mean cone bud numbers (+/- standard errors) for mid-crown major whorl branches in Orchard 307 by treatment block and year

Places and Faces Tree Improvement Program

2003/4



6.0 Extension and Communications

6.1 Extension Technical Advisory Committee (ETAC) Subprogram

Don Summers

The Extension and Communication Subprogram supports FGC goals and objectives through extension, communication, and training projects related to tree improvement and forest genetics. In the 2003/4 business plan, the committee approved a number of projects that were later delayed because of changes underway with the *Forest and Range Practices Act*. The remaining program work is summarised in this report.

We made significant progress on a number of extension notes. Details for those are outlined below.

Extension Notes

Extension Note 4: The Reproductive Biology of Western White Pine, J. Owens.

Extension Note 5: Environmental Effects on Yellow-cedar Pollen Quality, O. Hak and J. Russell

Extension Note 6: Applications of DNA Markers in B.C. Tree Improvement Program, C. Newton

Two additional extension notes are in various stages of review. Work should progress with those under the 2004/5 business plan.

Preparatory work has been completed for a client survey to assess the effectiveness and usability of extension products related to tree improvement and forest genetics. We should be ready to conduct the survey in 2004/05.

One additional project was requested during the year. We helped fund some updates to signs on an operational trial in the Prince George area.

Appendix 1 FGC Seed Planning Unit

UNIT	SPECIES	PLANNING ZONE	ELEVATION
1	Douglas-fir	Maritime Low (south)	<700m
2	Red Cedar	Maritime Low	0-600 m
3	Western Hemlock	Maritime Low	0-600 m
4	Interior Spruce	Nelson Mid	1000 - 1500 m
5	Interior Spruce	Nelson High	>1500 m
6	Sitka Spruce	Maritme All (Low)	0-750 m
7	Lodgepole Pine	Nelson Low	<1400 m
8	White Pine	Coast	<1000 m
9	Amabilis Fir	Maritime	<700 m
10	Lodgepole Pine	Thompson Okanagan Low	<1400 m
11	Yellow Cedar	Maritime	<1000 m
12	Lodgepole Pine	Prince George Low	<1200 m
13	Western Larch	Nelson Low	<1300 m
14	Interior Spruce	Prince George Low	<1200 m
15	White Pine	Kootenay/Quesnel Low	<1400 m
16	Lodgepole Pine	Thompson Okanagan High	>1400 m
17	Lodgepole Pine	Bulkley Valley Low	<1200 m
18	Lodgepole Pine	Central Plateau Low	<1000 m
19	Douglas-fir	Sub Maritime Low	200-1000 m
20	Lodgepole Pine	Nelson High	>1400 m
21	Douglas-fir	Nelson Low	<1000 m
22	Douglas-fir	Nelson High	>1000 m
23	Interior Spruce/Sitka Spruce	Sub Maritime/Nass-Skeena Transition	All elevations
24	Western Hemlock	Maritime High	>600 m
25	Interior Spruce	East Kootenay Low	<1700 m
26	Lodgepole Pine	Prince George High Elevation	>1200 m
27	Red Cedar	Sub Maritime	200-1000 m
28	Interior Spruce	Thompson Okanagan High	1300-1850 m
29	Lodgepole Pine	East Kootenay High	>1500 m
30	Interior Spruce	Thompson Okanagan Low	<1300 m
31	Douglas-fir	Maritime High	>700 m
32	Lodgepole Pine	East Kootenay Low	<1500 m
33	Red Cedar	Maritime High	600 m
34	Western Larch	East Kootenay Low	800-1500 m
35	Interior Spruce	Bulkley Valley Low	<1200 m
36	Grand Fir	Maritime Low	0-700 m
37	Douglas-fir	Quesnel Lakes	<1200 m
38	Western Hemlock	Maritime Low North	Merged, see HW Prog #3
39	Douglas-fir	East Kootenay	All elevations
40	Interior Spruce	Peace River Low	<1200 m
41	Douglas-fir	Prince George	<1000 m
42	Interior Spruce	Prince George High	>1200 m
43	Douglas-fir	Cariboo Transition	<1100 m

Appendix 2 Tree Species

CONIFERS	LATIN NAME	ABBREVIATIONS
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	Pl
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 3 Discussions by Tree Species

CONIFERS	ABBREVIATION	PAGE LOCATIONS
Western redcedar	Cw	7, 15, 17, 18, 37
Yellow-cedar	Yc	8, 18, 38, 39
Douglas-fir	Fdc	5, 15, 17, 18, 19, 20, 32, 33, 34
Interior Douglas-fir	Fdi	10, 20, 22, 23,
Amabilis fir	Ba	19, 40
Western hemlock	Hw	6, 15, 17, 19, 34
Western larch	Lw	13, 21, 36, 40, 41
Lodgepole pine	Pli	11, 12, 21, 22, 23, 24, 25, 28, 29, 30, 31, 41, 42, 43, 44
Western white pine	Pw	8, 18, 21, 26
Sitka spruce	Ss	5, 16
Spruce hybrid (interior spruce/s)	Sx	9, 11, 20, 21, 22, 24, 25, 26, 34, 35, 36, 40, 41, 42

HARDWOODS		
Hybrid poplars	Ax	
Paper birch	Bp	

Appendix 4 Authors and Species Topic

AUTHOR	SPECIES/DISCUSSION	PAGE
Aitken, Sally	Gene Conservation	3, 4
Alfaro, René	Ss	5, 6
Ashley, Valerie	Fdi, Lw, Sx	10, 11, 13
Bennett, Robb	Cone and Seed Pests	27, 28, 31, 32, 33, 34
Berger, Vicky	Pli	11, 12
Bird, Keith	Fdc	5
Brown, Patti	Fdc, Hw, Pw, Yc, Cw	17, 18, 37
Carlson, Mike	Pli	11, 12
Cartwright, Charlie	Hw, Ss	5, 6
Cox, Keith	Pw, Sx	26, 27
Crowder, Tim	Fdc, Pw, Ba, Hw	18, 19
Ferguson, Craig	Cw, Yc	7, 8, 9
Giampa, Gary	Sx, Lw, Pli	40, 41, 42
Graham, Hilary	Pli, Fdi	23, 24
Hak, Oldrich	Hw, Yc, Ba, Cw	34, 38, 39, 40
Hooge, Bonnie	Fdi, Sx, Lw	10, 11, 13
Hollefreund, Clint	Fdc	5
Hunt, Rich	Pw	8
Jaquish, B.	Fdi, Sx, Lw	10, 11, 13
King, John	Ss, Sx, Pw	5, 6, 8, 9
Lee, Tim	Sx, Pli, Fdi	21, 22
McAuley, Leslie	SPAR	2
Mehl, Helga	Sx	34, 35, 36
Murphy, John	Pli	11, 12
Nicholson, George	Pli, Sx	24
Newton, Craig	Sx, Lw	36, 42
Painter, Roger	Program Management/Extension	14, 15
Phillips, Giselle	Fdi, Sx, Lw	10, 11, 13
Pieper, Greg	Pli, Sx	24
Ponsford, Dave	Ss, Pw	5, 6, 8
Ritland, Kermit	Cw	37
Rudolph, Dan	Pw, Fdc	19, 20
Russell, John	Cw, Yc	7, 8, 9 37
Stoehr, Michael	Fdc, Pli, Sx	5, 34, 35, 36
Strong, Ward	Leptoglossus	28, 29, 30, 31
Summers, Don	Extension	45
Van Neijenhuis, Annette	Cw, Fdc, Hw, Ss	15, 16
Wagner, Rita	Pli, Sx	24, 25
Walden, Dave	Fdi, Sx, Lw	10, 11, 13
Walsh, Chris	Pli, Sx, Lw, Pw	20, 21, 36, 43
Webber, Joe	Pli	43
Wigmore, Bevin	Cw	37
Woods, Jack	Program Management/SelectSeed	1
Yi-Xie, Chang	Pli	12

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Back Cover

Don Pigott completing a roadside collection for Washington Gapare's research on the distribution of common and rare alleles in core and peripheral populations of Sitka spruce.

Forest geneticists on the field trip of the 2003 Western Forest Genetics Association Meeting learning about gene conservation activities in BC.

(left to right) Pia Smets, Andreas Hamann and Alvin Yanchuk presenting analyses of the current level of in situ gene conservation for tree species in BC on the field trip of the 2003 Western Forest Genetics Association Meeting in Whistler, BC.