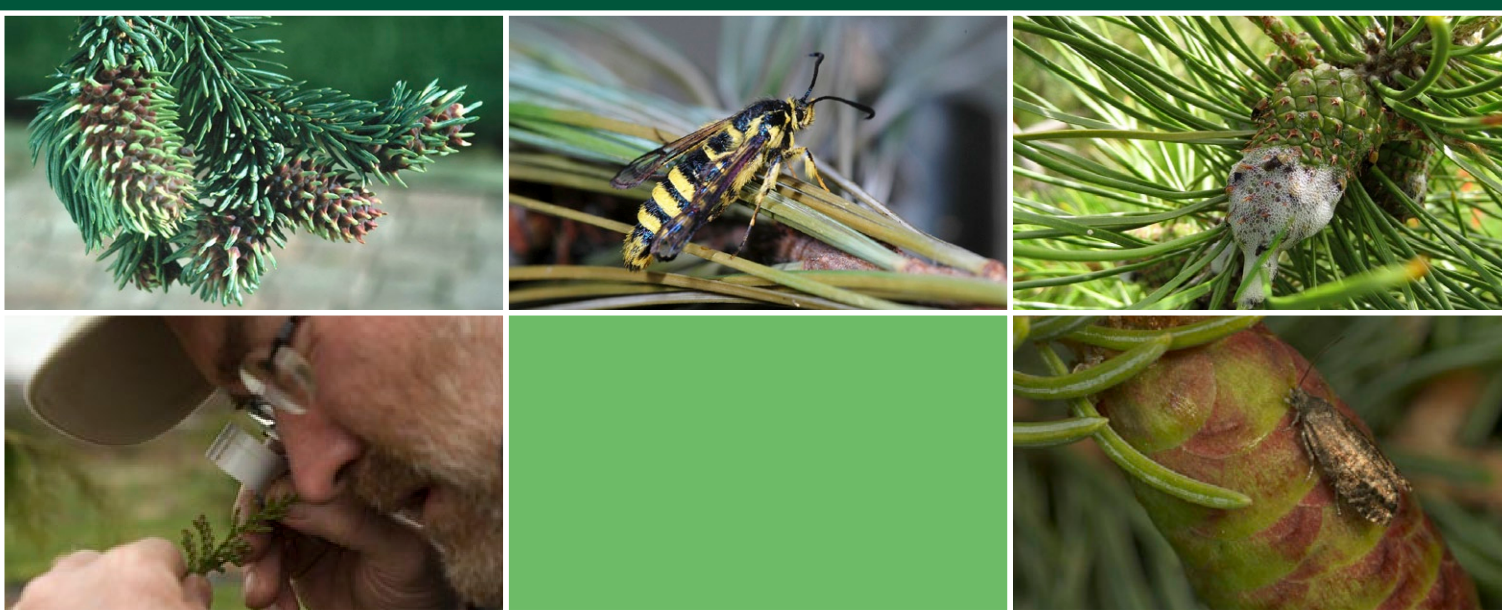
2009/2010

Forest Genetics Council of BC

Tree Improvement Program Project Report



Front cover

1. *Adelges lariciatus* on Lw cones & foliage
   PHOTOGRAPHER: Robb Bennett
2. *Pineus pinifoliae* – gall cross-section
   PHOTOGRAPHER: Dion Manastyrski
3. *Adelges lariciatus* cross-section
   PHOTOGRAPHER: Dion Manastyrski
4. *Dioryctria* adult eclosed
   PHOTOGRAPHER: Ward Strong
5. *Kaltenbachiola rachiphaga* damage
   PHOTOGRAPHER: Ward Strong
6. *Barbera colfaxiana* pupa
   PHOTOGRAPHER: Dion Manastyrski
7. *Contarinia oregonensis* adult
   PHOTOGRAPHER: Dion Manastyrski
8. *Adelges cooleyi* Spruce Galls
   PHOTOGRAPHER: Ward Strong
9. *Synanthedon sequoiae* adult female
   PHOTOGRAPHER: Ward Strong
10. *Aphrophora cribrata* nymphs attacking a lodgepole pine cone
    PHOTOGRAPHER: Jim Corrigan
11. Robb Bennet looking for *Mayetiola thujae* eggs
    PHOTOGRAPHER: Dion Manastyrski
12. *Cydia* adult
    PHOTOGRAPHER: Dion Manastyrski

Back cover

1. *Pineus* defoliation on Pw
   PHOTOGRAPHER: Ward Strong
2. *Barbera* adult
   PHOTOGRAPHER: Dion Manastyrski
3. *Leptoglossus* nymph
   PHOTOGRAPHER: Dion Manastyrski
4. *Adelges lariciatus* adult
   PHOTOGRAPHER: Ward Strong
5. *Conophthorus ponderosae* adult
   PHOTOGRAPHER: Dion Manastyrski
6. *Elatobium* feeding damage on needles of Sitka spruce
   PHOTOGRAPHER: Dion Manastyrski
7. Exit holes caused by *Megastigmus spermotrophus*
   PHOTOGRAPHER: Dion Manastyrski
8. *Conophthorus ponderosae* egg gallery
   PHOTOGRAPHER: S. Kegley
9. Developing adelgid gall on spruce
   PHOTOGRAPHER: Dion Manastyrski
10. *Adelges lariciatus* nymphs inside gall of spruce
    PHOTOGRAPHER: Dion Manastyrski
11. *Megastigmus spermotrophus*
    PHOTOGRAPHER: Dion Manastyrski

2009/2010

Forest Genetics Council of BC

Tree Improvement Program Project Report

Darrell Wood and Diane Douglas

Acknowledgements

Now in its thirteenth year, the Forest Genetics Conservation and Management Program continues to meet provincial strategic objectives related to select seed production, genetic gains, genetic conservation, and reporting. It is through the hard work and dedication of everyone involved that this program is successful, and this year is no exception.

The broad program continues to focus on structuring for a changing climate and for the implications this has on forest management. One of the primary means by which we can respond is the matching of seedlots (genotypes) with future climates to ensure forests are well adapted to the climate in which they grow. This will result in better health, greater productivity and ultimately a more secure forest-based economy.

In response to this need, the Seed Transfer Technical Advisory Committee (STTAC) is identifying priorities for climate-based seed transfer research, structuring a program for delivery of this research, and supporting development of new climate-based seed transfer standards. This work is directly aligned with priorities in the Ministry of Forests and Range, and receives the support of the Land Based Investment Program.

This publication, in conjunction with the Forest Genetics Council (FGC) Business Plan and FGC Annual Report, meets the reporting obligations of Council and the Forest Investment Account (FIA) Tree Improvement Program. It provides a project-level overview of our efforts and highlights our successes.

Sincere thanks to the project leaders for submitting their contributions. A very special thanks to the reviewers Lee Charleson, Jack Woods and Roger Painter and acknowledgments to all those who provided images for the report.

Again, thanks to all those who have worked on this program in the past year and over the past thirteen years, including Council members, review committees, species committees, various TACs and all the Project Leaders.

Darrell Wood
Manager, Business Operations
Tree Improvement Branch

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:

Tree Improvement Coordinator
Ministry of Forests and Range
Tree Improvement Branch
PO Box 9518 Stn. Prov. Govt.
Victoria, BC V8W 9C2

Images on the covers are courtesy of Dr. Robb Bennett, Dr. Ward Strong, Jim Corrigan - Ministry of Forests and Range, Dion Manastyrski, Earthpics and Sandra Kegley, USDA Forest Service . Most of these images are from the Pest Management leaflets: http://www.fgcouncil.bc.ca/doc-pestmaninfo.html#leaflets

Further Tree Improvement information can be found at our web sites:

Forest Genetics Council	http://www.fgcouncil.bc.ca
Ministry of Forests and Range, Tree Improvement Branch	http://www.for.gov.bc.ca/hti
Ministry of Forests and Range, Research, Innovation and Knowledge Management Branch	http://www.for.gov.bc.ca/hre/forgen

FGC Forest Genetics Council of British Columbia

Table of Contents

Tree Improvement in British Columbia

Forest Genetics Council of BC

The Forest Genetics Council of British Columbia (FGC) is a multi-stakeholder group representing the forest industry, Ministry of Forests and Range (MFR), the Canadian Forest Service (CFS), and universities. Council's mandate is to champion forest genetic resource management in British Columbia, to oversee strategic and business planning for a co-operative provincial forest genetic resource management[1] program, and to advise the province's Chief Forester on forest genetic resource management policies. FGC members provide strategic direction to the provincial forest genetic 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 genetic conservation program, developing long-term production capacity, doubling the average genetic gain of select seed, and increasing the amount of select seed[2] used. The annual FGC Business Plan defines activities and associated budgets to achieve this goal.

Ministry of Forests and Range Program Overview

Forest genetic 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 genetic resource management program that is implemented by stakeholders in the forest industry, the Ministry of Forests and Range (MFR), Canadian Forest Service (CFS), and universities.

The Forest Investment Account (FIA) is a major funding agency for forest genetic resource management in British Columbia. Through the Tree Improvement Program (TIP), FIA invests in forest genetic 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.

[1]Forest genetic resource management is a co-operative effort. In broad terms, the MFR leads tree breeding activities, and operational production of reforestation materials is a collaborative effort between MFR and the private sector. The Canadian Forest Service, MFR Research Branch, and universities undertake research supporting tree improvement, while private institutions focus on applied research related to operational production.

[2]Select seed has a genetic worth (GWg) for growth rate of greater than zero (non-selected wild seed has a GWg of zero), and is the product of tree improvement programs that include tree breeding and seed orchards. Tree breeding programs select trees in wild populations, test offspring for economic and adaptive traits, and transfer vegetative material from the best trees to seed orchards. Seed orchards propagate the best trees from breeding programs through grafting, growing the grafted trees in orchards where they can inter-pollinate, and collecting seed with high genetic worth for operational reforestation. For some species, select seed includes wild collections from specific provenances that exhibit superior growth rates.

FIA – FGC Tree Improvement Subprograms

The Forest Investment Account (FIA) FGC Tree Improvement Program is consistent with the provincial strategy for forest genetic resource management developed by the Forest Genetics Council. There are eight subprograms:

- Genetic Conservation
- Tree Breeding
- Operational Tree Improvement Program (OTIP)
- Expansion of Orchard Seed Supply (SelectSeed Co. Ltd.)
- Extension and Communication
- Genecology and Seed Transfer
- Genetic Resource Decision Support
- Seed Orchard Pest Management

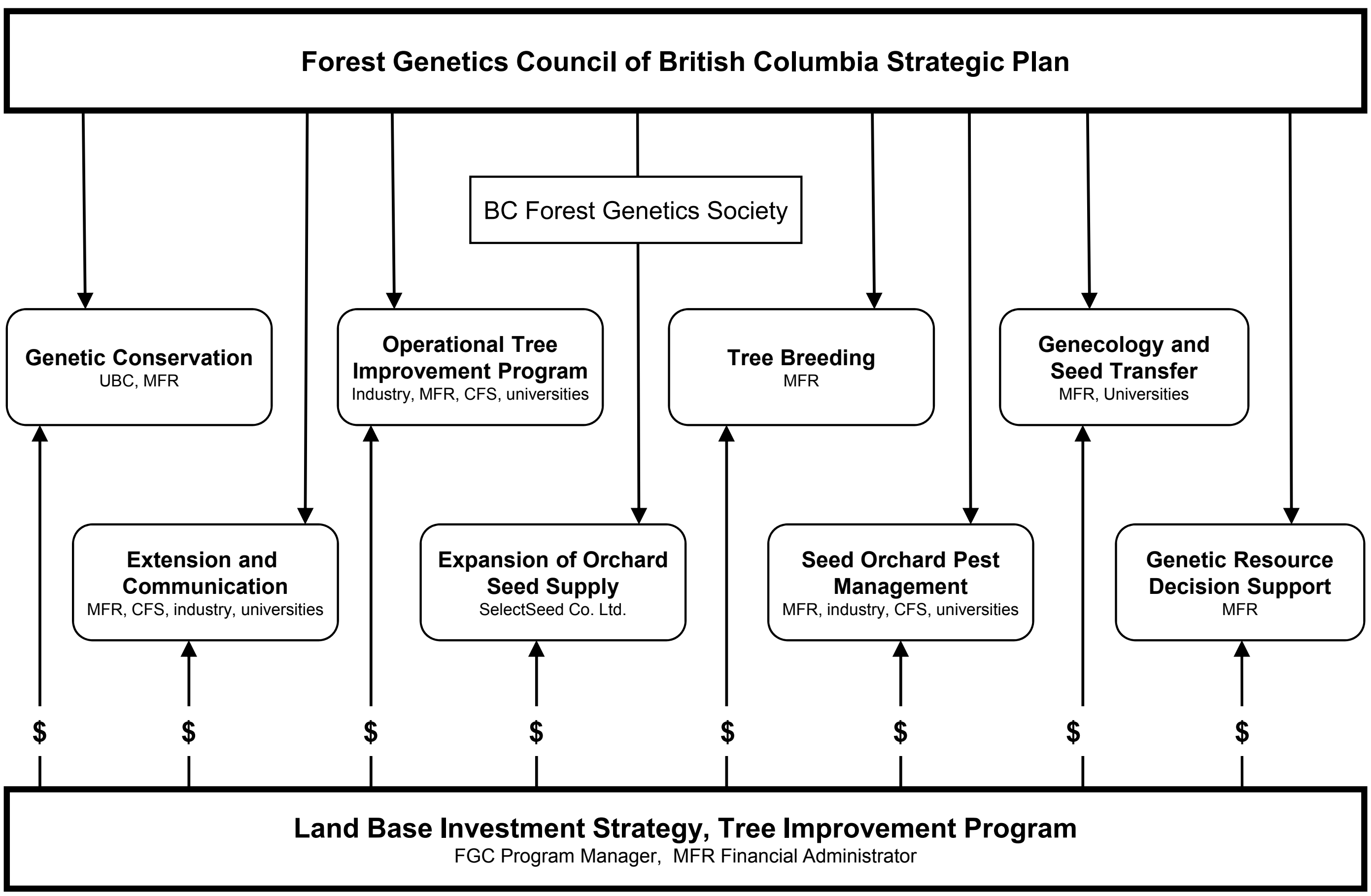


Figure 1. Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest genetic resource management areas.

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

Jack Woods

Overview

SelectSeed is a provincially registered company that is wholly owned by the Forest Genetics Council of BC (FGC) through its registered Society and operated by a Board of Directors. SelectSeed's mandate from the FGC is to establish and manage seed orchards needed to meet FGC objectives for seed supply. SelectSeed derives revenue through Forest Investment Account (FIA) contributions and seed sales. Over time, FIA contributions have diminished and seed sales have increased. By about 2013, it is expected that SelectSeed will meet all of its cash requirements through seed sales. SelectSeed operations are guided by an annual business planning process that is reviewed and approved by the SelectSeed Board of Directors and the FGC. All SelectSeed orchard investments are through long-term contracts with private-sector companies. SelectSeed also provides program management services to the FGC, including business plan and annual report preparation, support for policy development, meeting organization, oversight of structural and planning issues, and legal and accounting matters.

Seed Orchard Operations

During the fiscal year ending March 31, 2010, SelectSeed orchards produced the largest crops to date, with harvest from all 14 orchards. Nine lodgepole pine orchards produced a total of 197 hectoliters of cones, yielding 60.3 kg of seed (SelectSeed's share of this crop was 36.4 kg). As with other lodgepole pine orchards in the north Okanagan, seed set was better than normal, with an average yield of 294 grams per hectolitre of cones. Three Douglas-fir orchards produced 119.5 hectoliters of cones, yielding 102.5 kg of seed (SelectSeed share 65.7 kg). Two interior spruce orchards produced 36 hectolitres of cones, yielding 31 kg of seed (SelectSeed share 20.1 kg).

The total value of seed added to SelectSeed's inventory was approximately $563,000. Of this, seed sales totaled $484,542, well above the forecast level of $231,000. Seed inventory of about $76,000 (all Fdi Nelson Low) remains in storage and will be marketed in 2010. With a larger inventory of seed to sell, the SelectSeed customer base increased to 28 companies and agencies, including major licensees, BC Timber Sales, the Ministry of Forests and Range (MFR), woodlot owners, and community forests.

Orchard establishment is largely complete for all 14 orchards, although some planting continues to replace ongoing mortality from graft incompatibility and pest damage. No propagation was carried out for the existing 14 orchards in the spring of 2010. Approximately 300 grafts of Douglas-fir were made for a possible new orchard for the Thompson Okanagan (TO) seed zone. In addition, arrangements were made to grow 3000 Fdi rootstock for more grafting.

FGC program management

FGC program management activities included the coordination of Business Plan development and reporting on progress indicators, as well as governance and organizational matters pertaining to Council meetings and the BC Forest Genetics Society. The FGC was represented on issues related to seed, genetics, and policy matters. During the year, a discussion paper on private-sector participation in orchard seed production for Crown land was finalized in conjunction with MFR staff, and recommendations were passed along to the Provincial Chief Forester. Submissions were also prepared on the following topics, and follow-up discussions undertaken:

- MFR silviculture strategy discussion paper
- Pacific Carbon Trust request for information regarding carbon credits in forestry.

Reports and plans completed during the year on behalf of the FGC include:

- FGC 2008/09 Annual Report
- FGC 2009/10 Business Plan

Support was provided to Council's Technical Advisory Committees and species committees, and species plans were maintained, updated, and made available for 50 provincial seed planning units. A website was also maintained on behalf of the FGC. A number of communication activities were completed, including formal and informal talks to various forest industry staff, presentations at conferences, and numerous presentations to committees.

SelectSeed management and administration

All SelectSeed financial and governance needs were completed. These include financial and legal matters on long-term seed orchard agreements, maintenance and audit of books of account, Company Act reporting requirements, Board of Director support, financial reporting on the SelectSeed Multi-Year Agreement, and reporting to the FGC.

2.0 Genetic Conservation Technical Advisory Committee (GCTAC)

Dave Kolotelo, Tree Seed Centre, TIB, MFR

The Genetic Conservation Technical Advisory Committee (GCTAC) has oversight for genetic conservation within the FGC and has three main budget line items: UBC Centre for Forest Conservation Genetics (CFCG), Ministry of Forests and Range activities, and *ex situ* seed collections.

These areas are elaborated on below, separately for activities during the 2009/10 fiscal year.

2.1 Centre for Forest Conservation Genetics (CFCG)

Sally Aitken, University of British Columbia

2009-10 was a year of transition to a reduced budget and somewhat curtailed activities for the Centre for Forest Conservation Genetics. Staff scientist Christine Chourmouzis completed her excellent work with the Centre on cataloguing conservation status, updating the CFCG website, and producing extension and publication-related materials, and left the CFCG in Oct. 2009. Christine is the lead author on MFR Technical Report 53 on the *in situ* conservation status of BC's indigenous tree species, and is a co-author on Technical Report 54 on the conservation status of economically important species in breeding programs, both published in 2009. Associate Director Tongli Wang, in collaboration with others, completed the new climate tool ClimateWNA (Western North America), which provides estimates of current and future climates for 85 variables across the current and potential future ranges of most of our native species. ClimateWNA is now available for download from the CFCG website (www.genetics.forestry.ubc.ca/cfcg). He also completed the analyses for and produced a draft manuscript documenting the new 'Flying BEC zone' predictions of the future distribution of climates associated with our current ecosystems. Colin Huebert completed his MSc research on Garry oak genecology, the first research to document population variation in adaptive traits in this species.

We continue to make good progress in the area of understanding the responses of species and populations to climatic conditions. Tongli Wang, Greg O'Neill and Sally Aitken published a scientific paper on a new approach for analyzing genecology data, called the Universal Response Function (URF) approach. Pia Smets established a new growth chamber experiment to characterize the responses of populations of western larch and western redcedar to temperature and drought to provide short-term predictions to complement long-term field experiments, in collaboration with the Ministry of Forests and Range western larch and western redcedar breeding programs. Sierra Curtis-McLane completed the second year of assessments of germination and survival in the whitebark pine assisted migration seed-based common garden experiment. She also completed a scientific paper on the response of lodgepole pine radial growth to annual climate using tree-ring analysis of a subset of trees and sites from the Illingworth trial. Sierra applied the URF approach to tree ring data and had considerable success extending responses across a wider range of annual temperatures than is possible using cumulative growth and mean climatic variables from provenance trial test sites.

We received funding from a variety of other sources in 2009-10 for some existing projects but also for some unrelated climate modeling and genomics research. Funding was received from Genome BC for a one-year project to investigate the genetic structure of the Sitka-white spruce and white-Engelmann spruce hybrid zones in BC using state of the art single nucleotide polymorphisms from candidate genes. This funding met field work and lab expenses for Amanda de la Torre Cuba's project on "Genetic structure and conservation of managed interior spruce populations", which had been originally proposed to the Genetic Conservation Subprogram. Funding was also received through the Future Forests Ecosystems Scientific Council of BC (FFESC) program for Tongli Wang's work on modeling the future distribution of BEC units using Random Forests, another project initially supported through the GCTAC program. The MSc research expenses of Nina Lobo were transferred from the Genetic Conservation subprogram to S. Aitken's Natural Sciences & Engineering Council of Canada (NSERC) Discovery Grant when her project shifted from *Arbutus* to an investigation of spatial genetic structure of adaptive variation in Sitka spruce. Finally, Tongli Wang received a contract for climate modeling work with Environment Canada that is unrelated to forestry research, and this enabled us to balance our budget.

Testing climate change predictions for whitebark and lodgepole pine

Sierra Curtis-McLane, PhD candidate

Abstract: Lodgepole pine (*Pinus contorta*) annual radial growth relative to climate and genetics

Relationships between provenance climate, test-site average climate and cumulative tree growth have been deduced from long-term provenance trials. However, the impacts of seasonal and annual climate variation on annual growth in provenance trials have often gone overlooked. The latter trends characterize population responses over a wider range of temperature and precipitation levels than is possible using total growth and normal climate data, thereby providing a more comprehensive picture of how populations may respond to predicted changes in temperature and rainfall by the end of the 21st century. In this study, we relate annual radial increments to annual and summer climate variables using lodgepole pine (*Pinus contorta*) populations growing in a long-term provenance trial in western Canada. To our knowledge, our study is the first to model tree-ring data using quantitative genetics population (PRFs) and universal response functions (URFs). We found annual radial growth to be greatest for populations originating from the center of the species range and growing in test sites with moderate to warm annual climates. Radial growth begins declining around 4.6°C mean annual and 13.9°C mean summer temperature for all populations, with summer high temperatures functioning as the primary limiting factor. As temperatures rise, radial growth will begin declining in warmer locations by the mid to late-21st century, with significant implications for carbon sequestration. Our novel method of combining dendrochronology and genetics techniques will substantially improve predictions of how trees will respond to climate change if replicated in provenance trials worldwide.

Abstract: Whitebark pine assisted migration trial

Assisted migration – the translocation of a species into a climatically-suitable location outside of its current range - has been proposed as a means of saving vulnerable species from extinction as temperatures rise due to climate change. We explore this controversial technique using the keystone wildlife symbiote and ecosystem engineer, whitebark pine (*Pinus albicaulis*). Species distribution models (SDMs) predict that whitebark pine will be extirpated from most of its current range over the next 70 years. However, the same models indicate that a large quadrant of northwestern British Columbia is climatically suitable for the species under current conditions, and will remain so beyond the 21st century. To test the accuracy of this model, as well as the capacity of treated (stratified and nicked) and untreated whitebark pine seeds to germinate, survive and grow relative to geographic, climatic, microsite and provenance conditions, we planted seeds from nine populations in 18 common gardens ranging from 600 km southeast to 800 km northwest of the current northern boundary of the species range. During the first two growing seasons, germination occurred in all test sites, with treated seeds germinating at three times the rate and a year earlier, relative to untreated seeds. Seed weights and x-ray-based viability estimates helped predict germination rates among populations, regardless of seed treatment. Warmer test-site temperatures positively influenced untreated, but barely affected treated, seed germination. However, survival, health and growth of treated seeds were positively influenced by longer growing seasons and warmer summer and winter temperatures, with seeds containing fuller megagametophytes continuing to perform best. This experiment is not a call nor a license to facilitate the migration of whitebark pine. Rather, it exemplifies studies that should be undertaken in the creation of scientific and ethical guidelines for assisted migration prior to a time of critical need.

Potential impacts of climate change on the distribution of ecosystems and tree species in BC

Tongli Wang

This is the second year of this project supported by the Future Forests Ecosystems Scientific Council of BC program. Modeling and projections of climate envelopes of BEC zones using Random Forest for the reference period (1961-1990) and future periods were mostly done in the first year. Wrapping up the results as a peer-reviewed manuscript has been the focus for this year. Two versions of the manuscript have gone through internal review. The final version is almost ready for submission to a peer-reviewed journal and circulation among colleagues.

The main objective of this project for this year was the predictions of climate envelopes for major forest tree species. A species distribution database, for several species has been constructed from over 35,000 sample plots across BC, the western states in US, and Alberta. However, substantial amounts of errors in BC plot data have been identified. Based on earlier test runs with several species, these errors could substantially affect the modeling outcomes. We tried to let the personnel who generated the plot dataset remove the errors, but it was not successful. Eventually we cleaned the data by applying a filter to eliminate the plots that do not fall into the expected BEC subzones. Due to the inconsistency in BEC units labels between the plot dataset and BEC unit dataset, reformatting the labels for over 23,000 plots was a big effort. In the end, about 5000 plots were discarded from the dataset for modeling.

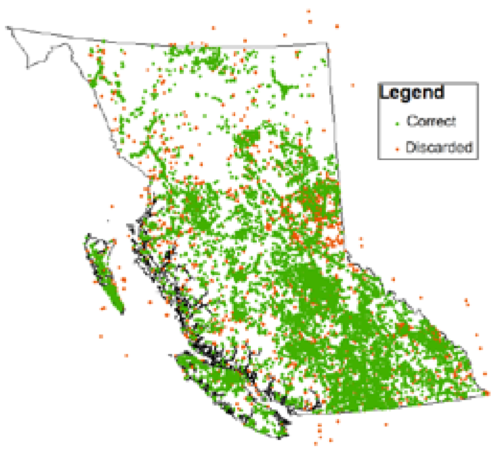


Figure 2. Ecological plots from BC that are being used and those discarded in modeling climate envelopes of BC major species ranges.

Once the data were cleaned, the modeling work was back on track. However, during the last year, Rehfeldt and Crookston (who first applied Random Forest in modeling species ranges) proposed a new approach to construct datasets for the modeling. Instead of using a common dataset to model all the species, a stratified dataset was proposed for each species based on standard deviation of each climate variable within a species range in order to balance the present vs. absent samples. This is a scientifically improved but more laborious process. The R code for stratifying the dataset has now been developed, and modeling Douglas-fir, lodgepole pine and aspen is in progress. Additional species will follow in 2010.

Species and Population responses to Climate
Pia Smets

In 2009-10, Pia Smets established a new growth-chamber experiment to evaluate the response of western larch and western redcedar populations to a wide range of temperature. We have been refining methods for such experiments for several years, and now have a system for simulating relatively natural, variable climate regimes to characterize the effects of temperature on seedling growth with and without drought, while maintaining consistency among treatments in light intensity and photoperiod. These experiments are designed to supplement field common gardens, provide information on a shorter timescale, and provide information on responses to a broader range of temperature than captured in most field provenance trials.

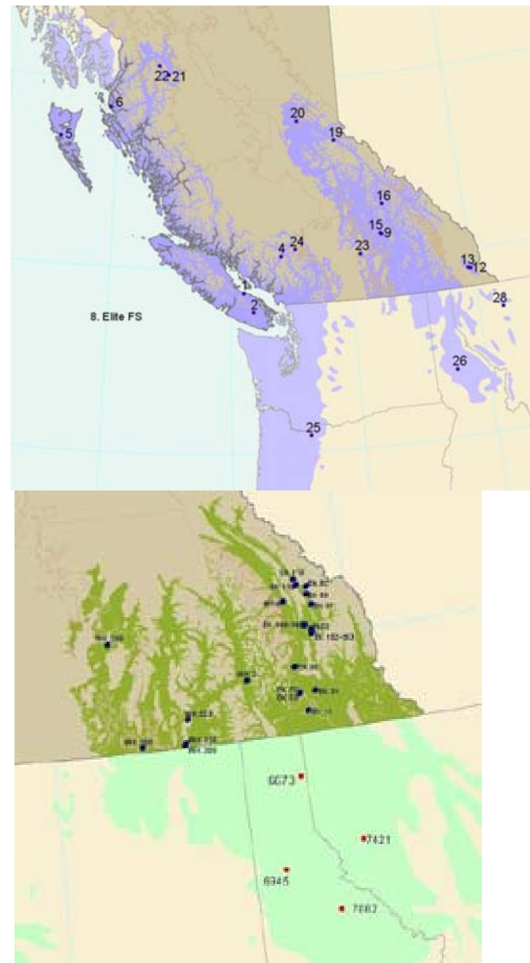


Figure 3. Western redcedar (top) and western larch (bottom) provenances included.

Seedlots were obtained from John Russell for ~20 western redcedar provenances, while Barry Jaquish provided a similar number of western larch seedlots (Figure 3). Multiple seedlots of each species were also obtained from US sources. Seeds were stratified in December and sown in January in five growth chambers at UBC. The first growing season will be partially replicated two times. Half of the seedlings will be maintained for two growing seasons and one artificial winter, providing a balance between obtaining more than one year of growth data on some seedlings, and obtaining true replication of the first year of growth.

Growth chambers simulate mean annual temperatures of 1, 4, 7, 10 and 13C. Conditions from spring through fall are simulated in terms of temperature and photoperiod, and variability in temperature among days in any one two-week growth period is built around the mean. Lodgepole pine and interior spruce seedlots have also been included in the coldest and warmest treatments to add data to previous experiments for these species, and to provide more interspecific comparisons. A proposal has been submitted to the Genecology and Seed Transfer TAC Call for Proposals to support the second year of this experiment, which contains a detailed description of the experiment. It is available on request.

Development of a climate-based seed transfer system
Tongli Wang

This project was mostly postponed due to funding uncertainty last year. However, we still made some progress in working out a solution to modify a small number of BEC variants in order to use these as the basic units for the new climate-based seed transfer system. We have also submitted a proposal to Forest Genetics Council of British Columbia Genecology and Seed Transfer TAC for partial support on this project. The proposal is available to on request, and provides details of the proposed research.

Ecological and conservation genetics of Garry oak (*Quercus garryana*)
Colin Huebert

Colin Huebert completed and successfully defended his MSc thesis on the ecological and conservation genetics of Garry oak in July, 2009. Based on two years of phenotypic data from a common garden experiment at UBC, he found moderate levels of population differentiation for growth, phenology and cold hardiness among populations from across the species range. Variation in stem form and leaf morphology was large but has not yet been analyzed. Seed transfer recommendations for Garry oak were proposed in the thesis based on the results. A copy of the MSc thesis will be distributed to all GCTAC members, and a scientific manuscript is in preparation for submission to a peer-reviewed journal. The common garden experiment at UBC continues to be maintained and will be re-measured as part of an undergraduate student project in the summer of 2010, largely funded by an NSERC undergraduate research award. A second site at Lake Cowichan was planted late in 2008, and will be measured for the first time at the end of the summer, 2010. The new data will be incorporated into the manuscript in preparation.

Development of extreme variables and other climate modelling tasks
Tongli Wang

A project on the development of extreme variables for climate change modeling was funded by Environment Canada in collaboration with the Adaptation and Impacts Research Division, Environment Canada. This project was taken on by Tongli Wang because of the uncertainty of funding for the CFCG last year. ClimateBC and other climate models currently provide only monthly and annual means for temperatures and precipitation. We have investigated the relationships between monthly climate means and extreme events occurring during a long period (30 years) on monthly basis using weather stations' daily data. High-resolution maps will be generated for some extreme variables including temperatures exceeding 40°C and its frequency of occurrence in a 30 year period for current and future time periods.

We continue to develop, improve, host and maintain the model ClimateBC, and have now completed ClimateWNA (Western North America). Activities include:

1) Providing general help to users: ClimateBC has been an essential tool and widely used in climate related studies in BC and western Canada. Questions and requests for help are routine.

2) Adding new GCM scenarios to the models.

3) Launch of ClimateWNA (Western North America). The program was developed last year, but it was not released due to lack of weather station data to validate the some of the derived climate variables. This problem was solved through collaboration with the US Forest Service. ClimateWNA can be accessed at: http://www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html

Genetic structure of managed interior spruce populations
Amanda de la Torre Cuba

As the result of two large genomics projects focused on indigenous Canadian spruce species (Treenomix and Arborea), a wide array of genetic tools are available for characterizing genetic structure and diversity in the spruces. These include both selectively neutral, highly genetically variable markers (microsatellites) and large numbers of single nucleotide polymorphisms (SNPs) from candidate genes that may have relevance for adaptation to environmental conditions. Our previous work with Sitka spruce (see Holliday and Aitken, submitted; and Holliday et al., submitted, below under Publications) has identified 35 SNPs associated with bud phenology and cold hardiness in Sitka spruce and thus involved in local adaptation to climate. PhD candidate Amanda de la Torre Cuba is using a combination of SNPs and microsatellite markers to investigate the genetic structure of the interior spruce introgression zone, from lower-elevation white spruce to high-elevation Engelmann spruce. She will develop a hybrid index for individuals from this zone; and determine the species contributions to the breeding populations in several Seed Planning Units (SPUs) for interior spruce. The GCTAC previously received a detailed proposal describing Amanda's PhD research.

We received funding of $108K for this project from Genome BC in 2009, and with that funding have identified over 100 SNPs that differ substantially in frequency between white and Engelmann spruce, some of which are associated with adaptation to climate in Sitka spruce. Amanda has also optimized a number of microsatellite markers that are highly variable for use in this zone. In the summer of 2009, she collected foliage samples from 1500 trees in the interior spruce breeding program in several SPUs. DNA has been extracted from most of these trees, and genotyping is proceeding for a large number of SNPs and for microsatellites. Growth data is available for these genotypes from the Ministry of Forests and Range (MFR), and we will also be collecting data on phenology of approximately half of these trees in the spring and summer of 2010 for analysis of associations with SNP markers.

Publications and submitted manuscripts by CFGC personnel

Chourmouzis, C., A.D. Yanchuk, A. Hamann, P. Smets and S.N. Aitken. 2009. Forest tree genetic conservation status report 1. *In situ* conservation status of all indigenous tree species. Ministry of Forests and Range Forest Science Program Technical Report 53.

Curtis-McLane, S., V. LeMay and S.N. Aitken. Lodgepole pine (*Pinus contorta*) annual growth relative to climate and genetics. Submitted to Ecological Applications Jan. 2010.

Holliday, J.H. and S.N. Aitken. Widespread ecologically relevant genetic markers developed from association mapping of climate-related traits in Sitka spruce. New Phytologist. Submitted Jan. 2010.

Holliday, J.H., M. Yuen, K. Ritland and S.N. Aitken. Postglacial history of a widespread conifer produces inverse clines in selective neutrality. Molecular Ecology. Submitted Jan. 2010.

Huebert, C. 2009. The ecological and conservation genetics of Garry oak (*Quercus garryana* Dougl. ex Hook). MSc thesis, Faculty of Forestry, University of British Columbia.

Krakowski, J., C. Chourmouzis, A.D. Yanchuk, D. Kolotelo, A. Hamann, and S.N. Aitken. 2009. Forest tree genetic conservation status report 2. Genetic conservation status of operational tree species. Ministry of Forests and Range Forest Science Program Technical Report 54.

Mbogga, M., A. Hamann, and T. Wang. 2009. Historical and projected climate data for natural resource management in western Canada. Agricultural and Forest Meteorology 149:881-890.

Mimura, M. and S.N. Aitken. 2010. Local adaptation at the range peripheries of Sitka spruce. Journal of Evolutionary Biology 23: 249-258.

Wang, T., G. O'Neill, and S. N. Aitken. 2010. Integrating environmental and genetic effects to predict responses of tree populations to climate. Ecological applications, in press.

Schroeder, T. A., A. Hamann, T. Wang, and N. C. Coops. 2009. Occurrence and dominance of six Pacific Northwest conifer species. Journal of Vegetation Science, in press.

2.2 *Research Branch Conservation Activities*

Jodie Krakowski, Research Branch, MFR

Genetic diversity is a fundamental element of biodiversity within and among species and ecosystems. Sound forest stewardship explicitly considers indicators of genetic diversity and meets criteria to preserve sustainable levels of genetic diversity to ensure that populations can persist over the long term in their current habitats, and also can adapt to future environmental conditions. Sufficient population sizes must remain intact to conserve important but rare traits such as pest resistance and retain the full spectrum of adaptive potential. Long-lived tree species need to withstand a wide range of environmental stresses. Many mechanisms conferring stress tolerance are influenced by genetics. Studies have estimated threshold population sizes needed to meet these objectives, and the GCTAC has supported evaluations of their efficacy and reliability.

The Ministry of Forests and Range (MFR) continues to work with partners to achieve conservation objectives in order to fulfill Genetic Resource Conservation and Management program and stewardship goals. Primary partners this year included the UBC Centre for Forest Conservation Genetics (CFCG) and MFR Tree Improvement Branch (TIB) who both provided key support in transitioning the *in situ* catalogue of indigenous tree species from CFCG, where it has guided the development of a key baseline report (http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr053.htm) to MFR. This data is also supporting linkages with CONFORGEN (http://www.conforgen.ca/CAFGRIS.html), a federal initiative of the Canadian Forest Service and Canadian Council of Forest Ministers cataloguing genetic resource conservation. Other projects are detailed below.

Cataloguing *in situ* genetic conservation status of indigenous B.C. tree species

This publication quantifies the genetic conservation status of 49 native trees and tall shrubs across the province within protected areas, by biogeoclimatic zone. MFR Technical Report 53, a co-publication with UBC CFCG and FGC, is available in electronic format at http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr053.htm.

Field verification of *in situ* genetic conservation status of two model species

Field verification was conducted this year on two model species: a wind-pollinated conifer (grand fir) and a bird-dispersed, insect-pollinated shrubby tree (cascara) to test the assumptions behind the models used to estimate species abundance. Protected areas in the CDF, CWH, IDF, and ICH zones were surveyed and observed compared to predicted values. A robust but efficient methodology was developed to assess species distributions. Mapping support to target field work was provided by Tree Improvement Branch.

The objective is to get reliable samples of different types of species such as large and small trees, specialists and generalists, etc. that can be used as models to adjust the assumptions for species distributions to support the cataloguing project. Ground truthing is planned to continue for additional species with different life history traits in other areas of the province.

Plate 1. Grand fir at Creston BC.

Plate 2. *Rhamnus purshiana* (cascara) fruit.

Updating the *in situ* genetic catalogue of indigenous B.C. tree species

Empirical observations and current spatial data are being incorporated into a new analysis of the conservation status of species *in situ*. Since the baseline analysis reported in Chourmouzis et al. (2009) based on 2001 data sets, there have been major improvements in software, processing capacity, data coverage, and accuracy, as well as substantial changes to the BEC mapping and protected areas network. Results of this update will incorporate adjustments based on 2009 and planned 2010 field observations. This information can provide decision support for population conservation priorities. Integrated Land Management Bureau (ILMB) has agreed to provide some support as a part of the interagency collaboration initiative of the BC Government as resources were not available for a GIS contractor planned for this year. This project is expected to continue into the coming fiscal year as it is extremely complex and requires intensive analyses and quality assurance of the many data sets.

Cataloguing conservation status of commercial BC tree species

The companion report quantifying the genetic conservation status of commercial tree species by seed planning unit (SPU) with active progeny trials has been completed. Population genetic representation is summarized including seed collections (*ex situ*), key progeny trials (*inter situ*), and within protected areas (*in situ*). MFR Technical Report 54, a co-publication with UBC CFCG and FGC, is available in electronic format at http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr054.htm. Additional data has been collected to extend this work to other species with genecological information and limited or no tree improvement programs. Our wide range of *ex situ* installations (e.g., clone archives) will be incorporated into subsequent updates.

Whitebark pine genetic conservation strategy

A strategy identifying key goals and priorities for the next 3-5 years, and partners for capacity building within each area, has been drafted. Input was solicited from many individuals and incorporated into the current version. The genetic conservation strategy is intended to be a module that can be incorporated to support a range of whitebark pine restoration and conservation programs. Copies are available at: http://www.fgcouncil.bc.ca/GCTAC-WhitebarkPine-GenConsStrat-BC-2009.pdf

Funding for this non-commercial species has been limited. Building support through partners wherever possible provides key opportunities to capitalize on the periodic, unpredictable cone crops that are the foundation of whitebark pine conservation. The strategy was presented to the Southern Interior Silviculture Committee (SISCO) and the Whitebark Pine Ecosystem Foundation this year, and an earlier draft to solicit feedback from stakeholders was distributed at a meeting in Victoria evaluating options for whitebark pine blister rust screening. Guidelines for cone collecting and for stand and tree evaluations are also available upon request.

Gap analysis of genetic conservation: British Columbia, Alberta and Saskatchewan

$10,000 in support was committed to Dr. A. Hamann at the University of Alberta in support of a graduate student project conducting a spatial analysis of gaps in species conservation in protected areas in the western provinces. This project has been progressing with the assembly and quality control of data sets. Preliminary analyses are underway.

Genetic trial data uploaded into CAFGRIS

MFR is a partner in CAFGRIS, the Canadian Forest Genetic Resources Information System, under the auspices of CONFORGEN (Canadian Conservation of Forest Genetic Resources Program) (http://www.conforgen.ca/CAFGRIS.html). With the support of Canadian Forest Service (CFS) IT staff and under the direction of Dr. Tannis Beardmore and Mr. Brian Low, MFR has catalogued our complete archive of genetic trials in their secure, online database. BC was the trial case and other provinces are expected to use this model to create a national database of forest genetics resources.

Publications

Chourmouzis, C., A.D., Yanchuk, A. Hamann, P. Smets, and S.N. Aitken. 2009. Forest tree genetic conservation status report 1: *in situ* conservation status of all indigenous BC species. UBC Centre for Forest Conservation Genetics, Forest Genetics Council, and BC Min. For. Range, For. Sci. Prog. Victoria, B.C. Tech. Rep. 053. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr053.htm

Krakowski, J., C. Chourmouzis, A.D. Yanchuk, A. Hamann, P. Smets, and S.N. Aitken. 2009. Forest tree genetic conservation status report 2: genetic conservation status of operational tree species. UBC Centre for Forest Conservation Genetics, Forest Genetics Council, and B.C. Min. For. Range, For. Sci. Prog. Victoria, B.C. Tech. Rep. 054. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr054.htm

3.0 Tree Breeding

3.1 Coastal Douglas-fir Program

Michael Stoehr, Keith Bird, Lisa Hayton and Helga Mehl

The highlight of the year was the completion of the establishment of Series 4 of our advanced generation testing and selection in coastal Douglas-fir. There are 160 full-sib families represented in this test, established using the alpha (incomplete block) design with single-tree plots on four sites and 32 replications each. A total of 84 parents are tested. Each test site has over 5000 test trees, which will be subjected to selection at age 11 or 12. The test sites are near Powell River, north of Campbell River, west of Chemainus and on the Caribou Main, south-west of Campbell River.

Other work accomplished in SPU 01 was the tagging of test trees in Series 3 and the collection and analysis of increment cores taken from the full-sib site at Holiday from trees of the best families of Series 1. Wood density (WD) and microfibril angle of the test trees were assessed using X-ray densitometry and diffraction procedures. This work was done in co-operation with Shawn Mansfield of UBC. We made more selections in the Realized Gain trials and in the full-sib tests of Series 1 and 2 at Holiday and North Arm, respectively. All selections were grafted and are growing at Cowichan Lake Research Station (CLRS). In SPU19, (the SM zone of Fdc), we measured the three test sites in the Pemberton area and released preliminary BVs for the purpose of roguing orchard 181 at Puckle Road. As part of the Genecology study in this SPU (EP1200), we thinned the test site at CLRS, slated to be measured in the fall of 2010 together with the sites at Pemberton, Railroad, Saloompt and Talchako.

Publications:

Stoehr, M.U., N.K. Ukrainetz, L.K. Hayton, A.D. Yanchuk. 2009. Current and future trends in juvenile wood density for coastal Douglas-fir. CJFR 39:1415-1419.

Hawkins, B.J., M.U. Stoehr. 2009. Growth, phenology, and cold hardiness of 32 Douglas-fir full-sib families. Canadian Journal of Forest Research 39:1821-1834.

Krakowski, J., M.U. Stoehr. 2009. Coastal Douglas-fir provenance variation: patterns and predictions for British Columbia seed transfer. Ann. For. Sci. 66:811-821.

Stoehr, M., K. Bird, G. Nigh, J. Woods, A.D. Yanchuk. Realized genetic gain in coastal Douglas-fir in British Columbia: implications and yield projections. Silvae Genet. (accepted).

3.2 Western Hemlock Forest Genetics Program

Charlie Cartwright and Doug Ashbee

Due to fiscal restraint and the low priority of the hemlock program in the FGC ranking process, there has been limited activity in the last year. Measurements, and issueing of new breeding values, have been postponed and only maintenance required in order to secure our investment in test sites already in the ground has been performed.

From products billed data it is clear that substantial amounts of hemlock are still harvested, but from planting data we can estimate that over 70% of hemlock ground is naturally regenerated. This practice risks both patchiness and delays in stand development due to brush capturing the site, (as happened in Plate 3). As well, realized gain trial results indicate substantial losses in vigour due to inbreeding depression from wild stand derived seed. Seed transfer trials also show that seed sources ideally adapted for growth are generally located 200 km south for western hemlock in the South Maritime seed zone (SPU 3). As time passes, climate change is likely to exacerbate this adaptational lag effect so that natural regenerated stems will be increasingly less fit. Another drawback from this current silvicultural process is that planting seedlings from best seed orchard lots could add as much as 19% to stand volume at age 60. As well, American competitors in the Pacific Northwest plant roughly 8 times as much hemlock as our province on a land base that is 30% smaller, which may eventually result in significant negative economic impacts for our companies. Hopefully if optimism rises in the forest industry as the economy pulls out of its downturn, interest in taking advantage of improved seed may increase.

Plate 3. Planted hemlock trial surrounded by ground left for natural regeneration impacted by salal.

3.3 True Fir Forest Genetics Program

Charlie Cartwright and Doug Ashbee

Grand fir and noble fir provenance trials have now been in the ground for several decades. This past year collections of plant materials were made from our test sites in order to preserve range–wide genetic variability and secure genotypes of superior stem form among trees of the fastest growing provenances. For noble fir the scion were collected based upon age 16 years data and for grand fir age 20 figures were available. Although true firs are not good performers in seed orchards, preserving the diversity and vigor within the species may well be of great benefit. About half of the collections necessary have been made. Based on measurements from our trials, gains in volume from utilizing seed from best provenances (B^+ seed) run to 10% and some improvements in stem form are also possible.

Pacific silver fir provenance trials are now 10 years old, but scheduled measurements have been postponed due to fiscal restraint. Only regularly scheduled maintenance is being performed in this program. Here again collections in order to secure range wide diversity, as well as vigor and good form, will be made from provenance trials. Collections will be completed gradually over the next 5 years.

Work with sub-alpine fir this year saw establishment of 6 provenance trials. There were seed sources from the Yukon, Mexico, Vancouver Island and central Alberta. Sites were located from the Washington State border to the Yukon Territory. Eight sites had been planned, but delays in budget process meant postponing installation of the last 2 trials. As well as this work, regular maintenance proceeded with 9 previously installed test sites.

3.4 Western Redcedar Breeding Program

John Russell, Craig Ferguson and Jodie Krakowski

The western redcedar breeding program is moving towards developing durable populations for resistance to current, and future known and unknown, biotic threats as well as maintaining adaptability and growth (Plate 4 and Plate 5). Current known biotic threats include ungulates, heartwood fungi and cedar leaf blight. Understanding resistance mechanisms for these organisms has been ongoing and a key component is secondary extractives, both in the foliage and heartwood. We are also beginning to explore genetic correlations among the different biotic threats, and with growth. Figure 4 illustrates that height growth on low elevation maritime ecosystems is negatively impacted as cedar leaf blight (CLB) severity increases.

Plate 4. Western redcedar progeny tests on productive coastal maritime sites near Powell River. Top polycross families at this site were near 7 metres in height after 9 years in the field. Cedar leaf blight (CLB) was not present at this site.

Plate 5. Western redcedar progeny tests on productive coastal maritime sites near Powell River. A western redcedar seedlings close to two meters after only two years in the field. Cedar leaf blight was not present at this site.

A deer resistance population has been developed selecting individuals with high needle monoterpene concentrations. However, operational deployment will require a suite of nursery and silvicultural tools to ensure adequate stocking and free-to-grow in the presence of deer browsing.

Recent trials near Cowichan Lake Research Station illustrates the importance of ensuring the deer have a palatability choice through mixed stocktypes in a single seedlot. Deer preferred to browse seedlings to rooted cuttings at one site, and younger, smaller and lower terpene seedlings at another site (Figure 5).

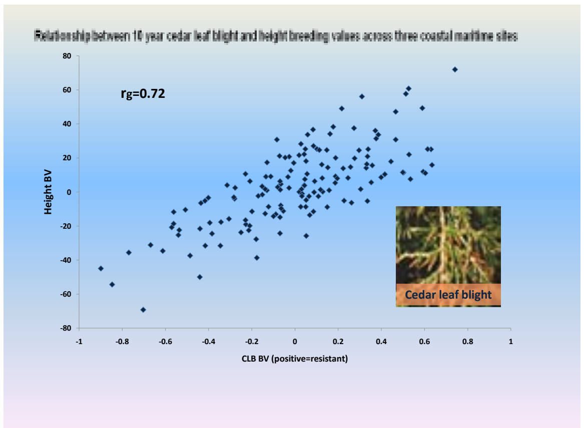


Figure 4. Relationship between cedar leaf blight and height breeding values across three maritime sites.

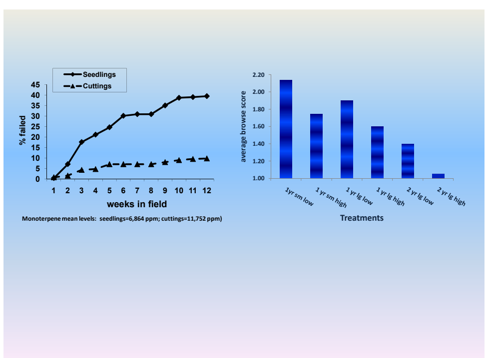


Figure 5. Deer browsing and choice for western redcedar at two field sites

Recent analysis of genecological data indicates that western redcedar is much more sensitive to climate across its range than yellow-cedar (Figure 6). Productivity is highest on sites with long, wet growing seasons. Populations have the best productivity in climates that are warmer and with longer growing seasons than their locations of origin. CLB is most severe in coastal mild, cool sites with warm winters and wet summers; populations originating from above 500 m across the species range are highly susceptible, while coastal low elevation populations appear to have evolved resistance.

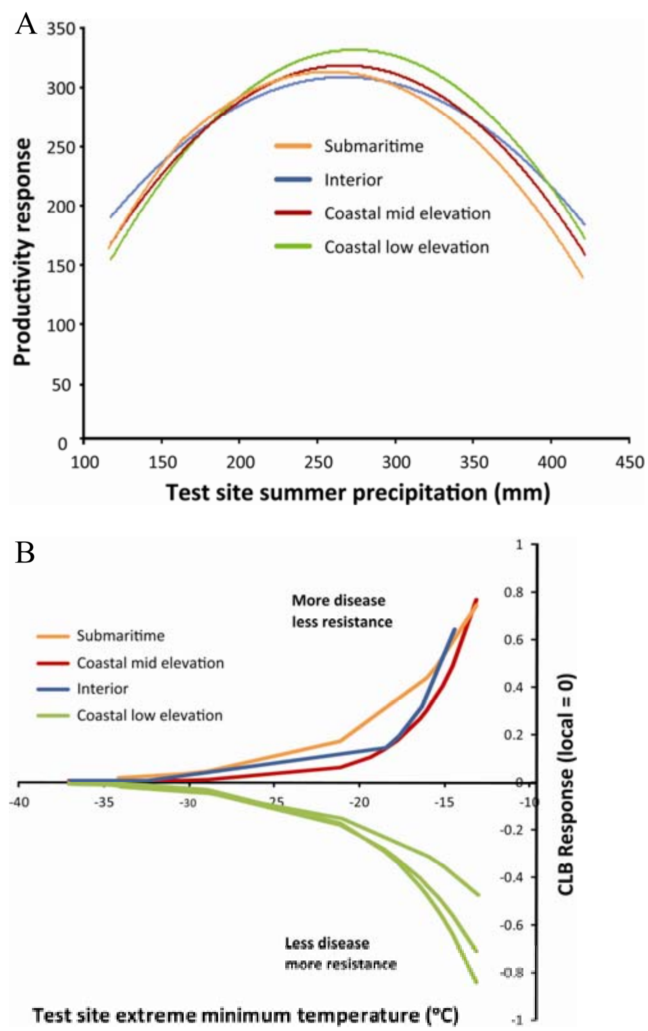


Figure 6. A. Response functions showing productivity versus test site summer precipitation of selected regionally grouped western redcedar populations B. Western redcedar population responses to extreme minimum temperature relative to site mean cedar leaf blight severity.

3.5 Yellow-cedar Breeding Program

John Russell, Craig Ferguson and Jodie Krakowski

This program is currently focussing on maintenance and measurements of the clonal full-sib field trials as well as advanced generation breeding among forward clonal selections. In addition a select clonal population with a genetic gain of 20% volume has been established with serial propagated donors in greenhouses at CLRS. This elite vegetative lot (veglot) has the potential to be 35% greater in early height as compared to wildstand seedlots across a wide range of ecosystems within the yellow-cedar maritime SPU (Table 1)

	Series 1		Series 2		Series 3
Average (meters)	HT 9	HT 12	HT 9	HT 12	HT 9
Top 20 clones	3.6	5.0	3.3	4.5	4.4
All clones	2.8	3.9	2.5	3.4	3.3
Seedlot control			2.4	3.3	3.1

Table 1. Yellow-cedar 9 and 12 year mean heights for three populations across three test sites in each of three series.

Analysis of 15 year yellow-cedar provenance data revealed very weak adaptive patterns associated with climate across its range, facilitating broad seed transfer. Productivity (combining height, survival, and frost hardiness) is most influenced by cool summer temperatures and summer moisture. Snowpack influences productivity primarily through frost damage, and likely by limiting early height growth. For future adaptation, populations have best productivity in climates that are warmer and with longer growing seasons than their locations of origin.

Plate 6. A 12-year-old yellow cedar clone on a low elevation coastal site near Powell River. Top clones at this extremely productive site were over 6.5 metres after 8 years in the field. The clone pictured here at 12 years is over 10 metres.

3.6 Interior Douglas-fir Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hooge

The BC Interior Douglas-fir tree breeding program began in 1982 and largely focuses on productive forest lands in the central and southern Interior. The species' breeding strategy is based on: 1) phenotypic selection in wild stands, 2) establishment of grafted breeding orchards and clone banks, 3) progeny testing using open-pollinated seed from wild stand trees, 4) delayed clonal seed orchards based on backward selection, and 5) controlled mating to produce pedigree material for second-generation selection. Tree height, diameter and volume are the major traits considered for improvement, while wood relative density is an important secondary trait. The recent discovery of resistance to *Armillaria* root disease in Interior Douglas-fir (Cruikshank et al. 2010) suggests that resistance to *Armillaria* could become an important trait of interest. The first-generation progeny testing program includes 1,466 open-pollinated families from six seed planning units (SPUs). Seed orchards were established in the north Okanagan in the early 1990's and are beginning to come into production. In 2009, nearly 1.5 million class A Interior Douglas-fir seedlings were requested for planting in B.C., which represents about 11 percent of the year's total planting of Interior Douglas-fir.

The second-generation crossing program focuses on the Nelson SPU and includes selected parents from the West Kootenay, Shuswap Adams and Mica regions. Since inter-varietal (coastal x interior Douglas-fir) hybrids have shown to be hardy and fast growing in the Nelson low elevation zone, the Nelson second-generation breeding population has been augmented with 16 high breeding value parents from the BC coastal breeding program and 16 forward selections from superior Submaritime provenances in the Trinity Valley range-wide Interior Douglas-fir provenance test.

In spring 2009, 272 controlled crosses were completed in six Douglas-fir SPUs and 260 pollen lots were collected, processed and stored for future breeding. Controlled crossing for the Nelson SPU is now about 80 percent complete. Unfortunately, because of severe budget restraints, no maintenance or measurements were conducted in the Interior Douglas-fir progeny testing program.

3.7 Interior Spruce Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hooge

The Interior spruce tree breeding program in British Columbia is structured in two phases. Phase one began in the mid-1960s and focussed on three ecologically and geographically unique regions: Prince George, Bulkley Valley and the East Kootenay. Phase two began in the mid-1970s and focussed on other geographic regions where Interior spruce is commercially and ecologically important. The program has progressed to the point where much of the current planting stock (more than 80 million seedlings per year) comes from improved first-generation seed orchards and full-sib second generation progeny tests are in place for three seed planning units. In the Prince George Series 1 program, 65 forward selections have been grafted and established in clone banks and breeding orchards. In 2009, 75 forward selections were made based on ten-year measurements. Scion material was collected from each selection and grafting was completed in early spring.

Breeding for 2nd-generation selection is now focussing on the Nelson low and mid-elevation SPUs. In 2009, 54 crosses were completed for the Nelson low SPU and 8 pollen lots were collected. Fourteen crosses were completed for the Nelson high SPU. Three-year measurements were completed on three Prince George Series II second-generation tests.

3.8 Western Larch Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hooge

In 2009, approximately five million western larch seedlings were planted in BC, 76 percent of which originated from the Kalamalka Forestry Centre seed orchards. No maintenance or measurements were conducted in the western larch progeny testing program. In the second-generation crossing program, fifty crosses were completed and 37 pollen lots were collected and stored for future crossing. Second-generation crossing in the East Kootenay and Nelson SPUs is now about 80 percent complete and we anticipate completion of the crossing program within three years. The six-year-old Nelson SPU realized gain genetic tests were maintained and measured (Plate 7). Average tree height on the fertile Interior Cedar Hemlock (ICH) site at Burton Ck (345 cm) was more than twice that of the dry, cold Taurus Ck site (171 cm). Overall mean height of the elite, seed orchard and wild stand control seedlot classes were 262.3 cm, 237.6 cm, and 216.8 cm, respectively. Moreover, trees planted at 3.5 m spacing were significantly taller than those planted at both 1.5 and 2.5 m spacing ($P<.05$).

Publications

Cruickshank, M.G. B.Jaquish and A.F.L. Nemec. 2010. Resistance of half-sib, Interior Douglas-fir families to *Armillaria ostoyae* in British Columbia following artificial inoculation. Can J. For. Res. 40:155-166.

Rehfeldt, G.E. and B.Jaquish. 2010. Ecological Impacts and associated management strategies for western larch in the face of global warming. Mitigation and adaptation strategies for global change. 15(3):283-306.

Tours and extension

Jaquish, B. 2010. Ecological impacts and associated management strategies for western larch in the face of climate change. Research Branch Seminar Series. January 20, 2010.

Lecture: UBC Forest Genetics 302: Forest genetic resource management and climate change. March 11, 2010.

Jaquish, B. 2010. Western larch genecology and climate-based seed zones and seed transfer. Annual meeting B.C. Forest Genetics Council. Vernon, BC. March 25, 2010.

Jaquish, B. 2010. Western larch genecology: new climate based seed zones and seed transfer guidelines. SISCO Winter Workshop. Naramata, BC. April 13, 2010.

Plate 7. Six-year-old western larch tree from Elite genetic class at the Burton site of the Nelson Seed Planning Zone realized gain genetic test.

3.9 Lodgepole, White and Ponderosa Pine and Interior Broadleaved Species

Michael Carlson, Vicky Berger, Nicholas Ukrainetz

Lodgepole Pine

The lodgepole pine breeding program has advanced to the second generation of progeny testing in five seed planning zones (BV, CP, PG, TO and NE). Within each seed planning zone (SPZ), 50 parents were selected for superior growth, and 50 parents were selected for superior wood density. Breeding was conducted among the parents within each of these groups to create 65 controlled cross families per group. These families were deployed on 3 test sites within each SPZ along with several local control and seed orchard (A-class) seedlots. These tests will become a supply of high gain material to be incorporated into seed orchards. The first generation, open pollinated progeny tests continue to provide information for updating seed orchard parent tree breeding values and opportunities to assess pest and disease resistance, while the provenance tests remain a wealth of information for modelling impacts of climate change and seed transfer regulations.

A method for calculating breeding values for gall rust resistance was achieved by using a combination of rigorous statistical analyses of binary trait data and the simple percentage of trees within a family that are free from stem galls (Figures 7 and 8).

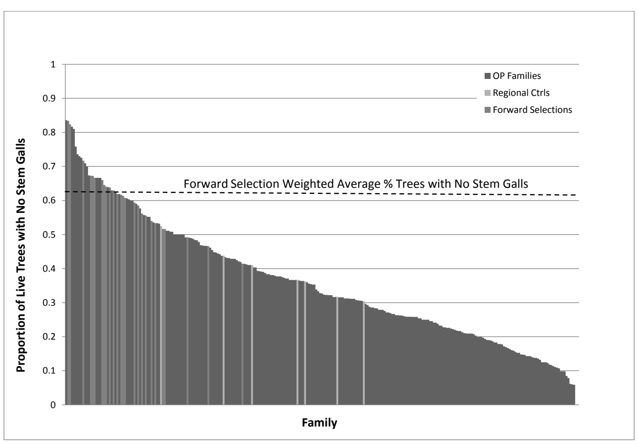


Figure 7. Family variation for the proportion of trees within a family with no stem galls. The dotted line indicates the average proportion of trees with no stem galls in families from which forward selections were made for gall rust resistance.

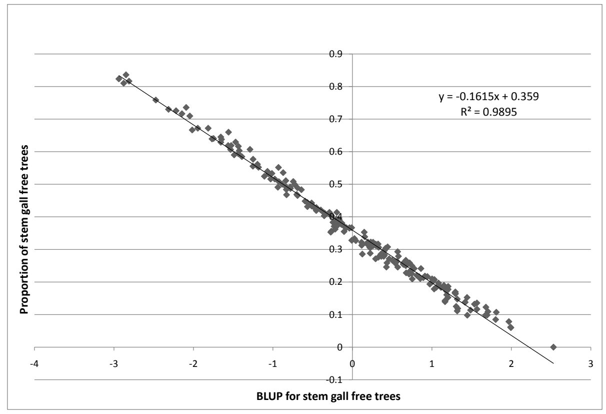


Figure 8. A standard curve showing the strong relationship between family breeding values for the binary trait (infected and not infected) and the proportion of trees within a family with no stem galls.

The major factor affecting the survival and merchantability of trees infected with gall rust is the presence of a stem gall. The resulting breeding value is an indication of the percentage of offspring from a parent that are expected to be free from galls on the stem. It is expected that 38% of trees in control seedlots will have no stem galls versus 52% for the Finlay gall rust resistant forward selections. This is likely a conservative estimate given the higher frequency of resistance genes in a clonal orchard.

Conventional breeding values for seed orchard 230 were updated using 9-year data collected from two progeny test sites in the Nass-Skeena transition (NST) SPZ.

A total of 198 of our highest priority parent trees have been grafted and planted at a new clone bank and breeding arboretum located at the Skimikin Seed Orchard (Plate 8).

Plate 8. New breeding arboretum established at the Skimikin Seed Orchard with high priority, high breeding value parent trees used for breeding in the second generation progeny test program.

Two pine test sites were retired at the Skimikin Seed Orchard: the low elevation genetics of elevation adaptation (GEA) trial site and the branch angle study. Four of the six blocks of the branch angle study were measured prior to removal. The data reveals a high level of genetic control for branch angle (Figure 9).

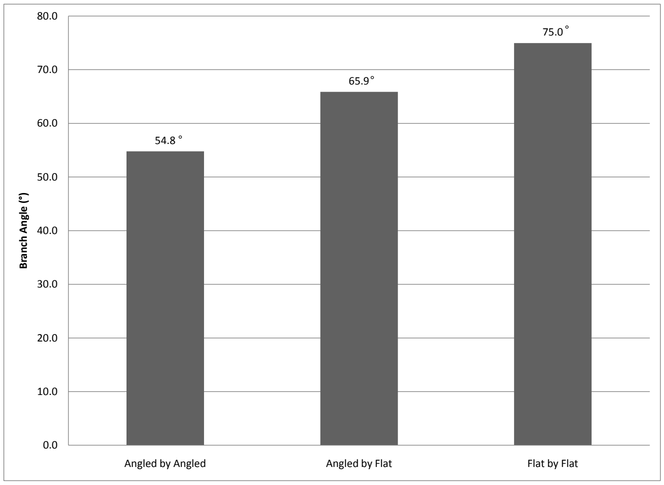


Figure 9. Results from the lodgepole pine branch angle study which tested a number of controlled cross families of parents selected for high branch angle (angled) and low branch angle (flat).

In an ongoing effort to investigate the genetic control of disease resistance in lodgepole pine, we have maintained good relations and collaboration with Richard Reich, Regional Pathologist in Prince George, who successfully established a series of test plantations in high gall-rust hazard areas with controlled crosses between resistant parent trees that were created at the Kalamalka Forestry Centre in Vernon. Richard will continue to monitor the plantations as they experience infection by various diseases. We were also fortunate to collaborate with Richard Reich and Anders Fries (Swedish geneticist) to assess and measure 5 test sites established in a collaborative effort between various government and private organizations in Sweden and BC. The tests were established in 1986 to test the susceptibility of Scots Pine to insects and diseases that attack and infect lodgepole pine, since lodgepole pine is actively planted and managed as a crop species in Sweden.

Data from the Big Bar – Chilcotin provenance – progeny test series was analyzed and revealed patterns of genetic variation among provenances and families. Seed for the test was collected from 5 trees within 53 provenances and planted on 5 test sites. Although five year data is insufficient to make decisions, the patterns of variation are encouraging and suggest that opportunities exist for future forward selection efforts and identification of appropriate seedlots for the region. Five year data from two of the second generation progeny test SPZs (BV and PG) have been analyzed. In the first five years of growth, controlled cross families of parents from the Nelson SPZ are the top ranked families for height growth.

Western White Pine

The supply of blister rust resistant western white pine seed in the interior of BC is produced at the Bailey Seed Orchard (orchard 335) in Vernon. The seed orchard is composed of a combination of parent trees imported from Moscow, Idaho, and local seedlings from BC. The parent trees from Idaho were selected from a 17 year old, full-sib family screening trial growing at the Priest River Experimental Station. The full-sib families were created by inter-crossing tested and selected first generation parents. Seed from BC parent trees was screened for rust resistance at the Cowichan Lake Research Station. Surviving trees were selected for having good resistance reactions to white pine blister rust. Scion was eventually collected from selected trees, grafted and planted in the seed orchard. The genetic material now located in the Bailey Seed Orchard will form the breeding population for future breeding activities.

This year, a field test was established at the Skimikin Seed Orchard, in collaboration with retired Canadian Forest Service research pathologist Rich Hunt, to test the relationship between age and resistance to white pine blister rust (it is hypothesized that resistance develops with age). Six families and one control seedlot from three different age classes were randomly allocated across six blocks. In 2012, a fourth age class will be planted and the plantation will be inoculated in late summer of the same year with blister rust spores. At the time of inoculation, the four age classes will be 1, 4, 5 and 6.

Screening of full-sib and half-sib families with parents originating from Idaho continued at the Skimikin Seed Orchard. Seedlings with good resistance characteristics were selected and planted in a holding area which will be monitored in subsequent years for rust resistance and resistant trees will be grafted and planted in seed orchards for seed production. The program is now shifting focus to parent trees of BC origin and breeding is ongoing to produce full-sib families for screening.

Interior Paper Birch

The interior paper birch program consists of three test series which assess several provenances and families across a wide range of test sites. EP 1069.11 tests 18 provenances collected across the range of interior paper birch on 6 test sites from Kispiox to Creston. EP 1069.12 was located at the Skimikin Nursery and contains open pollinated families collected from 19 stands in the Kootenay Region. EP 1069.13 is an elaborate genecology study located on three test sites (Prince George, Skimikin and northern Idaho) and contains several latitudinal, longitudinal and elevational transects.

In 2007, 36 trees were selected from EP 1069.12 based on 9 year volume (Plate 9). Scion was collected and used to establish two paper birch seed orchards. In 2009, eight additional selections were made before the experimental plantation was retired and removed later that year.

Plate 9. Example of a tree selected from EP1069.12 which tested 193 families from 19 stands located in the Kootenays. After selecting trees for two seed orchards, the test site was retired..

Dr. Michael Carlson Retires

As of April 2010, Mike Carlson has officially retired from the Forest Service. Mike served as a tree breeder with the Ministry of Forests since 1983, and managed the lodgepole pine, western white pine and interior hardwoods programs. During his many years on the Forest Genetics Council and chair of the Interior Technical Advisory Committee, Mike provided sound scientific and field knowledge and set the standard for cooperation among stakeholders. He is best known for his volunteer and community service, extension work, tree planting, tree give-aways, his amicable nature and many friendships. Mike continues to support forest genetics as an *emeritus* scientist with the Forest Service.

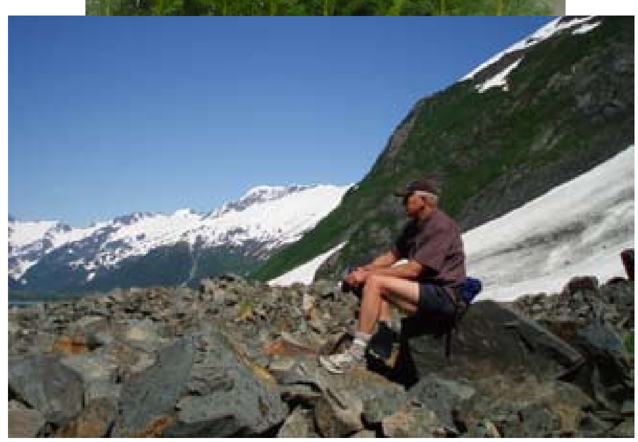


Plate 10. Michael Carlson at work in the nursery and at play on a ridgetop in Alaska.

3.10 Assisted Migration Adaptation Trial (AMAT)

Greg O'Neill, Michael Carlson, Vicky Berger, Nick Ukrainetz

Despite several significant administrative and financial hurdles, the AMAT is still on track. Having just completed planting of the second series of 12 sites, we are currently arranging site prep, fencing, layout, and weather data downloading contracts for summer 2010. In fall 2010 we will confirm the locations of the final series of 12 sites. 2011 will prove to be the most challenging year for planting, with sites at locations as disparate as Whitehorse and Sacramento, California.

Results from the AMAT could result in changes to BC's seed transfer system that may lead to significant regional changes in seed demand. While changes to BC's seed transfer system will be phased in, and are still several years away, the AMAT team devoted considerable effort toward extension activities in 2009/10. The project was presented or discussed at the following programs, meetings, tours or publications:

- BC Forest Professional magazine (May/June 2009)
- CBC TV The National (June 2009)
- BC Forest Service News (June 2009)
- Nature (June 2009)
- Associated Press (July 2009)
- Minister Yapp – Vernon (Aug 2009)
- Western Forest Genetics Association – Asilomar, CA (Aug 2009)
- UBC Okanagan – Kelowna (Dec 2009)
- Vulnerability of Canada's Tree Species to Climate Change (Johnson et al. 2009)
- CBC Radio – Southern Interior (Dec 2009)
- USDA Forest Service – Corvallis, OR (Mar 2010)
-

As a result of our extension activities, the AMAT team is collaborating with researchers at UNBC and UBC, and researchers in Quebec and the USDA are examining opportunities for projects similar to the AMAT. The CFS has embarked on a series of publications featuring assisted migration. Two recently submitted articles (Ukrainetz et al. and O'Neill & Nigh) will discuss barriers to assisted migration that are being addressed via the AMAT.

The AMAT team thanks its many collaborators who have kindly provided advice, seed and test sites, and looks forward to developing further collaborations.

Plate 11. Vicky Berger and George Franssen install weather station monitoring equipment at AMAT field site in Monashee Mountains.

Plate 12. Nicholas Ukrainetz, Darryl Person and Michael Carlson on AMAT site reconnaissance trip near Kitimat.

4.0 Seed Transfer Technical Advisory Committee

Lee Charleson

The Seed Transfer TAC (STTAC) was established in fall 2008 following discussions held by FGC's Genecology and Seed Transfer Committee. STTAC was formed for the purpose of developing priorities in genecology research, vetting project proposals and providing budget recommendations to FGC for genecology and seed transfer research, and raising issues to CTAC and ITAC for their participants' consultation.

After a successful first year, the members of STTAC continue to develop priorities, improve the process for a call for proposals and the delivery mechanisms, and recommend a budget for submission to FGC in a timely manner.

A subcommittee originally led by John Russell, later by Jodie Krakowski, developed the research priorities listing in two stages, first by species and then by activity for each species. Adjustments and improvements were made to the priorities table developed and used a year ago, resulting in some ranking changes. The entire STTAC supported the new priorities list. Emphasis on commercial species elements of current distribution, future distribution, cubic metre harvest, planting numbers, and revenue resulted in the high ranking of the big five species (Pli, Fdi, Cwc, Fdc, Sx). ITAC and CTAC members expressed concern as the new priorities may generate too much emphasis on research and expenditure on any one of the top five species. (For example, lodgepole pine was ranked #1). New to the list of eligible projects for funding was the identification, in a separate table, for development of a seed transfer system.

Funding approval for the recommended proposals arrived late in the year. This resulted in difficulties for proponents of approved projects to commence their work since, in some cases, the biological window to conduct the planned work was quickly passing. Some project funds were turned back and some projects were partially completed for this reason.

Twenty-five projects were submitted to the call for proposals in winter 2008-2009, all in the research category. Sixteen projects met the eligible criteria and were approved funding by FGC. The approved STTAC budget is $300,000. The projects conducted this year, 2009-2010, are summarized below. Since projects funds were released in summer 2009, projects were either completed, partially completed or not undertaken.

In winter 2009-2010, responses to the call for proposals brought forward 24 research-based proposals and 2 seed transfer system proposals. The review committee, composed of seven people, reviewed the proposals and made project and funding recommendations to FGC at the end of the fiscal year.

Table 2. Seed Transfer TAC projects and activities completed.

Project #	Project Title	Proponent	Agency / Company	Activity
Act01	Black Cottonwood genecology study	Chang-yi Xie	MFR RB	Brushing, tagging, and monitoring
Ba01	EP0824 – Provenance Studies of Amabalis Fir	Charlie Cartwright	MFR RB	3 tests maintained
Bg01	EP0823 – Provenance Studies of Grand Fir	Charlie Cartwright	MFR RB	4 sites maintained
Bl02	EP0824 – Provenance Studies of Subalpine Fir	Charlie Cartwright	MFR RB	Test maintenance completed; test establishment and monitoring were completed in part.
Bl04	Patterns in frost, heat, and drought response of Abies lasiocarpa populations from a range of climates	Sylvia L'Hirondelle	MFR RB	Test measurements were conducted.
Bn01	EP0857 – Provenance Studies of Noble Fir	Charlie Cartwright	MFR RB	Minor maintenance completed.
Cw01	Western redcedar interior climate change and seed transfer study (EP 1323.02.21)	John Russell	MFR RB	5 test sites established.
Cy01	Genecology and climate change studies to address causes of yellow-cedar dieback (EP 1324.02.21)	John Russell	MFR RB	Seed procurement work.
Hw01	EP0813 – Provenance Studies of Western Hemlock	Charlie Cartwright	MFR RB	11 test sites maintained.
Mb01	Bigleaf maple genecology study	Chang-yi Xie	MFR RB	Brushing and tagging.
Sx02	Brushing spruce climate change test sites	Barry Jaquish	MFR RB	5 sites brushed.
Sx03	Climate stations for the interior spruce genecology/climate change study	Greg O'Neill	MFR RB	Work completed.

5.0 Operational Tree Improvement (OTIP) - Thirteenth Year in Review

Darrell Wood

The objective of the Operational Tree Improvement Program (OTIP) is to increase the quality and quantity of seed produced from existing forest companies and Ministry of Forests and Range seed orchards. It also provides technical support for orchard production and management, including pest management. OTIP spending is based on Species Plans. Projects are developed through a call for proposals process that is based on Species Plan priorities.

As a result of this funding, this program has the ability to meet future seed demands through key investments in:

- breeding
- testing
- seed pest management
- seed orchard quality and quantity boosts
- orchard development

The Operational Tree Improvement sub-program (OTIP) provides the focus for investing in our orchards for the purposes of increasing genetic gain, as well as seed yields. With the deployment of replacement stock from the breeding programs, the genetic worth of orchards continues to increase. As well, provincial objectives for high-quality select seed operational reforestation are being met. This year, as in past years, considerable work was done with stock replacement and studies on seed supply issues.

OTIP uses a performance management system to monitor progress and set reasonable targets for project success. Orchardists and researchers have responded to this approach and in many instances have achieved beyond the planned targets this year.

For more information regarding budget and OTIP business details, please refer to the FGC Annual Report 2009/10 at: http://www.fgcouncil.bc.ca/FGC-BusinessPlan-2009-10.pdf

5.1 Orchard Projects

5.1.1 Saanich Forestry Centre (WFP)

Annette van Niejenhuis

Western Forest Products (WFP) operates production tree seed orchards for Seed Planning Units in the Maritime zone at the Saanich Forestry Centre. Low elevation Douglas-fir, low elevation western redcedar, low and high elevation western hemlock, and low elevation Sitka spruce seed orchards as well as yellow cypress hedge orchards are established. A high-gain high elevation Douglas-fir seed orchard was added in 2008. As a co-operator in the Forest Genetics Council programs, WFP acquires OTIP funds to implement incremental management techniques to deliver quality seed in quantity to the coastal forest regeneration programs.

Low Elevation Coastal Douglas-fir Crop and Orchard Enhancement

Orchard upgrading continued; we replaced 328 poor or dead ramets in orchards 166 and 405. Average genetic worth of these orchards are 16 and 19 respectively. Deer browse of small stock is a serious issue.

We implemented supplemental mass pollination using previously stored and fresh pollen for 14.5 litres with a genetic worth of 17 in April 2009. We harvested an exceptionally large cone crop at 107.7 hl, which yielded 68.8 kg of seed and is predicted to deliver 2.6 million seedlings at normal sowing rules. Examination of the 2008 girdling data is not conclusive with regard to cone production as many untreated trees had significant cone crops.

High-elevation Douglas-fir Replacement Orchard

We planted 31 ramets in the first and third quarters of the year to replace mortalities and poor ramets. This orchard will produce crops of 13% volume gain at rotation. Deer browsing is currently an issue.

Western Redcedar Orchard and Crop Enhancement

We harvested a western redcedar cone crop of 11.7 hl which yielded 12.9 kg of seed, estimated to produce 2.6 million seedlings for reforestation programs. This crop has a genetic worth of 16.

We obtained 71 ramets of parent trees identified from series 4, 5, and 6 progeny trials from the Sechelt orchard. We rogued 435 low-gain ramets in orchards 189 and 198 and raised the orchard genetic worth from 9 to 15 and from 11 to 18 respectively.

Low-elevation Western Hemlock Crop Enhancement

Seed of high genetic worth in storage for western hemlock far exceeds current coastal seed needs, thus we did not manage or harvest the 2009 crop. Orchard maintenance continued; the orchard will be upgraded with roguing and ramet replacement before additional crops will be managed. Significant outbreaks of woolly aphids were monitored.

Western Hemlock Orchard and Future Crop Enhancement

In western hemlock orchard 187 we managed a small crop in 2009. Supplemental mass pollination of breeding value 11 was applied in the first quarter, and yielded a crop for 26.3 thousand plantables at genetic worth of 10. We acquired 33 grafts to replace poor and dead ramets; 11 ramets were planted in the 4th quarter. Maintenance of the holding stock continued, together with maintenance of young orchard stock. Deer antler rubbing is evident in this orchard.

Sitka Spruce Orchard and Crop Enhancement

The 2009 crop in the weevil-resistant Sitka spruce orchard 172 yielded 10.1 hl of cones for 5.4 kg of seed at genetic worth (resistance) of 87. This crop is projected to produce 943 k plantables. We applied supplemental mass pollination to this crop: 3 litres of both stored and fresh pollen of breeding value 93 (weighted average) was applied to 432 ramets in the orchard. An additional 4.4 litres of pollen was stored.

Response to induction treatments applied in 2008 was significant; both pollen buds and cones were significantly more abundant on treated trees than controls. Girdling plus root pruning resulted in highest average production of reproductive structures, but was not significantly different from girdling alone or root pruning alone. Pest monitoring and management continued throughout the year.

Yellow Cypress Production Hedges Enhancement

We established a new donor orchard, including all high-gain selections from WFP trials that have demonstrated good rooting in greenhouse trials. Of a planned 3,500 ramets, 2,333 were established. The additional 1,167 ramets were set for rooting in 2009 and will be ready to plant to complete the donor orchard in 2010. This stock will deliver steckling orders with a genetic worth of 20.

5.1.2 Sechelt Seed Orchard (CanFor)

Patti Brown

Douglas-fir

700 ramets from orchard #177 were SMP'd with GW 20 pollen to increase seed yield. The crop trees were then sprayed with 1% dimethoate in mid April. 31 kg (1.4M potential seedlings) with a GW of 17% was harvested from this orchard.

Pollen monitoring in orchard #116, #177 and regional was conducted from mid March to early May. The squirrel population was kept under control with the use of live traps. Orchard #116 produced 51 kg of seed or 2.0M potential seedlings.

Western Redcedar

The maintenance of 2,400 redcedar ramets from test series 4 through 6 in the holding beds at Sechelt continued. Roguing to the top 20% was done in mid season. Orchard #186 was rogued to achieve a GW of 12% and monitored for cedar midge and lygus pests. 0.9kg of seed worth 12%GW was produced.

Western White Pine

The 600 cone producing ramets were monitored and spot treated for *Leptoglossus* control on a regular basis throughout the seed production season. Undeveloped cones attacked by *Conopthorus* were collected and burned prior to cone collection season for future control purposes. 64kg of Major Gene Resistant (MGR) seed was produced.

5.1.3 Mt. Newton Seed Orchard (TimberWest)

Bevin Wigmore

Douglas-fir

SPU0106 covers activities in five Fdc M low orchards: 134, 154, 183, 197 and 404. The management objective is to increase the genetic worth of these orchards from the current 12% to approximately18% by 2015, and maintain an average annual production of 5 million trees.

These orchards contain a total of 4700 ramets, about half of which are not yet in production. 700 more trees were grafted this year, and 850 trees were established in the fall. An additional 190 were purchased from CLRS as we continue to convert to high density plantings. 742 trees which were too small to plant out were maintained in holding beds.

SMP was required to augment the insufficient pollen cloud on 275 trees of the early and late clones. Both fresh and stored, high breeding value pollen was used and all stored pollen was tested before use. 10 litres of pollen was collected, dried and stored for future use. Internal and external pollen flights were monitored and a contamination rate for foreign pollen was calculated.

Insect pests were monitored and as the numbers of damaging insects was very low, no control measures were carried out this year.

$GA_{4/7}$ was used to induce a 2010 crop on 1900 ramets.

2009 was an exceptionally good crop year for our Douglas-fir orchards. 621 hectolitres of cones were collected, despite leaving some of the lowest gain trees unpicked. This produced over 435 kg of seed, for a yield of 0.700 kg/hl.

228 large ramets with GW<7 were rogued from the orchards during the winter.

Western Redcedar

SPU0205 covers activities in two Cw M low orchards: 140 and 152. These two orchards are similar in composition and are typically induced in alternating years to provide a steady seed supply.

320 orchard trees were maintained and managed to produce 10.5 kg seed which is enough to produce 2.2 million seedlings with a GW+15%. The crop trees were monitored for damaging insect pests, however levels were so low that control was not required.

120 trees were sprayed with GA_3 in July to induce a crop for 2010.

485 grafts from series 3 to 6 were maintained in holding beds awaiting field test results.

22 ramets with BV<9 were rogued prior to cone harvest, and a further 43 ramets with BV<13 in series 1 and 2 were rogued during the winter.

Western Hemlock

SPU0310 covers activities in Hw M Low orchard 182.

This orchard has been producing small crops since 2002 but has not yet reached full production capacity. Because of the small size of the trees, SMP was carried out on 117 trees to ensure adequate seed set.

All ramets were fertilized and maintained; however, no induction was carried out because of low demand for seed from this SPU.

5.4 kg of seed were collected from this orchard in 2009, which is enough for 954,000 trees with GW 14%.

5.1.4 Saanich Seed Orchard

Carolyn Lohr

Orchard Management Operations to Maintain Productivity and Increase Gain in Orchard 181 SM Fdc (SPU 1902

The objectives of this project are to enhance the seed yield and genetic worth of seedlots produced in orchard 181 by roguing according to progeny test results, utilizing orchard management techniques to optimize growing stock vigour and crop health, and monitor for and apply pest control if necessary.

The project consisted of identifying and roguing 200 backward selection ramets in 2009/2010 as a result of the Fdc breeders progeny test analysis.

A total of 1153 trees in the orchard including both forward and backward selections were managed through appropriate cultural practices. Graft and ID maintenance were conducted. Foliar nutrient samples were taken and analysed, nutrient prescriptions prepared and fertilizer applied. Soil moisture was monitored and irrigation applied as needed. Top pruning and crown management was conducted on all ramets to initiate potential cone producing sites. Graft unions were surveyed.

Crop management included phenological and bud surveys, pollen collection, and SMP on early and late ramets. Production for 2009 was 27.6 hl of cones and 13.659 kg of seed.

Pest surveys were conducted. *Contarinia* levels were low in 2009 requiring no treatment.

Orchard #181, after the initial rogue of the backward selections and addition of the initial forward selections is predicted to produce seedlots at GW 8+ (2010). The increase in gain from this orchard meets one of the main objectives of the FGC.

Plate 13. Transplanted orchard replacement ramets from holding bed.

Plate 14. Transplanted orchard replacement ramets from holding bed.

Upgrade Orchard #175 - Rust Resistance Western White Pine (SPU 0804)

The objective of this project was to upgrade the existing putatively rust resistant white pine ramets at the Ministry of Forests and Range (MFR) Saanich Orchard site with the Pw Breeding Program slow canker growth (SCG) and Difficult to Infect (DI) white pine ramets.

The project consisted of planting out 250 ramets in orchard positions in the fall of 2009. Stock planted consisted of SCG, DI and MGR ramets. These ramets were managed in holding beds prior to being planted out.

Fifty two original ramets from Rich Hunt's putatively rust resistant stock were rogued from the white pine orchard in the spring of 2009.

A total of 495 ramets were in the orchard and holding beds over the growing season. These were managed using appropriate cultural practices. Graft and ID maintenance were conducted, foliar nutrient samples taken and analysed, nutrient prescriptions prepared and fertilizer applied. Soil moisture was monitored and irrigation applied as needed. Crown management was conducted on all appropriate ramets to initiate potential cone producing sites.

Pest surveys were conducted and no control measures were required.

Deliverables from this project are established vigorous orchard stock with slow canker growth (SCG) and Difficult to Infect (DI) rust resistant mechanisms that will produce future seedlots of rust resistant seedlings.

Plate 15. Transplanting Major Gene Resistant (MGR) Western white pine from holding beds to orchard mounds.

Plate 16. Transplanting Major Gene Resistant Western white pine from holding beds to orchard mounds.

Genetic Enhancement and Production of Seed Crops from Second Generation Douglas-fir Seed Orchard #199 (SPU 0114)

The purpose of this project was to improve the genetic quality and the quantity of seed crops produced from second generation Douglas-fir Seed Orchard #199 at the MFR Saanich orchard site through management activities in several project categories.

A total of 1319 ramets in Orchard 199 and 411 high gain replacement ramets in holding beds were managed using appropriate cultural practices over the growing season. Graft and ID maintenance were conducted. Foliar nutrient samples were taken and analysed, nutrient prescriptions prepared and fertilizer applied. Soil moisture was monitored and irrigation applied as needed. Top pruning and crown management was conducted on all ramets to initiate potential cone producing sites. Graft unions were surveyed.

Pollen buds were collected from ramets BV 20 and higher resulting in 2 litres of stored pollen to be used for future pollen application. This pollen has potential to offset the effects of contaminant pollen, provide increased GW of crops produced and increased seed production in early and late clones. Due to transplant related stress, the orchard was not managed for cone production and no supplemental mass pollination applied.

Pest surveys were conducted and no control measures were required.

Deliverables from this project consist of vigorous orchard stock established with potential to maximize production of future crops as well as a moving front orchard with ramets capable of producing crops with genetic worth of 20 or higher by 2010.

Plate 17. Transplanting orchard 199 holding bed to Douglas-fir orchard.

5.1.5 Bowser Seed Orchard

David Reid

Genetic Upgrading and Enhancing Seed Yields and Quality from Second Generation Douglas-fir Orchards

This project was designed to upgrade the genetic composition of Douglas-fir seed through various management activities and to increase the seed yield of the seedlots produced here.

SPU 0110

Clones with breeding values of less than 12 were rogued from both orchards, 201 ramets in total: 157 ramets from orchard #162 and 44 ramets from orchard # 149.

Pollen was collected from clones with a BV of 18 or higher and a mix of fresh and stored pollen with an average BV of 20.8 was applied to orchard 162. Seedlot #63231 yielded 161.85 hectolitres of seed with a GW of 13 and a seed yield of .452kg/hl. Seedlot #62232 yielded 183.5 hectolitres of seed, with a GW of 15 and seed yield of .452kg/hl.

169 suitable candidates (negligible current year's crop; no crop last year; not induced last year; sufficient vigour and adequate number of cone-bearing sites) from orchard #162 and 17 from orchard #149 were induced using irrigation delay and the double overlapping girdle technique.

All orchard trees were maintained through appropriate cultural practices. Foliar nutrient samples were taken; fertilizer was applied for both growing stock and crop maintenance; ID and irrigation systems were maintained and irrigation was applied as required.

Surveys were conducted for *Contarinia*, *Dioryctria* and *Leptoglossus*. No control measures were undertaken for *Contarinia* or *Leptoglossus*.

Plate 18. Headquarters picking crew at Bowser site.

5.1.6 Kalamalka Seed Orchards

Chris Walsh

In 2009/2010, Kalamalka Seed Orchards received OTIP approval for 11 projects under the operational production sub-program. The funding allowed for 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, transplanting the older higher-value ramets to the orchards, and roguing lower-value ramets from the orchards;
- Improving orchard seed quantity and quality through cone induction and pollen management, including collecting high-breeding-value pollen from clone banks and applying Supplemental Mass Pollination; and
- Improving orchard productivity through pest management and other management activities.

Pest management activities included:

- monitoring pest levels to make informed decisions regarding control,
- using Safer's Soap sprays to control adelgids in Sx and Fdi,
- removing weevil-infested spruce leaders to reduce weevil populations,
- removing pine pitch moths damaging orchard tree stems,
- baiting for control of rodents feeding on tree roots,
- sanitation picking of cones in orchards with non-collectible crops to reduce pest populations,
- spraying to control *Dioryctria* in Pw and Fdi cones,
- spraying to control mites in Fdi and Sx,
- applying dormant oil to control larch adelgids, and
- spraying to control *Leptoglossus* in Pw, Fdi and Pli.

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

The OTIP funding was instrumental in increasing both the quantity and quality of seed produced. At Kalamalka in 2009 we produced approximately 430 kg of western larch, lodgepole pine, interior spruce, interior Douglas-fir, and western white pine seed equivalent to over 36 million seedlings with an average GW of +18. Large areas of the interior of the province are using Kalamalka seed.

Project	Species	SPZ	Orchard	Roguing	Grafts Made	Maintained	Transplants	Induction
SPU0401	Sx	NE	305			60	9	199
SPU0502	Sx	NE	306			60	5	179
SPU0701	Pli	NE	347			533		
SPU1302	Lw	NE	332			4	42	
SPU1501	Pw	KQ	335		150	68	78	
SPU1708	Pli	BV	230	196				
SPU2201	Fdi	NE	324					490
SPU3501	Sx	BV	620			27	7	145
Totals				196	150	752	141	1013

Table 3. Orchard Composition Activities by Project.

Project	Species	SPZ	Orchard	Pollen Collected (litres, dry)	Trees Pollinated
SPU0401	Sx	NE	305	2.0	598
SPU0502	Sx	NE	306	2.0	538
SPU0701	Pli	NE	307	3.0	1,556
SPU1501	Pw	KQ	335		1,861
SPU1708	Pli	BV	230	5.0	1,062
SPU2201	Fdi	NE	324	2.0	1,471
SPU3201	Pli	EK	340	3.0	1,314
SPU3501	Sx	BV	620	2.5	434
SPU3901	Fdi	EK	336	1.0	
SPU4401	Sx	NE	341	2.0	400
Totals				22.5	9,234

Table 4. Pollen Management Activities by Project.

5.1.7 Vernon Seed Orchard Company (VSOC)

Dan Gaudet

Projects undertaken have allowed VSOC to continue the quest for the best quality and quantity of seed from each orchard. With the understanding and acceptance of orchard seed by the silviculture foresters and nurseries, the orchardists have a demand that grows each year.

Monitoring for annual pests that limit orchard health and production is required to safeguard our production. As our orchards mature the number of diseases and insects grow annually. To not recognize the threat that comes into each orchard can quickly affect the ramet's health or a cone crop is lost. Spray timing is often the reason control is possible for each pest.

Our projects encompass what seems like the same activities each year but these important items are required for the Forest Genetic Council to reach towards its goal of 75% "Class A" seed use and a genetic worth average of 12%.

Important Activities:

1. Survey to identify flower development and promote the pollen availability and uptake. Supplemental Mass Pollination is required to ensure the proper pollen quantity is available for the early and late flowers. Application of early pollen to late flowers and then the use of late pollen often from the previous year to early flowers allows the pollination of clones that normally are outside each other's timing.

2. Monitoring of pests and disease is a constant. *Adelges cooleyi* in spruce begins the year in late March and later sprays are for *Rhyacionia buoliana* in pine and *Dioryctria abietivorella* in mature fir to protect cone crops. Disease in our orchards is not common but is found from time to time. Weekly monitoring in each orchard is our only means of knowing what we face. Other pest monitoring includes: *Synanthedon sequoiae, Oligonuchus ununguis, Leptoglossus occidentalis*, and *Pissodes strobi*. With early detection we are able to implement the timely spray control or removal to prevent loss of health or crop.

3. Roguing of orchard #214 – Prince George spruce was completed in July. Final preparation for the first planting of our 2nd generation orchard can proceed. All orchard ramet material was chipped and sent to a composting company for their use. Burn piles are not acceptable.

4. Induction is required in Douglas-fir to ensure a cone crop exists the following year. $G/A_{4/7}$ is commonly used on most sites to initiate flowering for the next year.

5. Crown management is required to control height and to initiate new growth in orchards. Pine orchards as they mature require stimulation to renew the ramet's growth and sustain their production potential.

6. Grafting is required to continually renew new ramets in orchards. With our pine struggling in the Okanagan environment we have begun moving our production to our new site in Quesnel. Our Quesnel site is specifically for our pine orchards to move north. Graft replacement has begun for the site with the first planting to begin 2010. When the new site comes into production the orchards in Vernon will be rogued and land used for other orchard development.

7. Spraying for mountain pine beetle protection is required due to populations that exist in our area. The boles of each ramet are sprayed in June and July to protect against an attack.

Many years of seedling demands lie ahead of us as we replant for mountain pine beetle – pine mortality, fires and annual allowable cut (harvesting). With the use of "A Class" seed our goal is to grow healthy productive forests. The increase in productivity with the use of "A Class" seed will help fill the short fall in timber supply earlier to support the use of our forests for recreation and harvesting in future years.

With the use of an Annual FGC Business Plan we are able to focus on the demand as it develops each year. This is an important factor in the success of our orchards.

						Pollen	SMP		Health & Pests	Crown	Holdingbed	
SPU	Project #	Title	Orchard #	Species	KPI	Collected	Treated	Rogue	Monitored	Managed	Grafts	Induction
#12+	1201	Nutrient Analysis	All	All	17	N/A						
#12	1202	Enhancing PG Pine	#222	Pli	3506		3506x3		3506	3285	1000	
#12	1208	Pollination & Pest	#236	Pli	4329	5	4329x3		4329			
#14	1403	Enhancing PG Spruce	#211	Pli	3499			447	3499			
#14	1421	2nd Gen Spruce Holding	#214	Sx	800	N/A			800		800	
#14	1423	Enhancing PG Spruce **Rogue**	#214	Sx	1239	N/A		1239				
#17	1701	Enhancing BV Pine	#219	Pli	5303		5303x3		5303		500	
#17	1706	Enhancing BV Pine	#234	Pli	2930	5	2930x3		2930			
#18	1801	Enhancing Cp Pine	#218	Pli	4143		4143x3		4143		500	
#37	3702	Increasing Seed Production	#226	Fdi	338	5	338x4		338			200
#37	3703	Increasing Seed Production	#232	Fdi	781	5	100x4		781			
#41	4102	Increasing Seed Production	#225	Fdi	338	5	338x4		338			120
#41	4103	Increasing Seed Production	#233	Fdi	775	4	100x4		775			100
#42	4202	Pest management - Spruce	#239	Sx	1017				1017			
#43	4301	Increasing Seed Production	#231	Fdi	962	5	962x4		962			400
4057	E32	MPB - Pest Spray	All Pine	Pli	12952	N/A			12952			

Table 5. Summary of Vernon Seed Orchard Company 2009/10 OTIP Projects.

5.1.8 Grandview Seed Orchards (PRT Armstrong)

Hilary Graham

Projects 0702, 0721, 1001, 1002, 1007, and 2101

PRT Grandview manages five lodgepole pine orchards and one Douglas-fir orchard, producing seed for the Thompson Okanagan (TO) low elevation and the Nelson (NE) low elevation seed planning units. Three of the Pli orchards are mature (308, 311, and 313), and two are young orchards (337 and 338) established in cooperation with SelectSeed Company in 2002. The Fdi orchard was also established in 2002 with older grafts and is nearing maturity.

In 2009/10, projects in each of the orchards received OTIP funding for activities to increase the yield and genetic gain of seed produced. These activities included grafting, holding bed maintenance, planting of grafts, roguing, insect and disease monitoring and control, rodent control, crown management, foliar analyses, pollen monitoring and distribution, pollen collection, flower induction (Fdi only), and supplemental mass pollination (SMP). In addition to the individual orchard projects, two incremental projects were funded.

Pli Orchards

In the spring of 2009, 163 grafts from the holding area were planted out to fill vacant orchard positions. To improve the quality of the older Pli orchards 230 grafts were made in 2009 and maintained in holding beds. Eighty two unproductive ramets were rogued from these three orchards, providing for long-term increase in GW as the vacant positions are filled with higher gain material.

Pollen management activities began in early May with pollen collection, monitoring, and distribution using an orchard air-blast sprayer. The young SelectSeed Pli orchards as well as the early- and late-flowering clones in orchards 311 and 313, received SMP applications. Pollen was collected from orchards 311, 313, and at the Kalamalka Forestry Centre. Shedding pollen was collected with a backpack vacuum by clone. Thanks to Michael Carlson and Chris Walsh for providing access to the Kalamalka clone banks. We collected six litres of pollen for the TO low orchards and three litres of pollen for the NE low orchards.

Foliar tissue samples were taken to determine the appropriate fertilizer mix for spring and fall applications. Throughout the season, we monitored all Pli orchards for insect, rodent, and disease problems. This ensured measures were taken to protect ramet health and developing cones. A single insecticide spray was applied to control *Leptoglossus* seed bug. Poison baits were set out to control rodents feeding on tree roots, and *Sequoia* pitch moths were removed by hand. In the fall of 2009, pruning was done in the larger orchards to open up the crowns, restrict ramet height, and maintain tractor access down the rows.

All projects were completed as planned in 2009/10 season. The 2009 cone harvest yielded seed volumes far in excess of expectations. In the Pli Thompson Okanagan low, we collected 45.5 kg of seed with the potential to produce

9.1 million seedlings. In the Pli Nelson Low, we collected 22.11 kg of seed with the potential to produce 4.4 million seedlings.

Fdi Orchard

Pollen monitoring began at the first flight of pollen in the orchard, indicating a moderate pollen load in the orchard. Because of the limited supply of natural pollen and a large flower crop, we applied stored pollen to receptive flowers four times (SMP). At the same time, pollen for future use was collected at the Kalamalka Forestry Centre, and from ramets within orchard 321 that had a particularly heavy pollen load. Thanks to Barry Jaquish and Valerie Ashley for providing access to the clone bank. Two litres of pollen were collected, processed, and put into freezer storage.

Throughout the season, we monitored the Fdi orchard for insect damage to the developing cone crop. An insecticide spray was applied early in the season to protect the crop from *Dioryctria* (fir coneworm), which has caused substantial damage to previous cone crops. With a well-timed spray and a small population of *Dioryctria* in the Fdi orchard in 2009, we had little to no damage evident at the time of cone harvest.

For crop induction, we applied gibberellic acid (GA) to 600 ramets by stem injection. With the exception of a few unresponsive clones, there is a good correlation with GA application and the appearance of flower buds in 2010.

The 2009 Fdi crop also exceeded targets with 84.1 kg of seed extracted (3.86 million plantables).

Grandview Seed Orchards Incremental Projects Mountain Pine Beetle – Pli Ramet Protection

In 2009 we continued with a proactive approach to the MPB problem, applying prophylactic insecticide sprays in advance of any beetle flights. In addition, MPB pheromone traps were set up around the PRT Armstrong site to monitor the presence and abundance of beetles in the area.

Trap monitoring indicated that the orchards were exposed to moderate populations of beetles during the summer of 2009. However, monitoring of orchard ramets throughout the season showed no MPB attacks on any of the treated orchard ramets. Numerous windbreak and landscape Pli and Py trees on the PRT site which were unprotected by the spray were heavily attacked and killed during this same period. The presence of beetles and absence of damage in the orchards indicates that the single prophylactic spray was again very effective in protecting our orchards.

Crop Statistics

As part of a collaborative project headed by Michael Carlson at the Kalamalka Forestry Centre, ramets were selected and data collected from the three mature orchards at PRT to assess seed orchard seed set and productivity. This data, collected at all interior Pli orchards using a standardized method, will contribute to our understanding of seed-set in the different Okanagan Seed Orchards. This will ultimately lead to recommendations for orchard management practices that will improve seed production.

The activities conducted in 2009/10 with the assistance of OTIP funding continue to move us 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.

Plate 19. MPB protective bole spray application.

Plate 20. Rodent control at PRT.

Plate 21. PRT Cone harvest crew 2009.

5.1.9 Eagle Rock Seed Orchards (Tolko Industries)

Greg Pieper

The Forest Genetics Council of B.C. 's Operational Tree Improvement Program supplied funding for several projects at Tolko's Eagle Rock Seed Orchards.

SPU 28-30 Orchard 342 - 343 Sx TO Low and Sx TO high

* Pollen previously stored was tested, rehydrated and applied to all receptive flowers using spritzers.

* Gibberillic acid (GA) was applied through stems injections using repeating syringes to 489 ramets to boost flower production in these orchards. GA was applied only to healthy ramets that didn't receive induction in 2008.

* Pest monitoring was carried out on a weekly basis for *Leptoglossus*, *Dioryctria* and adelgids. Adelgid populations were insufficent to require control. *Leptoglossus* and *Dioryctria* populations were also low, not requiring control.

* Non insect pests - pocket gophers were controlled using Gopher Getter Bait in the spring.

* Foliar samples were collected and sent to Pacific Soil lab for analysis.

* This was the first year crops in these two young SelectSeed orchards were realized. We collected 14 hectolitres of cones for 11 kgs of seed from 342 and 22 hectolitres for 20 kgs of seed from 343. There are 454 trees in 342 SelectSeed low elevation and 1054 trees in 343 high elevation orchard.

SPU 16 Orchards 310 (Tolko)and 339 (SelectSeed) TO High Lodgepole Pine

* 200 ramets of low breeding value and some of poor health were rogued from orchard 310 in August. We hired a faller to cut down the ramets and then hired an operator with an excavator to remove and load all debris into bins. The bins were hauled to Tolko's Cogen plant to dipose of as well as contribute to power production.

* Pollen previously stored was tested, rehydrated and applied to all receptive flowers using spritzers. A helicopter was used to distribute pollen that existed in both orchard 339 and orchard 310 for pollination in both orchards.

* Insects were monitored and only one spray was required in 2009 to control leptoglossus. *Dioryctria* and *Sequoia* pitch moths were removed by hand in orchard 339 and done on budget. It was a very light year for insects.

* Non insect pests such as pocket gophers were controlled using Gopher Getter Bait in the spring. Needlecast was not an issue in 2009.

* Foliar samples were collected and sent to Pacific Soil lab for analysis.

* 32 hectolitres of cones for 11.5 kgs from orchard 339 and 6 hectalitres for 2 kgs of seed from orchard 310.

* There are 3500 ramets in orchard 339 and 400 ramets remaining in orchard 310.

Project 4057E39 SPU16 Orchards 310 (Tolko) and 339 (SelectSeed)

* All ramets in orchard 310 and orchard 339 were bole sprayed with 2% Sevin to prevent attack from Mountain Pine Beetle. We had no attacks to date.

* Phermone traps were placed in four location (2 traps per location) around the orchard's perimeter. Insects were monitored throughout the growing season. Mountain Pine Beetle populations decreased significantly from the year previous.

Plate 22 . 2009 SelectSeed Sx Orchard.

Plate 23. Pollination application 2009.

Plate 24. Cone Collection Crew 2009.

Plate 25. Pollination by helicopter 2009 SelectSeed Orchard 339.

Plate 26. Pollination Pli 2009 by helicopter.

5.1.10 Prince George Tree Improvement Station (PGTIS)

Rita Wagner

SPU 1203, 1802, 1702, 4057E34

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).

Five Operational Tree Improvement Projects were conducted at the Prince George Tree Improvement Station in 2009-2010.

Phenology surveys were completed to keep track of receptivity periods which can vary considerably from year to year. As well, extremely late flowering clones received SMP. Pollen flights were monitored. Outside pine pollen flight is basically non-existent due to the devastation caused by the mountain pine beetle.

October foliar samples were taken for nutrient analyses. Fertilizer applications were increased ensuring maximum ramet health.

Branch damage caused by pesticide equipment, hydraulic lifts, heavy and wet snow, and strong winds required extensive tree maintenance.

Surveys for western gall rust, *Lophodermella* needle cast and root collar weevil and various other insects were completed. The Sevin application caused a significant decrease in root collar weevil activity. Root collar weevil activity usually increases dramatically in the wake of mountain pine beetle flights.

Detailed weekly tree by tree bark beetle surveys were carried out to pinpoint the correct date for pesticide application. Lindgren traps were set up throughout the site to monitor MPB flights. As in 2008, mountain pine beetle presence in the Prince George area continued to decrease in 2009. However, secondary bark beetle build up (*Ips*, *Pityogenes*, *Pityophthorus*) prior to and after the local mountain pine beetle flights necessitated the application of Sevin XLR. Some red turpentine beetles were caught in our beetle traps but so far there is not cause for concern. Adjustments to our custom-made, tractor-mounted application equipment enabled better targeting of the Sevin application.

Despite the two large cone crops in 2007 and 2008, all three orchards produced another good crop in 2009. The three provenance orchards yielded 37.66 kg of seed, the equivalent of approx. 7.84 million potential seedlings with a genetic worth of 6%.

Some squirrel trapping was required to avoid seed loss and loss of potential cone sites.

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 BC. 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.

Continued with maintenance of 250 grafts planted in 2008. Retagged 300 ramets.

70 grafts shipped from Kalamalka were heeled in over the winter for spring 2010 planting.

A wet spring resulted in extra rototilling and weed brushing in the holding area.

To ensure good ramet health the following management activities were carried out in the 12,000-tree clone banks: inventories, irrigation maintenance, fertilization, mowing and weeding/brushing, label replacement and foliar sampling. Extensive headland mowing was necessary to control weeds and prevent brush from moving in. Insect (root collar weevil and spruce leader weevil) and disease monitoring was carried out to keep abreast of potential pest problems. Updated clonebank data base.

5.1.11 Skimikin Seed Orchards

Keith Cox

Summary for Projects 404, 411, 501, 1503, 3502, 4002, and 4057E13.

Work was funded in eight of the seed orchards, the research plantations, and to help monitor and control the Mountain Pine Beetle infestation at Skimikin in 2009.

Nelson Mid and High Sx (404 & 501)

The West Kootenay (Nelson mid and high elevation) spruce orchards had 207 replacement grafts maintained in the holding area, and 11 were transplanted into orchard 301. The orchards were surveyed for insects and disease, six rust brooms (*Chrysomyxa Arctostaphyli*), and 19 weevil (*Pissodes strobi*) attacked tops were removed, rodents were baited, and the orchards were sprayed with *Btk* for spruce budworm.

Kamloops-Quesnel Pw (1503)

The white pine orchard (#609) was monitored extensively because of the mountain pine beetle and the pine cone moth, resulting in 52 trap counts being done over the season, plus many visual surveys. The orchard was sprayed with Sevin XLR in late May for the mountain pine beetle using two orchard lifts fitted with spray units. No trees were attacked.

Bulkley Valley Low Sx (3502)

In the three spruce orchards for the Bulkley Valley low the crop was sprayed for spruce cone maggot and spruce cone rust. Another 302 replacement grafts were made, 517 grafts were maintained in the holding area, and eight were transplanted into orchard 208. The crop was 41.8 hectolitres and yielded 58.769 kilograms of seed.

On August 21, 2009, the day the crop collection was complete, a wildfire started approximately five kilometers north-west of Skimikin on a dry, rocky, south-facing slope covered with mountain pine beetle killed lodgepole pine.

The fire remained at one to two hectares throughout the day as it was assessed and then dropped on by air tankers and a helicopter. At 3:30 pm a hot, searing wind from the SW fanned the fire and it quickly spread up the hillside out of control. It took approximately ten days for crews to contain the fire as it spread NE over the mountain and threatened the Notch Hill and Turtle Valley areas. We were on evacuation alert during that time and spent three tense days in smoke so thick that it was impossible to see what the fire was doing. All of our mobile equipment was moved into an open field and the cone crop and some key equipment were moved to Kalamalka.

Peace River Mid Sx (4002)

In the spruce orchard for the Peace River mid elevation zone (#212) the 2793 trees were monitored for insects, disease, and rodents. The orchard was sprayed with *Btk* for spruce budworm. A total of 21 weevil damaged tops were removed and the young orchard was baited extensively for rodents.

Research Plantations (411)

The on-site research plantations were also monitored for insects and disease and baited for rodents. The youngest spruce plantation was sprayed for rust mites. More white pine seedlings were planted for blister rust resistance screening. The *Ribes* garden was maintained and white pine seedlings were inoculated in September. The beginnings of the white pine Age Related Resistance Trial (ARRT) was planted in space made available in the new holding area, where grafts had been removed to establish the new white pine seed orchard (#351). The sites where plantations were removed in 2008 were cultivated and reseeded. A Douglas-fir and two lodgepole pine plantations were removed in the fall. Some of the larger trees were shipped to the Salmon River for riparian restoration work.

Mountain Pine Beetle (4057E13)

Extensive monitoring was done for the mountain pine beetle and orchards 345 (Py) and 609 (Pw) were sprayed with Sevin XLR in late May. The beetle traps were checked twice a week and the trap counts peaked in early June (June 2 - 300) and again in July (July 14 – 210). This was down considerably from 2007 when many of the trap counts were in the 1000s.

5.1.12 Kettle River Seed Orchard Company (KRSO)

Rick Hansinger

Pollination And Pest Management in Central Plateau Orchard 238 – Lodgepole Pine (SPU 1804)

Objectives

• Collect and store 3.0 litres of pollen for SMP in young Pli Orchard 238 to increase the production of Class A seed to 500,000 plantables by summer 2010.
• Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Results

• 2100 ml of pollen was vacuum collected in the Pli CP low orchard which was cleaned, dried and stored for application spring 2010. Genetic Worth G+21 class A. Approximately 1,900 ml of pollen was applied to 2,000 ramets during the receptivity period from May 29 to June 1. Sources of pollen were VSOC, Kalamalka and Kettle River. Three passes were completed. Remaining late pollen was air blasted with the turbo fan sprayer.
• Developing cones were inspected for the presence of *Leptoglossus* and the risk to the seed crop was deemed negligible, pesticides were not applied.

Output and Deliverables

• 11.3 hl of cones were collected which will later yield a total output of 208,000 potential trees.

Pollination and Pest Management in Prince George Orchard 237 – Lodgepole Pine (SPU 1210)

Objectives

• Collect and store 2.5 litres of pollen for SMP in young Pli Orchard 237 to increase the production of Class A seed to 500,000 plantables by summer 2010.
• Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Results

• 2550 ml of pollen was vacuum collected in the Pli PG low orchard which was cleaned, dried and stored for application spring 2010.Genetic Worth G+16.7 class A. Approximately 2,200 ml of pollen was applied to 2,500 ramets during the receptivity period from May 28 to June 3. Sources of pollen were VSOC, Kalamalka and Kettle River. Three passes were completed. Remaining late pollen was air blasted with the turbo fan sprayer.
• Developing cones were inspected for the presence of *Leptoglossus* and the risk to the seed crop was deemed negligible, pesticides were not applied.

Output and Deliverables

• 8.25 hl of cones were collected yielding a total of 919 grams of seed, 227 seeds/gr. Future potential trees - 129.4 K.

5.1.13 Sorrento Seed Orchards OTIP 1707, 1803 and 4057E37

Hilary Graham

Sorrento Seed Orchard manages two large lodgepole pine orchards established in 2003 in partnership with SelectSeed Company. These orchards supply seed for the Central Plateau (CP) low elevation and the Bulkley Valley (BV) low elevation seed planning units. The first cone crops were harvested in 2007.

In 2009/10 OTIP funding was approved to maximize potential seed yield through pollen application (SMP), pollen collection, and protecting the crops from insect damage. Also, with the orchard ramets increasing in size and susceptibility to attack from the Mountain Pine Beetle (MPB), an incremental project for MPB monitoring and protective spraying was approved.

These young orchards produce very little pollen and SMP is required for adequate fertilization. For the CP orchard, pollen was purchased from the Vernon Seed Orchard Company (VSOC) where a mature CP orchard is established. Pollen was collected for the BV orchard at VSOC, and the Kalamalka Forestry Centre (KFC). This pollen was applied four times to all receptive flowers during the pollination period. Thanks to the staff at VSOC and KFC for providing the pollen we required.

Monitoring for cone and seed pests was done weekly from mid-May to September to determine the need and timing for control measures. *Leptoglossus* seed bug was not observed until the time of cone harvest, and spraying was therefore not necessary.

Cones harvested in the BV orchard yielded 340,000 plantables in 2009. In the CP orchard, the 2009 harvest yielded approximately 196,000 plantables.

Mountain Pine Beetle (MPB)

In late May a protective insecticidal bole spray was applied to approximately 500 susceptible ramets in the two Pli orchards. MPB pheromone traps were set up and monitored for the season, indicating a small population of beetles in the area around the orchards. Orchard ramets were monitored throughout the season for any sign of MPB attack, and no ramets were affected.

Early seed production in these young orchards, and their protection from MPB attack directly supports the FGC's goals by making more genetically improved seed available for use in BC's forests.

Plate 27. Pollinating the CP orchard at Sorrento.

5.2 Technical Support Programs

5.2.1 Increasing Quality, Genetic Gain, and Quantity of Yellow-cedar Cuttings

Mark Griffin, John Ogg, Craig Ferguson and John Russell

SPU 1113

Introduction

This project involves increasing the quantity and quality of high-value yellow-cedar cuttings for the coastal program. Objectives include:

1. provide the cultural treatments required to improve hedge production,
2. enhance hedge composition by replacing lower-genetic-value families and clones with newly tested, improved clones.

Highlights

Pruning of greenhouse hedges occurred in May/June 2009. The media for the greenhouse-grown container-planted donor plants contained APEX 16-5-11 (in its second year of release), augmented bi-weekly with applications of hi-sol.

In the autumn of 2009 there were 7401 donor plants in the operational hedge. Analysis of the 12 year field measurements was undertaken on series II material and based on field performance, 4158 cuttings were set from the best performing clones for the renewal of the operational hedge. No roguing was done this year in the main production greenhouse. Roguing was deferred until 2010. Based on field performance data collected in 2007 the best 33 clones from series I were set as cuttings in fall 2008 to renew the operational hedge. Five additional clones from series III were also set at this time. By 2009, these clones needed to be transplanted but due to funding restrictions, they were not potted up, they were transplanted into 615 styroblocks. Next year, 3000 of these trees are scheduled to be potted up and be moved into the main production hedge.

In an effort to increase the rooting success of the clones in the hedge, some 3976 cuttings were set to test hedge rootability. A sampling of every clone from series 1&2&3 in the greenhouse was set to test each clone's propensity to root.

Clones will be evaluated and poor performing clones may be removed from production. Clones are being evaluated annually on an ongoing basis.

Production from the operational hedge, during the winter of 2010, some 50,000 cuttings were supplied to various nurseries for a BC Timber Sales (BCTS) sponsored yellow cedar cutting trial and some 4000 cuttings were supplied to Cairnpark for a North Island operational setting.

Plate 28. Series I cuttings ready to be potted to bulk up the operational hedge.

Plate 29. Series II cuttings set in 2009, scheduled to renew the operational hedge in 2011.

5.2.2 Estimating Pollen Contamination in Coastal Seed Orchards

Joe Webber

SPU 0113

Estimates of contamination in Douglas-fir (2009) and western redcedar (2010) orchards were determined by the procedures described by Woods et al. (1996) and were among the highest recorded. For Douglas-fir, contamination in Western Forest Products (WFP 166) and TimberWest (TW 183) orchards was 45.8 and 34.0%, respectively. For western redcedar, contamination in the two orchards (WFP 198 and TW 140) was 70% in 2009 and above 90% in 2010.

Table 6 shows the Douglas-fir contamination level from regional and orchard pollen loads for 2008 and 2009. Table 7 shows similar data for 2005-09. For 2005 to 2007, contamination levels were also estimated from DNA paternity analyses.

While there is good agreement between estimates of contamination from pollen monitoring and DNA paternity analysis at low levels of contamination (<20%), we expect the error associated with the estimate to be higher at higher levels of pollen load. To determine if pollen monitoring can provide useful estimates of contamination at higher levels, the 2009 Douglas-fir crops from both WFP and TW will be analyzed using the more robust DNA paternity analyses by Dr. Yousry El-Kassaby, UBC. These results will be available in 2011.

Western redcedar pollen contamination is large. Table 8 shows the contamination levels for both 2009 and 2010. Contamination values in 2009 were in the order of 70% and in 2010 the values exceeded 90%. It was the higher regional values and not lower orchard values that resulted in the high 2010 contamination values. There has not been any attempt to estimate contamination in western redcedar with DNA paternity analyses. Pollen monitoring can provide estimates of the levels of contamination in western redcedar orchards but there will be more uncertainty about its actual level at higher pollen load values.

We do not know the effect of contamination in western redcedar orchards. We assume contamination is negative but is it important? The breeding value of Saanich peninsula soil-based redcedar orchards is about 10%. If we assume a contamination level of 80% and its breeding value is 0%, then the GW of the seed lot would be reduced to 6% (5% female - 5%x0.8 males). Furthermore, the high levels of contamination in western redcedar orchards will reduce selfing which does have a negative effect on GW. What the actual effect of western redcedar contamination has on GW is uncertain. However, with such high levels of contamination, continued monitoring of contamination is warranted.

Woods, J.H., M.U. Stoehr, and J.E. Webber. 1996. Protocols for rating seed orchard seed lots in British Columbia. Ministry of Forests, Research Program, Res. Report 06. 26pp.

	2008		2009	
	WFP-166	TW-183	WFP-166	TW-183
REG PL	7.3	3.2	39.1	23.0
ORCH PL	48.9	28.6	85.4	67.8
%Contamination	14.9	11.2	45.8	34.0

Table 6. Estimates of Douglas-fir contamination from regional (REG) and orchard (ORCH) pollen loads (PL) for each of two orchards (WFP-166 and TW-183 in each of two years (2008 and 2009).

Douglas-fir Orchard Receptivity Pollen Load (7-day Monitors) and %Contamination (grains/mm^2)

	WFP					TW	
	2005	2006	2007	2008	2009	2008	2009
REG PL	4.6	6.7	24.6	7.3	39.1	3.2	23.0
ORCH PL	96.3	54.6	114.6	48.9	85.4	28.6	67.8
%Cont							
PM	4.8	12.5	21.5	14.9	45.8	11.2	34.0
DNA	9.7	11.7	19.3	na	na	na	na

Table 7. Estimates of Douglas-fir contamination (%Cont) from regional (REG) and orchard (ORCH) pollen loads (PL) for each of two orchards (WFP-166; 2005-2009 and TW-183; 2008-09). Contamination estimates from DNA paternity analyses are also shown where available.

	2009		2010	
	WFP-198	TW-140	WFP-198	TW-140
REG PL	84.3	51.0	109.1	109.1
ORCH PL	116.7	73.0	118.4	90.2
%Cont	72.2	69.8	92.1	100

Table 8. Estimates of western redcedar pollen contamination (%Cont) from regional (REG) and orchard (ORCH) pollen load (PL) data for each of two orchards (WFP-198 and TW-140) in each of two years (2009 and 2010).for 2009 and 2010.

5.2.3 Crown Pruning Technique for North Okanagan Lodgepole Pine Seed Orchards

Chris Walsh
Prepared by Joe Webber

Project SPU 0720

A top and lateral pruning trial was started in 2004 using the MFR Bulkley Valley lodgepole pine seed orchard 230 at Kalamalka. Tree height was about 4.5 meters and the crown shape was more of a ball from previous crown pruning. The three topping treatments were a control (Con), moderate topping to 3.5-.40 m (Mod) and a severe topping to 2.5-3.0 m (Sev) heights. Two lateral pruning treatments were used to facilitate both cone harvest (Pick) and tractor (Tract) access. All extending branches were pruned back for tractor access (Tract) and a second treatment removed interior branches to open the crown (light) and make cone picker (Pick) access easier.

Two years after topping, cone numbers and seed yields equaled or exceeded those from the untopped trees. Moderate topping with Pick lateral pruning produced more cones and seed yields, a trend that continued through to 2009.

Cone data for 2004-2006 were ocular estimates (with higher error) but cone numbers for 2007-09 were estimated by whole tree cone weights. Figure 9 shows the mean number of cones per tree for each of the three topping levels and Figure 10 shows the same data for each of the two lateral pruning treatments by topping level. While cone numbers in the topped trees were about equal to the control trees, lateral pruning of interior branches (Pick) on moderately topped trees (Mod) consistently produced higher cone numbers.

Seed yields also showed higher numbers for the top pruned trees. Figures 11 and 12 show the mean seed yields (filled seed per cone) by topping level (Figure 11) and by lateral pruning treatment within each of the three topping levels (Figure 12). Two years after pruning (2006), seed yields were highest in the two top pruned treatments (Figure 11) and remain highest until the end of the trial in 2009. There was no clear treatment effect of lateral pruning on seed yields (Figure 12). The trend for total seed per cone (data not shown) was similar.

To illustrate the effect of crown pruning in lodgepole pine seed production, we used the mean cone and seed numbers by top and lateral pruned blocks totaled over the three years (2007-2009). Cone numbers from 2005 and 2006 were not used because they were ocular estimates only. Figures 13 and 14 show the mean number of filled seed per tree (2007-2009) for each of the three top pruned blocks (Figure 13) and two lateral pruned blocks (Figure 14). This data clearly shows that moderate topped trees produce the highest seed yields and the picker pruned trees produced more seed than the lateral pruned trees across all three top pruned blocks. It appears that, the within crown pruning in the moderately topped trees produces the highest seed yields four (2008) and five (2009) years after pruning, likely a response to higher crown vigour in these trees.

Mean seed production per tree from the moderately pruned trees compared to the control trees over the period of 2007 to 2009, was 58,000 and 45,000, respectively. For the same period, mean seed production from picker pruned trees was 48,600, 63,400 and 54,900, respectively from control, moderate and severe pruned trees. The corresponding mean number of seed per tree from tractor pruned trees was 41,200, 52,600 and 48,100, respectively. If we just compare picker and tractor pruning in the moderate pruned block, picker trees produced about 11,000 more seed per tree. Clearly, top pruning in orchard 230 produced more seed than not top pruning. We attribute this increase to crown re-invigoration from pruning and can recommend moderate topping of trees every three to five years.

The trial also measured cone dry weights, cone and seed yields by crown height and the effect of protecting cones with insect bags.

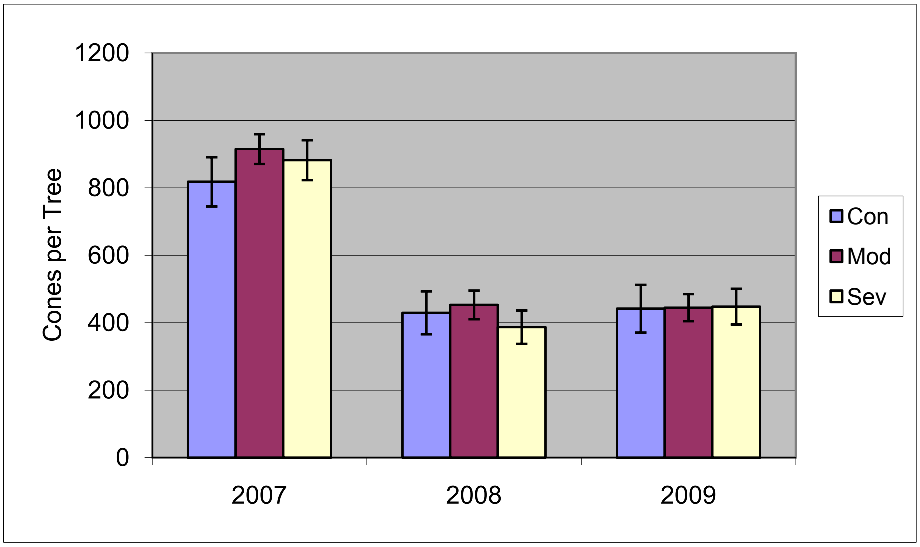


Figure 9. Mean (±standard error) whole tree seed-cone counts (calculated by whole tree cone weights) for each of the three topping treatments: Control (Con), Moderate (Mod) and Severe (Sev): 2007 – 2009.

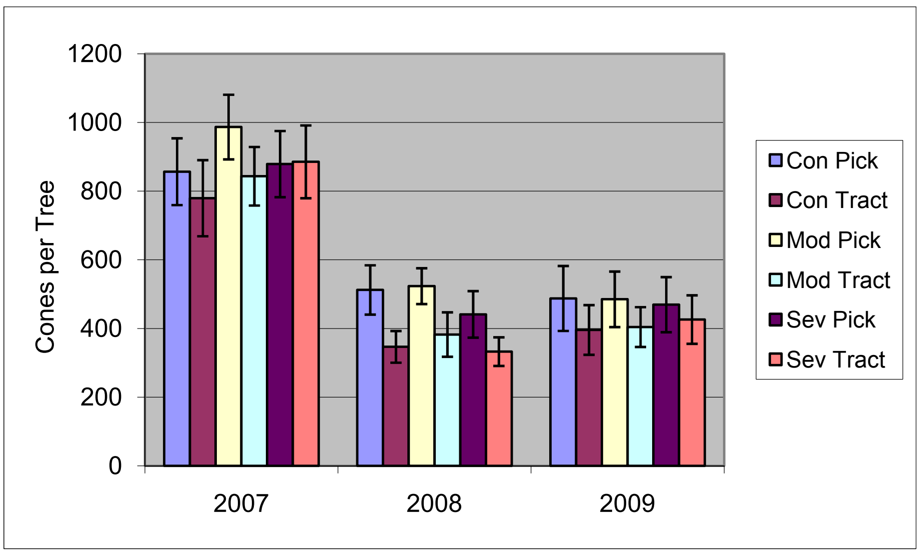


Figure 10. Mean (±standard error) whole tree seed-cone counts (calculated by whole tree cone weights) for each of the three topping (Con, Mod and Sev) and two lateral pruning treatments (Pick and Tract): 2007 – 2009.

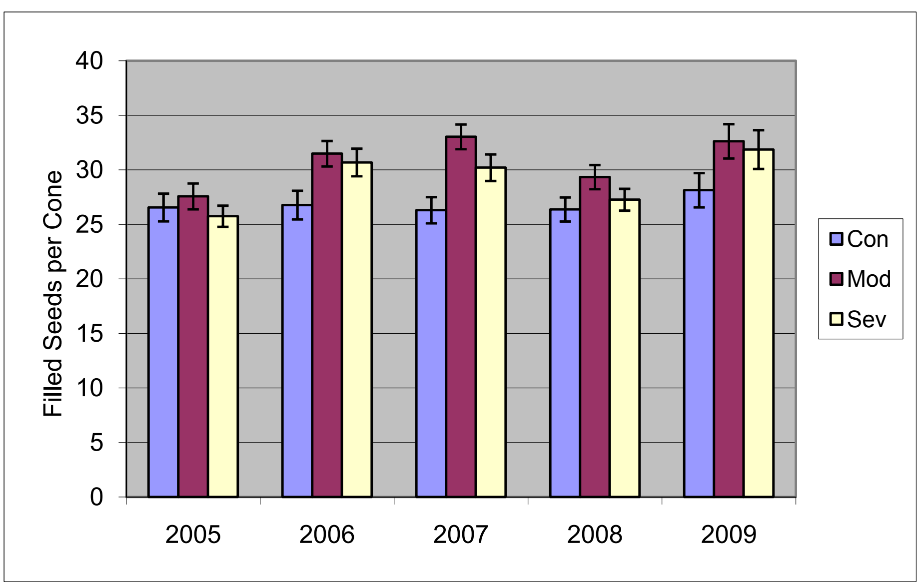


Figure 11. Mean (+/-standard errors) filled seeds per cone (FSPC) for each of the three topped blocks (Con, Mod, Sev): 2005-2009.

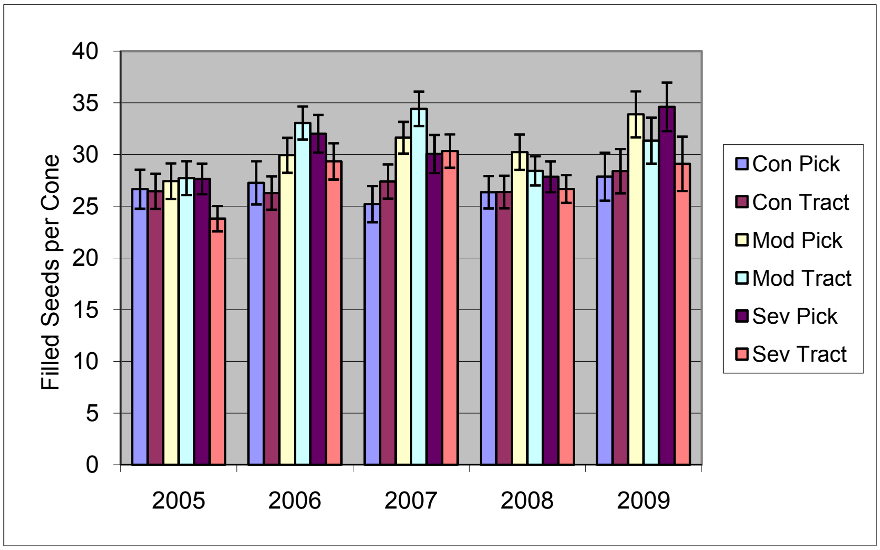


Figure 12. Mean (+/-standard errors) filled seeds per cone (FSPC) for each of the three topped (Con, Mod, Sev) and two lateral pruned (Pick, Tract) blocks: 2005 – 2009.

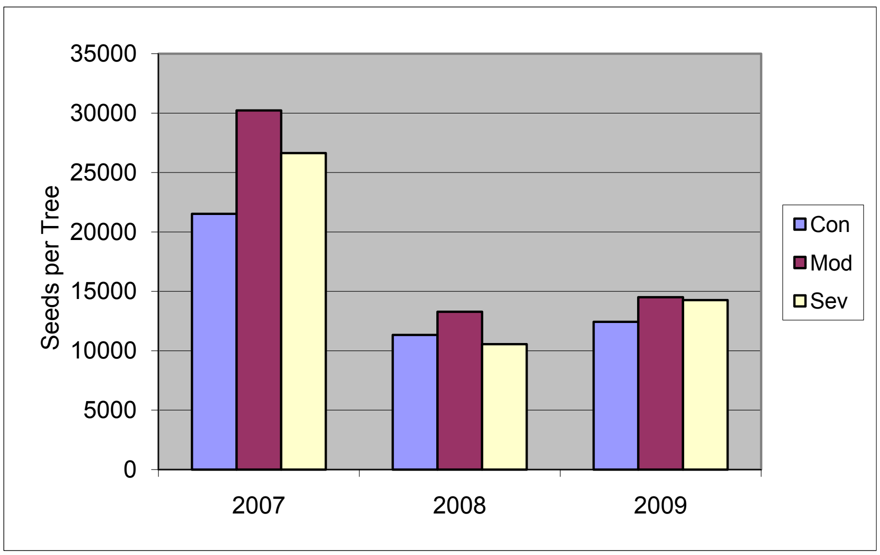


Figure 13. Mean filled seeds per tree for each of the three topped blocks (Con, Mod, Sev): 2007 – 2009.

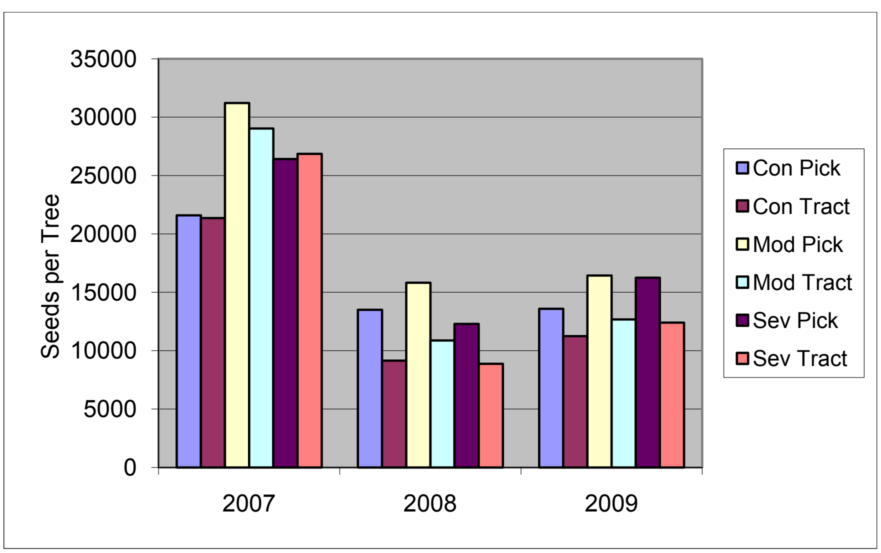


Figure 14. Mean filled seeds per tree for each of the three top pruned (Con, Mod, Sev) and two lateral pruned blocks (Pick, Tract): 2007 – 2009.

5.2.4 Collection of Crop Statistics for Interior Lodgepole Pine Orchards.

OTIP 0722 2009/10

Prepared for Michael Carlson by Joe Webber

Seed yields (filled seeds per cone) from north Okanagan orchards (NO) have not met expectations compared with seed yields routinely realized at Prince George (PG). This report summarizes the 2009 data collected for eight NO and three PG lodgepole pine seed orchards and provides a summary of annual statistics for cone and seed yields for the period 2006 to 2009.

Figure 15 shows the mean number of cones per tree. Cone numbers were down from previous years across all NO orchards and were about the same as those produced from PG orchards (especially if KAL 230 was excluded).

The trend for higher seed yields per cone but fewer cones at PG continued in 2009 (Figure 16). The mean filled seeds per cone (FSPC) for PG was 29.5 (±1.2) compared to the mean value across all NO orchards of 14.3 (±0.68), a difference of 15 FSPC between the two locations. Of note is the seed production from PRT. Excluding KAL 230, FSPC and total seed per cone (TSPC) are highest for all NO orchards and in particular, PRT 311 had similar yields to those observed in KAL 230.

However, even with more cone production from NO orchards the low seed yields per cone made overall production (seeds per ramet) from PG better. The mean number of seeds per ramet between NO and PG was 4384 (±422) and 5349 (±598), respectively. If NO orchard 230 were excluded, the difference between NO and PG would be greater than 1000 seeds per tree. Although standard errors are shown, they are not strictly comparable because sample size (N) for NO was 120 and for PG 45.

The mean TSPC for NO (KAL 230 data included) and PG was 21 (±0.81) and 35 (±1.4), respectively (Figure 17). The difference in 14 TSPC between NO and PG is important. We can account for some of the difference from insect-bag effects but there still remains about 10-12 TSPC that are lost in NO cones.

Insect bagged cones from 2009 produced about 2 FSPC (Figure 18) and 2 TSPC (Figure 19) more than unbagged cones, Over the four years observation, the loss of seed from unbagged cones ranged from about 2 to 5 filled seeds per cone with greatest losses occurring at Kalamalka and Tolko. There was no seed loss from unbagged cones at PG. We have consistently attributed the difference in bagged and unbagged yields to insect predation (*Leptoglossus*). While concern has been raised that this difference is not an insect effect, there is no other compelling reason being offered to explain the differences observed. Since insect predation does occur, it then becomes a discussion of magnitude. We do not suggest that low seed set from NO orchards is solely caused by insect predation but it is an important factor.

We continue to see about 10-15 fewer seeds per cone from NO orchards compared to PG orchards. If bagging effect accounts for about 4 seed per cone, we still cannot account for about 5-10 fewer seed per cone from NO orchards. We know the total seed potential (number of fully developed seed coats) in lodgepole pine is 30-40 and the number of actual seeds produced is about 20-25 (based on PG results).

Cone size may provide a clue. PG cone dry weights are about 2-3 grams heavier than NO cones (Figure 20). It is difficult to compare cone yields as a function of cone dry weight because we expect cone dry weight to vary by orchard seed planning units (SPU). In 2006 and 2009, we were able to compare three Prince George orchards (220-PG, 223-CP and 228-BV) with three VSOC orchards from the same provenance source (222-PG, 218-CP and 219-BV). Yields per cone mass were about double for PG orchards while cone mass alone from VSOC orchards was about 25% less than PG orchards. It appears from this data that the cone dry weight alone does not account for seed yield differences between PG and NO.

The steady rise in seed yields from PRT orchards is encouraging. While cone numbers have remained about the same over the four years, cone dry weight, and FSPC have risen steadily and remain the highest of all north Okanagan orchards (excluding KAL 230).

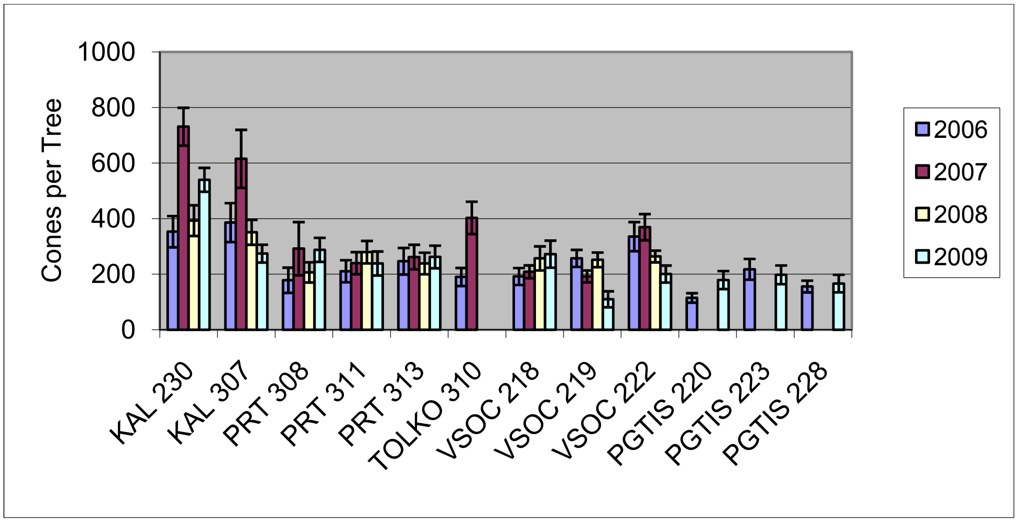


Figure 15. Mean (±standard error) total number of cones per ramet from each of five orchard sites and twelve lodgepole pine seed orchards: 2006 – 2009.

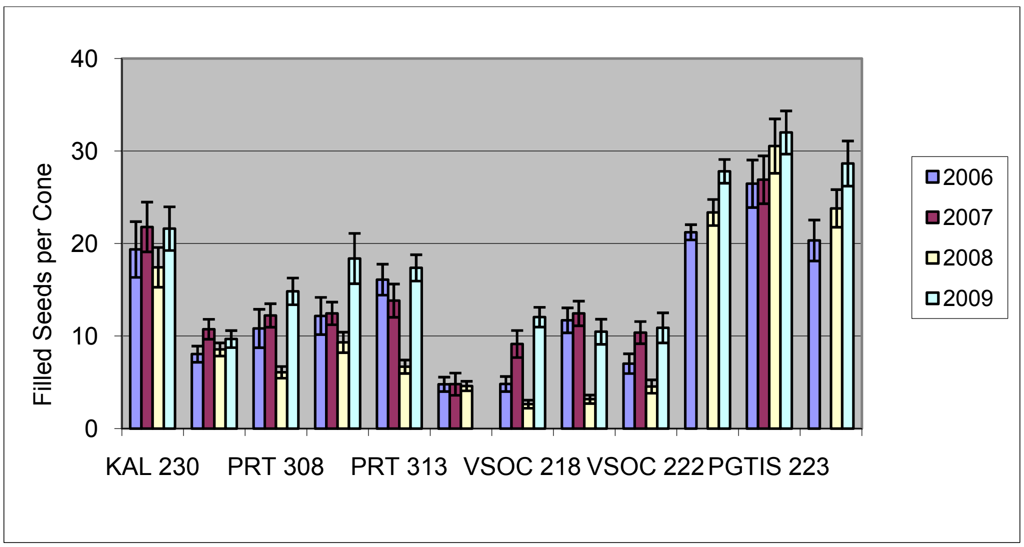


Figure 16. Mean (±standard errors) filled seeds per cone (FSPC) for each of five sites and twelve orchards: 2006 - 2009.

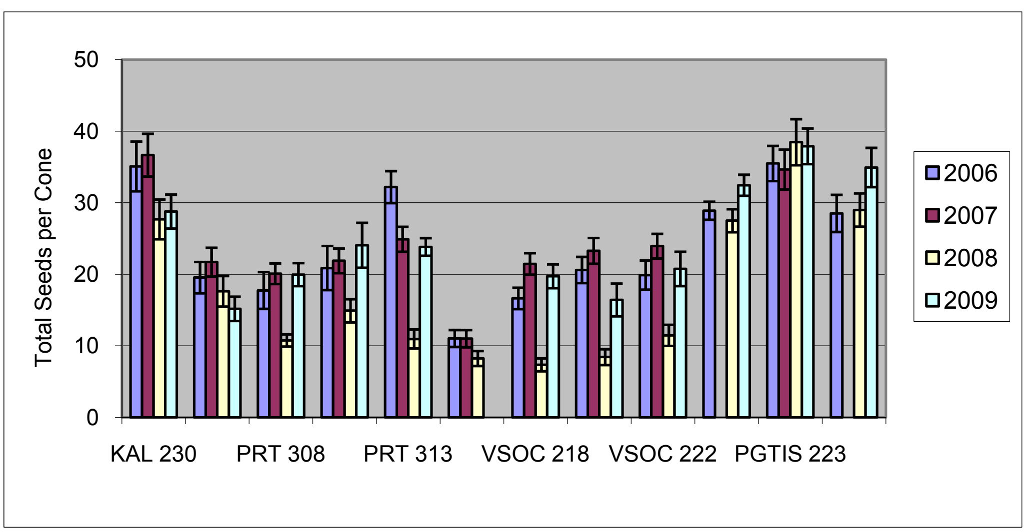


Figure 17. Mean (±standard errors) total seeds per cone (TSPC) for each of five sites and 12 orchards: 2006 - 2009.

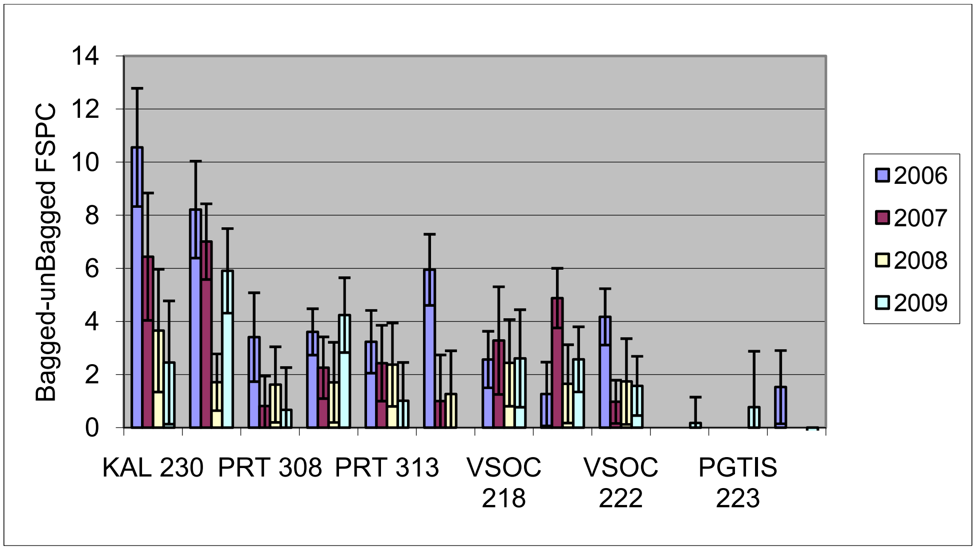


Figure 18. Mean difference (±standard errors) of filled seeds per cone (FSPC) between insect-bagged cones and unbagged cones from North Okanagan and Prince George orchard sites: 2006 - 2009.

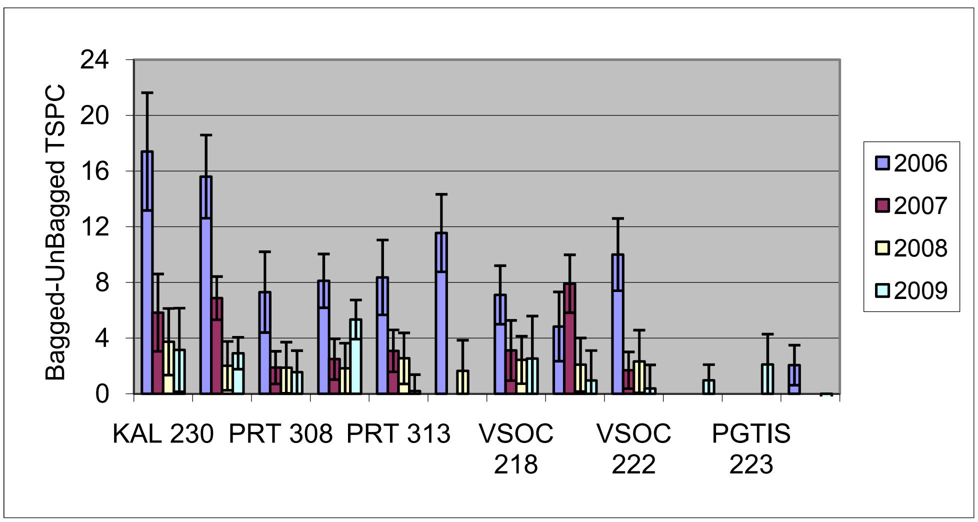


Figure 19. Mean difference (±standard errors) of total seeds per cone (TSPC) between insect-bagged cones and unbagged cones from North Okanagan and Prince George orchard sites: 2006 - 2009.

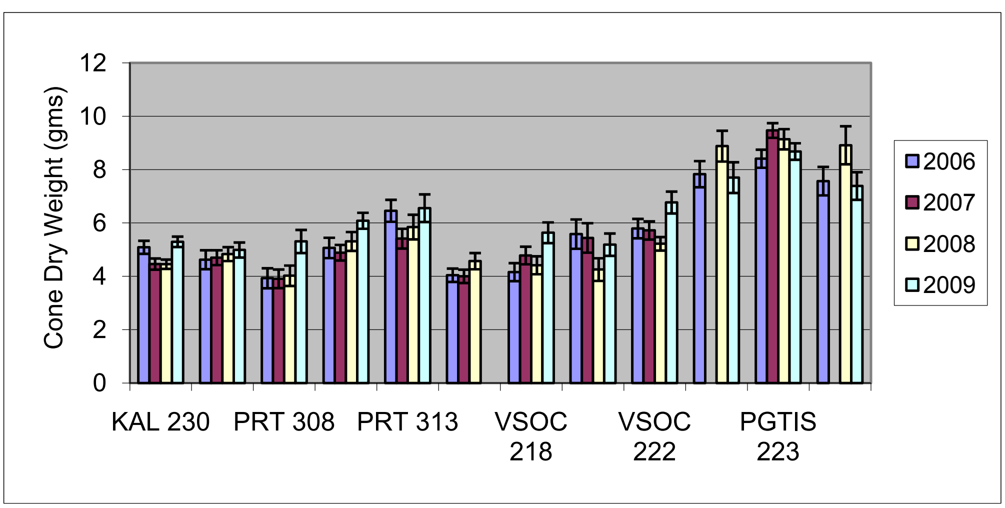


Figure 20. Mean cone dry weight (±standard errors) for each of the five sites and twelve orchards: 2006 - 2009.

5.3 Mountain Pine Beetle Incremental Projects

5.3.1 Protecting Orchard Trees from Mountain Pine Beetle (MPB) Attack

Gary Giampa

Objectives

To protect 4793 pine trees in three seed orchards from MPB attack and preserve seed production capacity. We will also protect 151 Pli pollen donors in the Research Branch blocks. This is a total of 4944 trees.

Activities

In consultation with the Interior Seed Orchard Pest Management Biologist, we applied insecticide to tree stems in seed orchards 230, 307 and 335 as well as the pollen donors prior to the 2009 MPB flight. An Integrated Pest Management monitoring program was initiated to continuously evaluate the efficacy of the pre-flight spray through the growing season. The monitoring program consisted of twice-weekly checks of pheromone traps to detect new flights of beetles dispersing into the orchards and regular orchard tours to detect new attacks on orchard trees.

Results

Monitoring data indicated that all mature Interior pine seed orchards were exposed to potentially harmful population levels of MPB in the summer of 2009. The prophylactic spray provided almost total protection. We did not lose any of the 4944 susceptible trees to MPB in 2009 (several unprotected windbreak trees were attacked, however).

Output and Deliverables

Results from the 2009 MPB protection program give us a very strong indication that seed orchard pine trees can be protected from MPB attack. While protection programs in Interior seed orchards probably will need to be carried out at most locations for the next 3-10 years, we are confident that the sources of seed needed to replant the pine forests of the province can be preserved until the ultimate collapse of the MPB populations around BC.

6.0 Extension and Communications

6.1 ETAC Activities

Diane Douglas

Workshops and Meetings

Support was provided for the Whitebark Pine Ecosystem Nelson meeting September 10-11, 2009. 48 people attended from BC, AB, Co, Mt, Id, NY and Yukon. In April, 2009, two Pest Management workshops for Seed Orchards were held. An interior Seed Orchard Pest Management workshop "Living in a Degree-Day World" was led by Jim Corrigan at Kalamalka Seed Orchards. Dr. Robb Bennett and Jim Corrigan held a Pest Management Coastal field day at Saanich Seed Orchards, "Front-line Pest Monitoring - Techniques and Rationale and Growing Degree Days".

A Coastal History Tree Improvement and Forest Genetics session was held at Cowichan Lake Research Station, September 16, 2009 with 35 attending. An afternoon tour was followed by a BBQ and evening session of stories.

Plate 30. Coastal History session afternoon field tour.

Presentations

Laura Gray, University of Alberta made a presentation on "Matching Planting Stock with Environments for Reforestation Under Climate Change".

Publications and Displays

The spruce manual "Developing Sitka spruce populations for resistance to the white pine weevil" summary of research and breeding program" was published. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr050.htm

The Forest Genetics Council had three conference display units developed on Value, Resilience and Conservation. http://www.fgcouncil.bc.ca/display.html

Plate 31. Forest Genetics Council conference-display panels, Value, Resilience and Conservation.

Plate 32. Coastal History attendees. Back row: Jack Woods, Web Binion, Jim Challenger, Brian McCutcheon, Ev van Eerden, Jenji Konishi, Keith Illingworth, Ingemar Karlsson, Chris Heaman, Cai Hermansen. Front row: Don McMullin, Dick Kosick, Harry Pillar, Don Carson.

7.0 Seed Orchard Pest Management

Robb Bennett

The Seed Pest Management Subprogram supports research, extension activities, and pest management operations to increase orchard yields of high quality seed. Ministry of Forests and Range (MFR) Research Branch scientist Dr. Ward Strong leads the research component. MFR Tree Improvement Branch personnel (Jim Corrigan) delivers extension services. Seed orchard personnel handle operational activities. The Pest Management Technical Advisory Committee (PMTAC) guides investments and activities and is comprised of members from MFR Research and Tree Improvement Branches, the Canadian Forest Service, private seed orchards, universities, and the Forest Genetics Council.

Research plans and budgets are established through an annual process of proposal development and discussions by the PMTAC. In the 2009-10 fiscal year, the PMTAC administered projects on conifer seed bug, fir coneworm, *Fusarium* fungi, Douglas-fir cone gall midge, systemic pesticides, a cone and seed insect field guide, lab and technical research support, as well as interior cone and seed pest management extension operations (previously administered through the OTIP subprogram). Projects are summarized below.

Project	**Species primarily impacted**	**Progress**
Conifer seed bug (*Leptoglossus occidentalis*): Host-finding mechanisms	All Pinaceae	Capitalized on our earlier findings with Simon Fraser University (SFU) that seed bugs use infrared wavelengths to detect cones. The first year of this new study concentrated on clonal infrared (IR) expression, effects on seed bugs of specific visible light wavelengths, and usage of IR and visible wavelengths as seed bug attractants.
Conifer seed bug (*Leptoglossus occidentalis*): Mark/release/recapture	All Pinaceae	Capitalized on several years of in-house study, 2 years of work with University of Northern BC and University of BC-Okanagan, and the recent results of the *Leptoglossus* infrared detection study (see above). The third year of this study focussed on immigration patterns and population dynamics, mechanisms of clonal preference, efficiency of visual monitoring, and orchard recolonization after pesticide spraying. A population dynamics computer simulation model was developed to help address these questions.
Fir coneworm (*Dioryctria abietivorella*): Reproductive biology	Fd, Sx, Lw, Pw	Capitalized on our long-term efforts towards understanding the complex life cycle and biology of this very important pest. The third year of this work with the University of Alberta focussed on aspects of mating behaviour, adult longevity, and effects of mating status on longevity.
Contarinia oregonensis pheromone development	Fd	Capitalized on 1990s Douglas-fir cone gall midge research at SFU and resulted in a simplified synthesis procedure for production of the midge's pheromone preparatory to new research on the management of this major pest.
Research lab and technical support	All species	Funding was provided for on-going lab operations and technical assistance in support of research activities.
Cone & seed insect control: Systemic insecticide injection trials	All species	The pesticides trials study (Crop Health Adv. & Res., Pest Management Regulatory Agency) is a continuation of an on-going project addressing high priority research initially funded in 2005/06. 2009/10 work focussed on foliar tests of new insecticide chemistries.
Cone and seed insect field guide	All species	Draft fact sheets for 13 high priority insects were prepared.
Interior pest management extension operations	All interior species	Funding provided on-going extension support to Interior seed orchards and natural stand seed production personnel: site visits, pest surveys/identification, damage predictions/assessments, pest status reports, development of management protocols, organization of mountain pine beetle management, day-degree data capture and analysis, professional presentations, input to professional groups, production of TIC*talk* extension articles.

Table 9. Seed Orchard Pest Management Projects.

Plate 33. Adult *Dioryctria abietivorelia* moth. (photo by Ward Strong).

Plate 35. Seed orchardists examine a seed orchard tree killed by red turpentine beetle. (photo by Ward Strong).

Plate 34. Tamara Richardson checks a spruce tree for a marked *Leptoglossus*. (photo by Ward Strong).

Plate 36. Adult red turpentine beetle (*Dendroctonus valens*). (photo by Ward Strong).

Publications

Strong, W. B. and R. G. Bennett. 2010. Sample plan for *Adelges cooleyi* (Hemiptera: Adelgidae) in spruce seed orchards. The Canadian Entomologist, 142(2):14-23.

Takács, S., K. Hardin, G. Gries, W. Strong, and R. G. Bennett. 2008. Vibratory communication signal produced by male western conifer seed bugs (Hemiptera: Coreidae). The Canadian Entomologist, 140(2):174-183.

Takács, S., H. Bottomley, I. Andreller, T. Zaradnik, J. Schwarz, R. G. Bennett, W. Strong, and G. Gries. 2009. Infrared radiation from hot cones on cool conifers attracts seed-feeding insects. Proceedings of the Royal Society B, 276:649-655.

Appendix 1 FGC Seed Planning Unit

#	Species	Common name	SPZ	Elev. band (m)	Project Category
1	Fdc	Douglas-fir	M	1-900	1
2	Cw	Western redcedar	M	1-700	1
3	Hw	Western hemlock	M	1-600	2
4	Sx	Interior spruce	NE	1000-1700	1
5	Sx	Interior spruce	NE	1700-2100	2
6	Ss	Sitka spruce	M	1-500	2
7	Pli	Lodgepole pine	NE	700-1600	1
8	Pw	Western white pine	M/SM	1-1000	1
9	Ba	Amabilis fir	M	1-1000	3
10	Pli	Lodgepole pine	TO	700-1400	1
11	Yc	Yellow-cedar	M	1-1100	2
12	Pli	Lodgepole pine	PG	700-1400	1
13	Lw	Western larch	NE	700-1600	1
14	Sx	Interior spruce	PG	600-1400	1
15	Pw	Western white pine	KQ	500-1400	1
16	Pli	Lodgepole pine	TO	1400-1600	2
17	Pli	Lodgepole pine	BV	700-1400	1
18	Pli	Lodgepole pine	CP	700-1300	1
19	Fdc	Douglas-fir	SM	200-1000	2
20	Pli	Lodgepole pine	NE	1600-2000	2
21	Fdi	Douglas-fir	NE	400-1200	1
22	Fdi	Douglas-fir	NE	1000-1800	2
23	Sx/Ss	Spruce	SM/NST	all	2
24	Hw	Western hemlock	M	600-1100	2
25	Sx	Interior spruce	EK	750-1900	2
26	Pli	Lodgepole pine	PG	1400-2000	3
27	Cw	Western redcedar	SM	200-1000	2
28	Sx	Interior spruce	TO	1300-2100	2
29	Pli	Lodgepole pine	EK	1500-2000	2
30	Sx	Interior spruce	TO	700-1500	1
31	Fdc	Douglas-fir	M	900-1200	2
32	Pli	Lodgepole pine	EK	800-1500	2
33	Cw	Western redcedar	M	700-1500	2
34	Lw	Western larch	EK	800-1700	1
35	Sx	Interior spruce	BV	500-1400	2
36	Bg	Grand fir	M	1-700	3
37	Fdi	Douglas-fir	QL	700-1400	2
38	Hw	Western hemlock	M north	1-600 (part of SPU 3)	
39	Fdi	Douglas-fir	EK	700-1400	2
40	Sx	Interior spruce	PR	<650 & 650-1200	2
41	Fdi	Douglas-fir	PG	700-1200	2
42	Sx	Interior spruce	PG	1200-1550	2
43	Fdi	Douglas-fir	CT	600-1400	2
44	Sx	Interior spruce	NE	1-1000	1
45	Pli	Lodgepole pine	BB/CHL	All	3
46	Bl	Sub-alpine fir	all int.	all	3
47	Bn	Noble fir	M	all	3
48	Aspen/birch/poplar		Interior	-	3
49	Alder/poplar/maple		Coast	-	3
50	Lw	Western larch	NE	1200-1800	2
51	Py	Ponderosa pine	S. Interior	300-1200	2

Appendix 2 Tree Species

CONIFERS	LATIN NAME	TREE SPECIES CODES
amabilis fir	*Abies amabilis*	Ba
grand fir	*Abies grandis*	Bg
noble fir	*Abies procera*	Bp
subalpine fir	*Abies lasiocarpa*	Bl
yellow-cedar	*Chamaecyparis nootkatensis*	Yc
Rocky Mountain juniper	*Juniperus scopulorum*	Jr
alpine (subalpine) larch	*Larix lyallii*	La
western larch	*Larix occidentalis*	Lw
Engelmann spruce	*Picea engelmannii*	Se
white spruce	*Picea glauca*	Sw
spruce hybrid (interior spruce)	*Picea* cross (Se and Sw mixtures)	Sx
Sitka spruce	*Picea sitchensis*	Ss
Sitka x unknown hybrid	*Picea sitchensis x*	Sxs
whitebark pine	*Pinus albicaulis*	Pa
lodgepole pine	*Pinus contorta*	Pl
shore pine	*Pinus contorta* var. *contorta*	Plc
interior lodgepole pine	*Pinus contorta* var. *latifolia*	Pli
limber pine	*Pinus flexilis*	Pf
western white pine	*Pinus monticola*	Pw
Ponderosa pine	*Pinus ponderosa*	Py
coastal Douglas-fir	*Pseudotsuga menziesii*	Fdc
interior Douglas-fir	*Pseudotsuga menziesii* var. *glauca*	Fdi
western (Pacific) yew	*Taxus brevifolia*	Tw
western redcedar	*Thuja plicata*	Cw
mountain hemlock	*Tsuga mertensiana*	Hm
western hemlock	*Tsuga heterophylla*	Hw

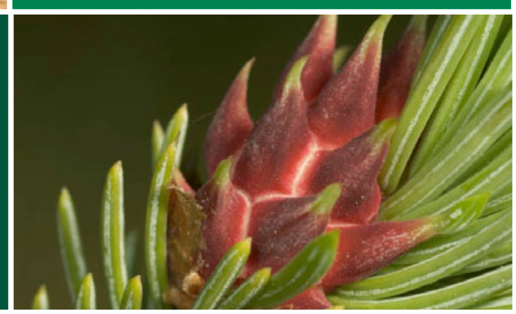
HARDWOODS		
red alder	*Alnus rubra*	Dr
black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	Act
hybrid poplars	*Populus* spp.	Ax
trembling aspen	*Populus tremuloides*	At
Garry oak	*Quercus garryana*	Qg

Appendix 3 Author Contact List

CONTRIBUTOR	AFFILIATION	TELEPHONE NUMBER
Aitken, Sally	UBC	604-822-6020
Ashbee, Doug	MFR	
Ashley, Valerie	MFR	250-260-4753
Bennett, Robb	MFR	250-652-6593
Berger, Vicky	MFR	250-260-4767
Bird, Keith	MFR	250-749-6811
Brown, Patti	CanFor	604-885-5905
Carlson, Michael	MFR	250-260-4767
Cartwright, Charlie	MFR	250-387-6477
Charleson, Lee	MFR	250-387-4839
Cox, Keith	MFR	250-835-8626
Douglas, Diane	MFR	250-356-6721
Ferguson, Craig	MFR	50-749-6811
Gaudet, Dan	VSOC	250-542-0833
Giampa, Gary	MFR	250-549-5576
Graham, Hilary	PRT/Sorrento	250-546-6713
Griffin, Mark	MFR	250-749-6811
Hansinger, Rick	Kettle River SO	250-446-2771
Hayton, Lisa	MFR	250-387-5443
Hooge, Bonnie	MFR	250-963-8416
Jaquish, Barry	MFR	250-260-4766
Krakowski, Jodie	MFR	250-749-6811
Kolotelo, Dave	MFR	604-541-1683
Lohr, Carolyn	MFR	250-652-5600
Mehl, Helga	MFR	
Ogg, John	MFR	250-749-6811
O'Neill, Greg	MFR	250-260-4776
Phillips, Giselle	MFR	250 260 4756
Pieper, Greg	Tolko	250-546-2272
Reid, David	MFR	250-652-5600
Russell, John	MFR	250-749-6811
Stoehr, Michael	MFR	250-356-6209
Strong, Ward	MFR	250-260-4763
Ukrainetz, Nick	MFR	250-260-4761
van Niejenhuis, Annette	WFP	250-652-4023
Wagner, Rita	MFR	250-963-8416
Walsh, Chris	MFR	250-260-4777
Webber, Joe	ProSeed Consulting	250-537-8871
Wigmore, Bevin	TimberWest	250-652-4211
Wood, Darrell	MFR	250-356-1127
Woods, Jack	SelectSeed	604-734-5778

2009/10

Forest Genetics Council of BC
Tree Improvement Program
Project Report



BRITISH COLUMBIA
Ministry of Forests and Range

FGC Forest Genetics Council of British Columbia