



2008/2009

Forest Genetics Council of BC

Tree Improvement Program Project Report

2008/2009

Forest Genetics Council of BC

Tree Improvement Program Project Report

Diane Douglas, Jack Woods and Keith Thomas

Acknowledgements

The Forest Genetic Conservation and Management Program is now in its twelfth year and 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 not an 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 Forest Genetics Council has set up a new Seed Transfer Technical Advisory Committee that is identifying priorities for climate-based seed transfer research, structuring a program for delivery of this research, and providing oversight over 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 Forest Investment Council.

This publication, in conjunction with the FGC Business Plan and FGC Annual Report, meets the reporting obligations of Council and the FIA Forest Genetic Conservation and Management Program. It provides a project-level overview of our efforts and highlights our successes. Sincere thanks to the Project Leaders for submitting their contributions, and to Diane Douglas for her work in compiling the report. A very special thanks to the reviewers Darrell Wood and Roger Painter. Acknowledgments also 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 twelve years, including Council members, review committees, species committees, various TACs and all the project leaders.

Keith Thomas
Tree Improvement Co-ordinator
Forest Genetics Council

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, B. C. V8W 9C2

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 Branch	http://www.for.gov.bc.ca/hre/forgen/index.htm

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 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 used. The FGC Business Plan defines the annual set of 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.

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.

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, grow the grafted trees in orchards where they can inter-pollinate, and collect 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 Ltd.)
- Extension and Communication
- Genecology and Seed Transfer
- Genetic Resource Decision Support
- Seed Orchard Pest Management

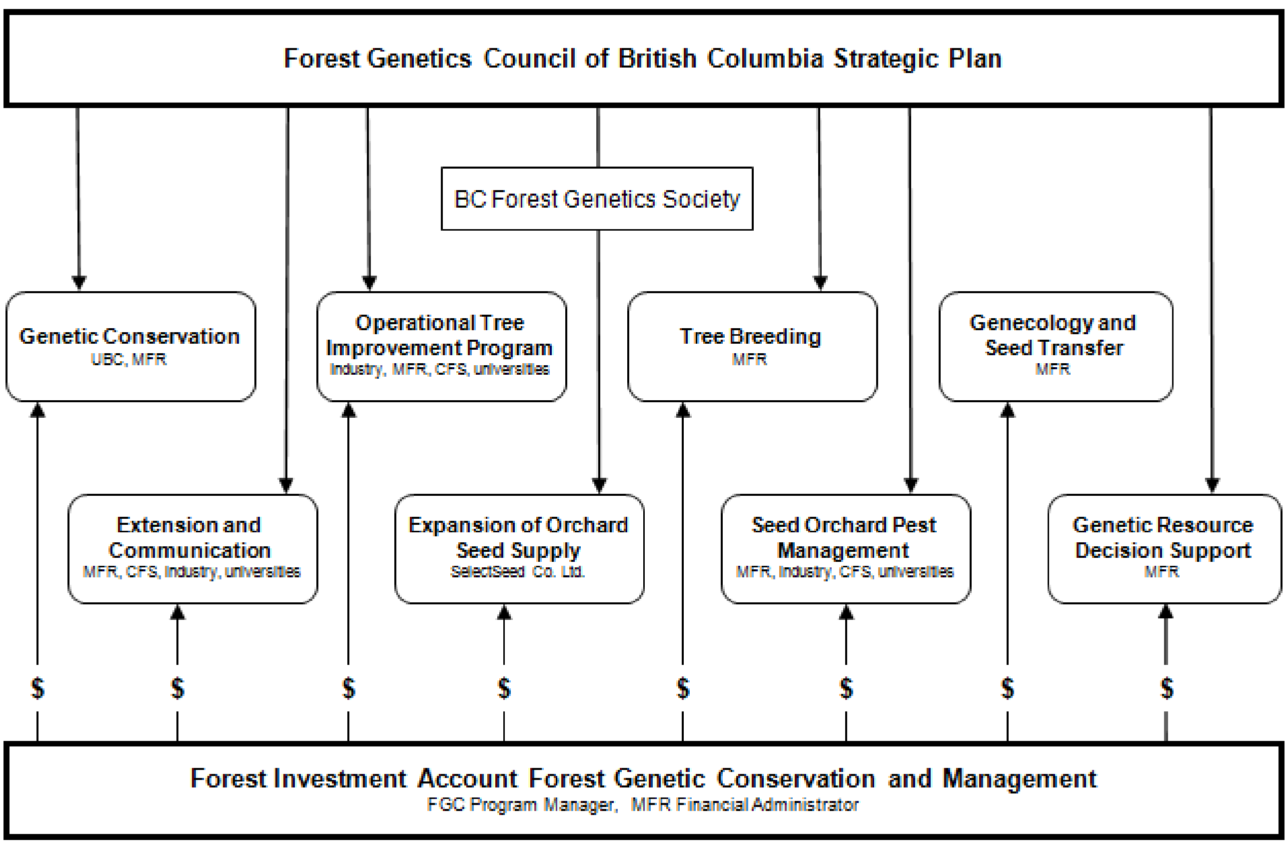


Figure 1. Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest genetic resource management areas.

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 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, 2009, SelectSeed orchards had a modest cone and seed production year. Harvest from nine lodgepole pine orchards totaled 74 hectoliters (hl) of cones, yielding 8.5 kilograms (kg) of seed. The SelectSeed-owned proportion of this harvest was 51 hl and 6.3 kg. The Douglas-fir Nelson low-elevation seed orchard operated in partnership with Pacific Regeneration Technologies Ltd yielded 7.9 hl and 1.8 kg, of which the SelectSeed-owned portion was 5.1 hl and 1.2 kg. These yields were below Business Plan forecasts due to poor filled seed numbers for lodgepole pine and an unseasonable frost that killed most of the emerging cones in the Douglas-fir orchard. Four other young orchards (two Douglas-fir and two interior spruce) did not produce manageable crops. Supplemental pollination was carried out in all lodgepole pine orchards, and in the Nelson low Douglas-fir orchard. Lodgepole pine first-year cones that will form the 2009 crop are substantially higher than the 2008 crop. Seed orchards and crops for 2008 are summarized in Table 1.

FGC Program Management

Program management activities carried out during the fiscal year on behalf of the FGC included writing and publishing the FGC Annual Report for 2007/08; organizing committee work and preparation of the 2009/10 FGC Business Plan and species plans; policy, committee, issue management and reporting; updating species plans; and coordinating FGC activities. During the reporting period, significant effort was put towards implementation of a genecology review and development of the Seed Transfer Technical Advisory Committee, in addition to providing support for, and leadership on, discussions pertaining to private sector participation in seed orchards.

Plate 1. Tolko May 07, 91 Interior spruce orchard supplying seed for the Thompson Okanagan high elevation zone and operated by Tolko Ltd. in partnership with SelectSeed Ltd.

Orchard #	Spp.	Seed zone	Planned # ramets	Total 2007 crop (kg)	Orchard company	Location
321	Fdi	NE low	2,187	8.5	PRT	Armstrong - Grandview
232	Fdi	QL	776	0	VSOC	Vernon
233	Fdi	PG	786	0	VSOC	Vernon
343	Sx	TO high	1,056	0	Tolko	Armstrong - Eaglerock
342	Sx	TO low	454	0	Tolko	Armstrong - Eaglerock
337	Pli	NE low	1,000	1.7	PRT	Armstrong - Grandview
338	Pli	TO low	4,796	2.6	PRT	Armstrong - Grandview
237	Pli	PG low	4,884	0.2	KRSO	Kettle Valley
236	Pli	PG low	4,500	0.4	VSOC	Vernon
339	Pli	TO high	3,508	2.6	Tolko	Armstrong - Eaglerock
234	Pli	BV low	3,000	0.7	VSOC	Vernon
240	Pli	BV low	3,100	0.1	Sorrento	Sorrento
241	Pli	CP low	2,000	0.1	Sorrento	Sorrento
238	Pli	CP low	3,100	0.2	KRSO	Kettle Valley
Totals			35,147	10.2		

PRT - Pacific Regeneration Technologies Ltd.; VSOC - Vernon Seed Orchard Co. Ltd.; KRSO - Kettle River Seed Orchard Co. Ltd.; Sorrento - Sorrento Nurseries Ltd.; Tolko - Tolko Industries Ltd.

Table 1. Summary of SelectSeed orchards and 2008 crops.

Plate 2. Aug 07, Douglas-fir Nelson low elevation seed orchard operated in partnership between SelectSeed Ltd. and Pacific Regeneration Technologies Ltd. (photo J. Woods)

2.0 Genetic Conservation Technical Advisory Committee

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. A significant gain in resourcing was realized this year through the re-allocation of a significant proportion of Jodie Krakowski's time to genetic conservation initiatives.

These areas are elaborated on below, separately for activities during the 2008/9 fiscal year.

2.1 Centre for Forest Conservation Genetics (CFCG)

Sally Aitken, University of British Columbia

The Centre for Forest Conservation Genetics (CFCG) http://www.genetics.forestry.ubc.ca/cfcg/ has now been in existence for over eight years. During that time period, with support through the Forest Genetics Council from Forest Renewal BC, and subsequently from the Forest Investment Account, we have evaluated the conservation status of all 50 or so of BC's native tree species, undertaken specific conservation genetics projects on nine of these species, supported research for five completed graduate degrees (three PhD, two MSc) with five more in progress, and CFCG have published over 30 scientific papers. More importantly, the CFCG has generated, compiled, analyzed and made available detailed information on current and predicted future distributions of tree species and patterns of genetic diversity within species; developed tools including ClimateBC; and developed strategies relevant for operational genetic conservation in BC. These accomplishments would not have been possible without the support of the Genetic Conservation Subprogram of the FGC and a high level of collaboration and cooperation with the BCMFR, as well as support from Natural Sciences & Engineering Research Council of Canada (NSERC) - Industry Research Chair, Discovery, Strategic and Postdoctoral Fellowship programs, forest companies supporting the NSERC Industry Chair in Population Genetics, Genome Canada and Genome BC, UBC (University Graduate Fellowships), and the Ministry of Forests and Range (assorted programs). We thank all of our collaborators, supporters, and GCTAC advisors for their assistance.

Conservation Genetics

In the 2008-09 fiscal year we completed two projects. The cataloguing of *in situ* conservation status of indigenous tree species (Report 1, Chourmouzis et al.) is now complete and a MFR technical report that compiles the status of all species in all biogeoclimatic zones is in the final stages of external review for publication in the next month or so. The second cataloguing report on the genetic conservation status of operational tree species, has also been completed (Report 2, Krakowski et al.) as the result of effective collaboration among the MFR's Research Branch, Tree Improvement Branch, and the CFCG. The population genetics project characterizing genetic structure and the lack of genetic diversity in Pacific dogwood was also completed for the MSc thesis of Karolyn Keir. The study investigating the genecology of Garry oak based on seedling common garden results is nearing completion and Colin Huebert will defend his thesis in 2009. Research continues to progress well on whether whitebark pine can survive and grow north of its current range limits both in the field and in the lab, and 2009 will be the final year of data collection for Sierra Curtis-McLane's project. This is one of several projects investigating the responses of populations of several species to controlled climatic conditions, and Pia Smets continues to develop and refine testing methodologies in this area.

Genetics and Climate Change

Tongli Wang continues to improve and revise predictions from climatic envelope modeling of species and ecosystem climatic niches, and is also developing a new approach to define climate-based seed transfer units in the province. ClimateBC continues to be a workhorse for a wide range of research and operational applications that require estimates of current or predictions of future climates, both for forestry research and in BC more generally, and Tongli continues to update and improve this publicly available toolkit. Finally, the CFCG continues to obtain provincial and federal funding external to the Forest Genetics Council Genetic Conservation Subprogram, and these funds leverage FGC-based contributions significantly.

Publications 2008-09

Aitken, S.N., S. Yeaman, J.A. Holliday, T. Wang, and S. Curtis-McLane. 2008. Adaptation, migration or extirpation: Climate change outcomes for tree populations. Evolutionary Applications 1: 95-111.

Bower, A.D. and S.N. Aitken. 2008. Genetic Diversity and Geographic Differentiation in Quantitative Traits, and Seed Transfer Guidelines for *Pinus albicaulis* (Pinaceae). Am. J. Bot. 95: 6676.

Holliday, J.A., R.S. White, J. Bohlmann, and S.N. Aitken. 2008. Global monitoring of gene expression during autumn cold acclimation among rangewide populations of Sitka spruce [*Picea sitchensis* (Bong.) Carr.] New Phytologist. doi:10.1111/j.1469-8137.2007.02346.x

Mbogga, M., A. Hamann, and T. Wang. 2009. Historical and projected climate data for natural resource management in western Canada. Agricultural and Forest Meteorology. In press.

O'Neill, G., A. Hamann, and T. Wang. 2008. Accounting for population variation improves estimates of climate change impacts on species' growth and distribution. Journal of Applied Ecology. In press.

Ukrainetz, N. K., K.Y. Kang, S.N. Aitken, M. Stoehr, and S.D. Mansfield. 2008. Heritability, phenotypic and genetic correlations of coastal Douglas-fir (*Pseudotsuga menziesii*) wood quality traits. Can. J. For. Res. 38: 1536-1546.

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

2.2 Research Branch, Conservation Activities

Jodie Krakowski, Research Branch, MFR

Research Branch has been finalizing a technical report prepared jointly with the Forest Genetics Council and UBC Centre for Forest Conservation Genetics on the *in situ* protection status of all (50) BC native tree species. Various database and spatial analyses were used to estimate species distributions and protected areas by biogeoclimatic (BEC) unit and to determine whether a threshold long-term sustainable population level of at least 5000 mature trees in at least 3 protected areas in each BEC zone were conserved. This population estimate has been determined as sufficient to protect the long-term adaptive and evolutionary potential in a population of trees with life history and biological characteristics typical for BC. This calculation was repeated to estimate protection levels over various population size thresholds which would provide a more accurate picture of gaps in protection, and could also accommodate species that have varying distribution patterns. This was calculated for current conditions and estimated impacts of climate change (based on projections of species distributions in 2055). Potential changes in species protection levels were calculated.

As a complement to this *in situ* conservation project we have also done an analysis incorporating our work with *inter situ* and *ex situ* genetic conservation for commercial tree species in BC. This entailed re-analyzing the same *in situ* data set by SPU (seed planning unit) and determining whether threshold conservation needs were being met by protected areas for each species within each SPU. We also did the same analysis evaluating our *ex situ* seed collections that are housed securely in the Tree Seed Centre in Surrey, which represents a key repository for our seed inventory and germplasm collections. A selected set of our long-term genetic research trials, such as provenance studies, were prioritized as *inter situ* genetic conservation installations. These represent collections of genetic material of known, local origin (within each SPU) that are well-adapted to the site and fulfill an intermediate role between *in situ* (natural populations in parks) and *ex situ* (collections stored off site) genetic conservation, and provide valuable long-term data on adaptation and other traits of interest. This analysis also helped identify gaps in terms of our management needs for commercially important species - there were 9 species evaluated in the report.

We are also planning for the next round of analyses since the current ones used data sets for forest and botanical inventory and protected areas that have significant new data available. Upcoming analyses will focus particularly on area/species combinations identified as having gaps to determine whether those gaps have since been filled with the addition of new protected areas, or improvement of species distribution mapping based on newer data. This will also allow us to prioritize species and areas for ground-truthing. This will represent the first study to conduct field verification of species protection levels. Two species with different distribution patterns that have identified conservation gaps across several coastal and interior BEC zones will be selected for ground-truthing to evaluate the effectiveness of the methods in achieving our objectives.

The summary of the *in situ* evaluation is published as MFR Technical Report 53 and the summary of the conservation genetic status of commercial BC species is published as MFR Technical Report 54.

Publications 2008-09

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, Res.Br., Victoria, B.C. Technical Report 053. http://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 BC Min. For. Range, Res. Victoria, B.C. Technical Report 054. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr054.htm

2.3 *Ex Situ* Collections

Dave Kolotelo, Tree Seed Centre, TIB, MFR

The GCTAC has been investing in *ex situ* tree seed collections as a complement or insurance for the genetic resources in protected areas. In general, the commercial conifer species are well represented in the *ex situ* collections (=seed bank) and priorities for new collections are as follows:

1) Whitebark pine(*Pinus albicaulis*), limber pine (*Pinus flexilis*) and subalpine larch (*Larix lyalii*)

2) Specific Priorities (Species - in particular BEC zones) identified through GCTAC reports

3) Having some representation from all indigenous BC tree species.

These collections are composed of a minimum of ten single-tree collections that are maintained separately in storage. In 2008/2009 the crops of whitebark and limber pine were poor and no cones collected, but fortunately the first *ex situ* collection of subalpine larch was collected at Cathedral Provincial Park. An additional 12 species were collected from 34 populations with summary details presented below in Table 2.

Species	Number of Populations	Total number of Trees
Larix lyalii	1	34
Juniperus scopulorum	3	25
Juniperus maritimis	2	40
Taxus brevifolia	1	11
Betula occidentalis	3	37
Cornus nuttalli	2	27
Crataegus douglasii	6	68
Crataegus columbiana	1	12
Malus fusca	3	34
Prunus emarginata	4	43
Prunus virginiana	6	69
Rhamnus purshiana	2	22
Betula glandulosa	1	12
TOTAL	**35**	**434**

Table 2. The species, number of populations and total number of trees collected from in 2008 for *ex situ* genetic conservation.

3.0 Tree Breeding

3.1 Coastal Douglas-fir Program

Michael Stoehr, Keith Bird and Lisa Hayton

The progeny tests of series 1 of the advanced generation breeding cycle, planted in 1999, were measured at age 11 from seed. The progeny are grouped in sublines to prevent inbreeding at the seed orchard level. In theory, only one seedling per subline is supposed to be forward selected for orchard seed production, guaranteeing no relatedness in the selections. However, one of eight tested sublines was much faster growing than the others 7 sublines resulting in identification of several progeny from that productive subline. An optimization program was applied to choose candidates with a constraint to maintain a certain level of diversity in these orchard selections. A total of 15 forward selections were identified with breeding values ranging from 15 to 30. Scions were collected from these and grafted in the spring of 2009.

Wood density estimates in the four progeny tests of series 1 using the resistograph were also determined. A separate seedling study to evaluate the effects of selection for height on physiological traits was completed and results analysed.

In late spring of 2008, breeding in series 4 was completed and seeds sown in early spring of 2009. This completes the third generation subline breeding phase in Coastal Douglas-fir.

In late fall of 2008 and early spring of 2009, a total of four test sites were established with control crossed seed orchard material to verify the upwards seed transfer movement of orchard seed past the 900 m elevation. A total of 30 orchard families were planted at two low elevation sites and at two high elevation sites (above 1000 m).

In the sub-maritime (interior-coast transition) zone, three progeny test sites were maintained (tagged, brushed and weeded) to be ready for the scheduled measurement in the coming year. Based on these measurements, seed orchard 181 will be rogued from below, based on age 6 (from seed) measurements.

An arboretum for the production of high-quality scions was established to provide optimal growing conditions to speed up vegetative growth in selected seedlings. This will enable us to supply orchard managers with large numbers of scions from relatively young trees for grafting.

3.2 Sitka Spruce Breeding Program

John King and Dave Ponsford

Weevil Resistance Program

Good News/Bad News. First the Good News we have finally seen the publishing of the Technical Report the reference of which is:

King, J.N. and R.I. Alfaro. 2009. Developing Sitka spruce populations for resistance to the white pine weevil: Summary of research and breeding program. BC Min. For. Range, Res. Br., Victoria, BC Tech. Rep. 050. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr050.htm

This report summarizes over 3 decades worth of activity starting with the provenance trial establishment in the mid 1970s to orchards that now deliver highly resistant Sitka spruce. This has been a highly successful collaborative effort between the BC Forest Service, the CFS, Universities (particularly Simon Fraser University), and the BC forest industry (particularly Western Forest Products). The major thanks go of course to the great technical teams that helped through the years in this program: from the BC Ministry of Forests and Range: Charlie Cartwright, Doug Ashbee, and David Ponsford. From the Canadian Forest Service: Lara van Akker and George Brown. Without the dedication of these people none of these results could have been achieved. For helping get this report out, I need to thank in particular Jodie Krakowski for the countless editing and Diane Douglas, ETAC, FGC for the financial help with publishing

The major activity for the future will be to monitor the F1 trials that have been established; weevil assessment for the first of these trials started in September 2008. Other projects include: ongoing research activities through UBC's genomics project[1] and through the support of a masters student at UVic (Natalie Prior). Most of this research is geared to understanding the resistance that has been uncovered.

The Bad News is of course that we have lost David Ponsford to retirement. David's last years were busy in establishing the F1 trials, which will be key to the ongoing work with this project.

[1] For details of the UBC genomics project see: http://treenomix.ca/Home/ResearchAreas/FunctionalGenomicsofConiferDefense.aspx

3.3 Western Hemlock Forest Genetics Program

Charlie Cartwright and Doug Ashbee

Low-elevation Maritime Hemlock (SPU 03)

Since planting of western hemlock has continued to be relatively limited, program efforts have been greatly reduced for the last three years. In general, the only activities carried out are those required to capitalize on past investment.

Support activities such as realized-gain or seed transfer work have generally been discontinued.

Accomplishments include a summer student tagging seed transfer and older progeny test sites in order to keep them secure and available for future information needs with no maintenance anticipated in the next 5-10 years. Also due to his efforts, 3 sets of age 10 measurements from seed transfer trials were collected.

Regular maintenance of 3 of the 40 provenance trials was carried out in conjunction with adjacent *Abies* tests that were to be brushed. Brushing was also done for 5 year old advanced generation clonal tests which were subsequently measured.

As a result of the very considerable efforts of post doctoral fellow, Eduardo Cappa, analysis of the Hemlock Tree Improvement Cooperative advanced generation 10-year old trials has been completed. Selections based on his work, as well as material from 5-year old clonal tests will be grafted in the spring. Depending on demand, an advanced generation orchard composed of best original parents plus forward selections from the advanced generation seedling and clonal tests may be deployed in several years.

It is hoped that investment in use of hemlock improved seedlots versus wild type natural regeneration may result in interest in carbon sequestration (for greenhouse gas offsets).

High-elevation Hemlock (SPU 24)

As with low elevation hemlock, only the most urgent work was carried out. Two trials were brushed and subsequently measured this fall. It is hoped that revised breeding values resulting from these efforts will be released for this series of tests in the spring. All other activities for this SPU have been suspended.

3.4 True Fir Forest Genetics Program

Charlie Cartwright and Doug Ashbee

Pacific Silver Fir (SPU 09)

Regular maintenance of pacific silver fir seed transfer trials has kept to schedule over recent years. In 2008/09, emphasis was on brushing the more remote installation located in the North and Mid-Coast.

Based upon climatic transfer distance analysis and results from provenance trials, an increase of 100 m was made to the upper elevation limit for wild stand seed.

Sub-alpine Fir (SPU 46)

Over the past few years nursery based provenance trials for this species have been measured as planned, and now field trials have been sown based on data from the earlier tests. For variation in early height by provenance only minor proportions appeared due to latitude or elevation (except for plants from seed sources near the margins of the species range). For this reason, guidelines for upward transfer of wild stand seed has been expanded by 200 m. Due to balsam woolly adelgid quarantine, the field tests could not be grown at our own facility, so much of budgeted expense was for growing stock. The experimental design calls for 64 provenances from across the range to be deployed on 2 large 1.5 ha sites with 48 to be planted on six 1.0 ha installations. 27 sources are in common with the earlier nursery based trial series and 8 are in common with the Ministry of Forests and Range multi-species climate change tests. Three of the smaller locations will be on the same site as the assisted migration adaptation trial (AMAT).

Grand and Noble Firs (SPU 36/47)

The only activity carried out this year was site visits with the intent of handing over responsibilities for the installations from the retiring provenance technician Doug Ashbee to other staff. Access to trials was reviewed and their general condition noted.

3.5 Western Redcedar Breeding Program

John Russell and Craig Ferguson

There are 930 parents established in first-generation polycross tests for the maritime low SPU. Seven annual series of tests were planted on 46 sites over six SPUs. Breeding values for volume at rotation are currently available for over 600 parents from series 1 through 3 based on 10-year heights, series 4 on 7-year, and series 5 and 6 on 5-year.

Approximately 75 parents from the first five series have been selected based on height for advanced generation and established into breeding orchards. Breeding for second generation is ongoing.

Full-sib and self families from deer browse resistant selections (high needle monoterpene concentration) are currently being established into field trials and further within-family selections for browse resistance and needle monoterpene concentrations are ongoing.

3.6 Yellow-cedar Breeding Program

John Russell and Craig Ferguson

There are currently clonal values from approximately 5000 clones represented in three series of annual testing based on nine-year data from the first and second series of cloned progeny tests and six year from the third series. These new clonal selections have been repropagated for operational release. Maintenance continued this year in both field trials and breeding orchards, as well as monitoring of pollen performance and production for collection for advanced-generation breeding.

Various technical support projects were maintained and measured. These include clonal maturation, clonal competition, pollen viability and deer resistance studies. Fifteen-year data has been collected from both the first and second series of provenance trials.

3.7 Coastal White Pine Breeding Program

John King, Rich Hunt (CFS), Dave Ponsford and David Noshad

Rich Hunt, officially retired since 2004, has worked with our programs (including interior white pine) in monitoring the screening of the F1 seedlings. He will, unfortunately, no longer be involved with the white pine blister rust (WPBR) program as of the end of March in 2009. Although we will miss Rich we have been lucky to have David Noshad as a resident pathologist to help in this program. David's enthusiasm and energy will ensure that the program and Rich's legacy continue.

The major activity this year was the assessment and evaluation of the F1 trials. A tremendously successful extension meeting on WPBR resistance and its implementation was held at Vernon last year (June 2008). We are hoping to organize something similar for the Coast.

Recent publications include:

King J.N., A. David, D. Noshad, J. Smith. 2009 [In press]. Genetic approaches to the Management of blister rust in white pines. Forest Pathology.

King J.N., 2008. [In press] Provenance Variation in Western White Pine: The Impact of White Pine Blister Rust. In: D. Noshad, E. Noh, J. King, R. Sniezko, eds. Proceedings of the Breeding and Genetic Resources of Five-Needle Pines Conference. IUFRO Working Party 2.02.15. Yangyang, Republic of Korea, Korea Forest Research Institute.

Noshad, D., J.N. King, A.K.M. Ekramoddoullah 2008. [In press] *In vitro* evaluation of western white pine partial resistance against blister rust caused by *Cronartium ribicola*. In: D. Noshad, E. Noh, J. King, R. Sniezko, eds. Proceedings of the Breeding and Genetic Resources of Five-Needle Pines Conference. IUFRO Working Party 2.02.15. Yangyang, Republic of Korea, Korea Forest Research Institute.

Noshad, D., J.N. King, A.K.M. Ekramoddoullah, 2008. [In press] An investigation into characterization of resistance against white pine blister rust. Canadian Journal of Plant Pathology.

3.8 Coastal Broadleaf Species Genetics Program

Chang-Yi Xie

Red Alder

Clone banks for both the southern and northern seed planning zones have been established at Cowichan Lake Research Station, with 89 and 54 clones respectively. Clones were selected with their breeding values of 10-year stem volume as the primary criterion and form and branching traits as the secondary criteria. The average breeding values of the top 20 unrelated clones are 29% for the southern and 23% for the northern seed planning zone. The two seed planning zones are delineated with the boundary at 52 degrees latitude.

The test results have been published in New Forests (Vol. 36:273-284, 2008). Red alder provenances responded differently to the environmental conditions of the two sites. Provenances tended to perform better at sites near their origin. The results support earlier work that two breeding zones should be delineated with the boundary at approximately 52° N. One may expect an average of about 5% decrease in stem volume and 6% increase in mortality, respectively, for each degree of southward and northward transfer of seed sources from their origins. Selecting the top 20 unrelated individuals for seed orchard establishment would result in 29% and 23% gain in stem volume at a rotation age of 40 years in the southern and northern zones, respectively. Correlation between ranks of the predicted breeding values for height at different ages and stem volume at age 10 increased rapidly when the plantation was young and became relatively stable after 6 years of out-planting. Stem volume had a much stronger correlation with diameter (≥0.84) than with height (≤0.67). Early selection at age 6 based on stem volume is therefore recommended.

Black Cottonwood

Data from the common-garden study at Surrey were analysed and a manuscript has been published in the Canadian Journal of Forest Research (Vol. 39: 519-526, 2009). The results demonstrated an ecotypic mode, north-south regional differentiation along the 'no-cottonwood' belt between the Kitimat River and Dean-Bella Coola River. The species' distribution biography, ecological characteristics, and life history suggest that restricted gene migration was the main factor responsible for the observed geographic patterns of genetic differentiation. The proposition of restricted gene migration between the north and south regions is also supported by a study using selectively neutral microsatellite genetic markers (El-Kassaby et al at UBC). The ecotypic mode of regional genetic differentiation should be taken into account during genetic resource management of black cottonwood in BC.

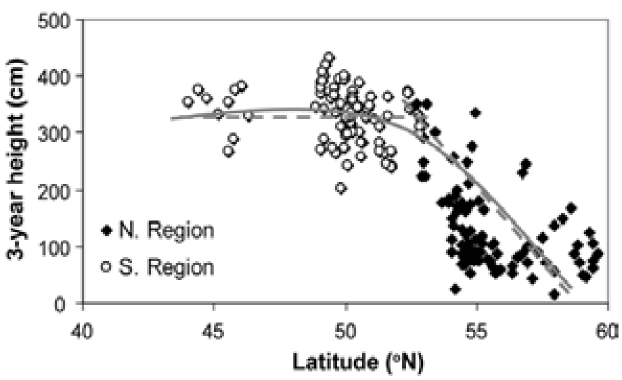


Figure 2. Black Cottonwood-Latitudinal trends of three-year height: curved solid line shows the trend for combined regions; straight broken lines show the trends for separate regions.

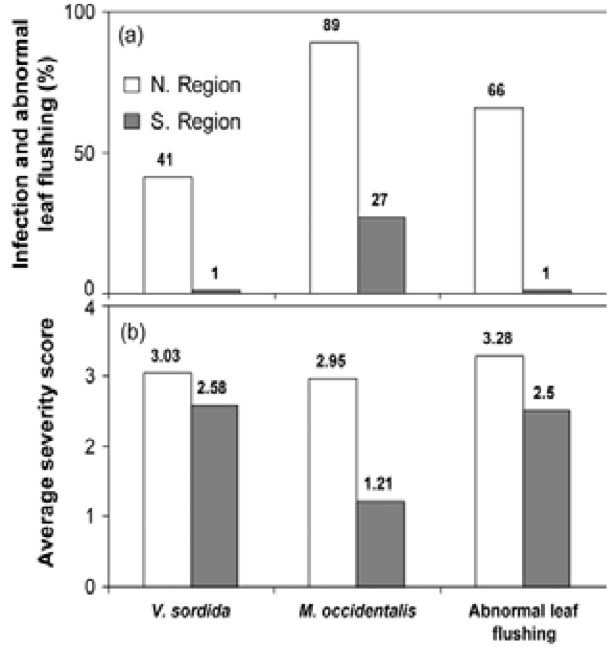


Figure 3. Black Cottonwood-Comparison between northern and southern regions in (a) level and (b) serverity of disease infection and abnormal leaf flushing.

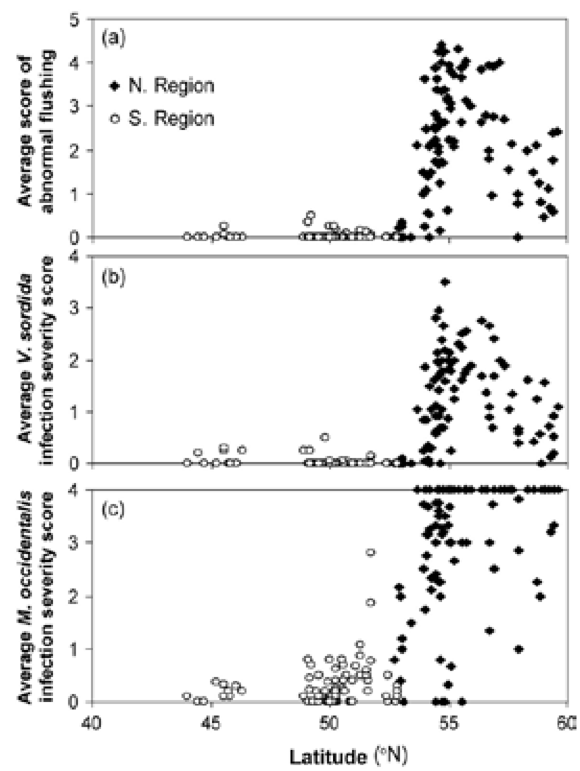
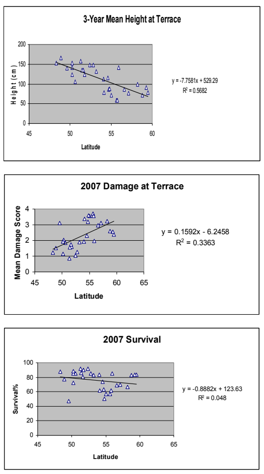


Figure 4. Black Cottonwood-Differentiation between northern and southern regions in severity of (a) abnormal flushing, (b) infection of *Valsa sordida*, and (c) *Melampsora occidentalis*.

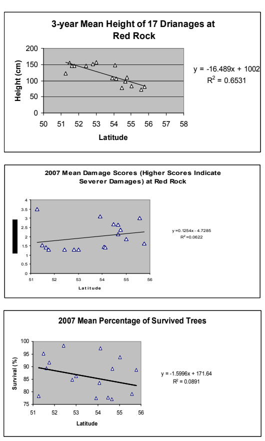
The second assessment (3 growing seasons after planting) of long-term provenance-progeny trials at Terrace and Red Rock has been completed. Preliminary data analyses indicate that trees from the south grew faster, were heathier, and survived better not only in the region of their origin (i.e. south) but also in the north (Terrace) and interior (Red Rock). This finding, if supported by more mature data, should have significant implication for genetic resources management of the species in BC.



Performance at Terrace

Zone	Mean Height	Mean Damage Score	Mean Survival
Interior	128	1.93	84
North	81	3.08	68
South	141	1.60	82

Figure 5. Black Cottonwood performance at Terrace.



Performance at Red Rock

Zone	Mean Height	Mean Damage Score	Mean Survival
Carlson's Clone	115	2.99	79
Interior	123	2.12	81
North	93	2.15	85
South	153	1.47	91

Figure 6. Black Cottonwood performance at Red Rock.

Big Leaf Maple

Establishment of the four big leaf maple provenance-progeny trials has been accomplished. Those four sites are Skutz Falls on south Vancouver Island, Sayward on north Vancouver Island, Powell River on the north Coast and Carey Island in the southern mainland. About 4500 trees of 400 families from 43 provenances were planted at each site. Powell River and Sayward have the lowest mortality of about 1-2 percent. Trees are generally healthy and growing well. Some grew over 3 feet in the first growing season. Vegetative competition is a problem at Skutz Falls with many trees covered by a thick layer of trailing berries. Mortality at this site was about 3% after the first growing season. Mortality will be much higher next year if those suppressed trees can not be released. Brushing is under way at this site and needs to be done annually for the first few years. About 8% of the trees at Carey Island were dead. As this site was planted so late (in June), a 92% survival rate is actually better than expected. Grass competition has to be managed at this site and deer browsing needs to be monitored. The other three sites are fenced and therefore no sign of browsing was noticed. Browsing and vegetative competition seem to be the two most important factors determining the success of maple plantation. Fencing the sites and using larger planting stocks (723A) were correct decisions. Formal assessment will start next year.

3.9 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 focuses largely on productive lands in the central and southern Interior. The breeding strategy is based on: 1) phenotypic selection in wild stands, 2) grafted breeding orchards and clone banks, 3) progeny testing using open-pollinated seed from wild stand ortets, 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 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 1990s and are in the early stages of production. In 2008, nearly 2 million improved class A Interior Douglas-fir seedlings were requested for planting, which represents about 13 percent of the species' total.

The second generation crossing program focuses on the Nelson SPU and includes selected parents from the West Kootenay, Shuswap Adams and Mica regions. Since intervarietal hybrids have shown to be hardy and fast growing in the Nelson low elevation zone, the Nelson breeding population has been augmented with 16 high breeding value parents from the BC coastal Douglas-fir breeding program and 16 forward selections from superior Submaritime provenances in the Trinity Valley range-wide Interior Douglas-fir provenance test (Plate 3).

Plate 3. Two 30-year-old selected trees from the Alexander provenance growing at the Trinity Valley range-wide Interior Douglas-fir provenance test, near Enderby BC. These trees have been included in the 2nd generation crossing program for the Nelson low elevation seed planning unit.

Despite a heavy frost and snow storm in early April 2008, 114 controlled crosses were completed in six Douglas-fir SPUs and 83 pollen lots were collected, processed and stored for future breeding. Controlled crossing for the Nelson SPU is now about 80 percent complete. Three 20-year-old Mica progeny tests and two 25-year-old Quesnel Lakes/Cariboo Transition progeny tests were maintained and measured and data analyses are in progress (Plate 4).

Plate 4. 25-year-old Mitchell Bay Interior Douglas-fir progeny test, which evaluates 397 open-pollinated families from the Quesnel Lake and Cariboo Transition seed planning zones for growth and adaptive traits.

Extension Events

Jaquish, B. 2008. Screening Interior Douglas-fir families for resistance to Armillaria. Invited presentation at 2008 Forest Pest Management Forum, Gatineau, PQ Dec 2-4, 2008.

3.10 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.

Breeding for 2nd-generation selection is now focussing on the Nelson low elevation SPU, which requires 236 crosses. In 2008, 68 crosses were completed, which brings the total number of completed crosses to 157. Crossing for this zone is expected to be finished in 2010. Breeding is also on-going for the Thompson Okanagan SPU at Tolko Industries' Eagle Rock seed orchard and is approximately 90 percent complete. In 2008, the 43 full-sib seedlots used in the multi-disciplinary, inter-agency terminal weevil experiments were re-created. These seedlots will be used in future spruce pest resistance studies.

In 2008, site maintenance and measurements were conducted on a number of progeny tests and research sites including: three 10-year-old full-sib 2nd-generation progeny tests in the Bulkley Valley Series 1 program; eight 25-year-old EP819 o.p. tests in the old Finlay and Quesnel Lake seed zones; four 10-year-old open-pollinated tests in the Peace River seed zone; and, three 10-year-old somatic embling field trials. Eight sites in the 4-year-old spruce climate change study were brushed.

In fall 2008, a 10-year-old somatic embryogenesis screening trial near McLeese Lake and a 3-year-old PG Series II 2nd-generation nursery trial at Kalamalka that had both been augmented with *Pissodes* leader weevils were evaluated for leader damage. The augmentation at Kalamalka was extremely successful. Leader kill among the 142 parents included in the test ranged from 0-100 percent (Plate 5).

Plate 5. Three-year-old Prince George Series II Interior spruce second-generation nursery test at Kalamalka Forestry Centre showing family variation in leader kills following augmentation with *Pissodes* leader weevils. Full-sib families are represented by three-tree row plots.

3.11 Western Larch Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hooge

Commercial planting of western larch continues to increase in BC with over 5.5 million seedlings planted in 2008, 69 percent of which were class-A. In early April 2008, a late spring frost and snow storm caused considerable damage and loss of western larch flowers (Plate 6). These losses were the first to occur on the Vernon site. Consequently, only 34 2nd-generation crosses were completed and 50 pollen lots were collected and stored for future crossing. Second-generation crossing in the East Kootenay and Nelson SPUs is 73 percent complete and we anticipate completion of the crossing program within three years. The three-year-old East Kootenay realized gain genetic tests were maintained and measured.

In 2008, a new study was initiated in collaboration with scientists at UBC to study genetic relationships and inheritance of wood properties in western larch. In the fall, increment cores were collected from 25 wild-stand parent trees from the East Kootenay SPU population and 16 trees from their respective open-pollinated families on each of three 15-year-old progeny tests (1,225 cores collected in total). Increment core analyses are on-going at UBC.

Plate 6. Female western larch seed cones, damaged by a rare late spring (April 19, 2008) snowfall and frost-event. Heavy seed cone damage in western larch resulted in poor breeding success and seed orchard production at the Kalamalka Forestry Centre.

3.12 Lodgepole, White and Ponderosa Pine and Interior Broadleaved Species

Michael Carlson, Vicky Berger, Nicholas Ukrainetz

Lodgepole Pine

Grafting for our Pli replacement breed arboretum was completed in 2008 with some 400 grafts at Kalamalka by Vicky Berger (Plate 7). Ground to receive some 800 grafts in total was prepared at the Skimikin Seed Orchard (SO) site by Keith Cox and crew and planting will go ahead in the spring of 2009. Clones saved are all those not well represented in SOs that have been used in one or more controlled crossing schemes for second generation family testing, gall rust resistance or other research.

Plate 7. Vicky Berger grafting Pli breed arboretum replacement trees.

The second generation Bulkley Valley family test series (150 families, 3 sites) was measured for 5-year total tree heights and assessed for diseases and damages.

Eleven Pli provenance (stand) screening trial sites, 5 in the Cariboo and 6 in the Thompson-Okanagan were also measured for 5-year total tree heights and disease/damage assessed. These two screening trails were designed and established originally under FIA funding and are now funded by the Pli breeding program and contributions from the West Fraser and Weyerhaeuser companies.

Thirty eight more Western gall rust-free (WGR) trees were harvested in our Tutu and Blackwater Creek northern test sites near McKenzie (Plate 8). 3,000+ scions were collected and grafted at the Skimikin Seed Orchard site. This brings the total # of grafts for a Western gall rust resistance orchard for the central interior to over 7,000. MFR will plant this orchard in the spring of 2009 at Skimikin. The range of percentage of stem-gall free trees among 280 open pollinated families in the test series is 6% to 85% (Figure 7). The top 26/280 families provided 91 stem-gall free selections for the orchard with an average family score of 62%. An additional increment of gain is expected by selecting stem-gall free individuals within these families. The final range of genetic worth from this seed orchard is expected to be between 65% and 75% stem-gall free, a significant improvement over regional control seedlots in the series which averaged 36% stem-gall free trees at 18 years of age.

Plate 8. Nick Ukrainetz with a stem-gall free select tree at the Tutu Creek Site.

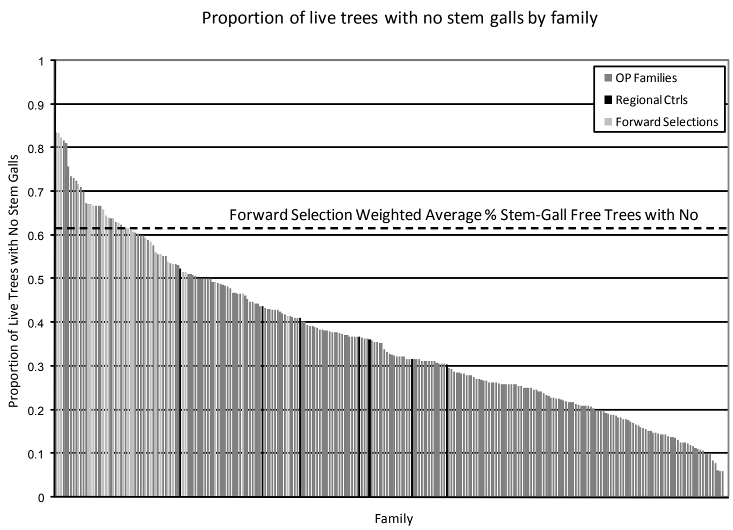


Figure 7. Proportion of live Pli trees with no stem galls by family.

Western White Pine

A Western White Pine Management Workshop was organized and held in Vernon June 17/18 2008. Organizers Michelle Cleary, Stefan Zeglen, Mike Carlson, Diane Douglas and Vicky Berger put together a stimulating and informative two day event with presentations by pathologists (from Idaho, California and BC), and ecologists, silviculturists, tree breeders, seed orchardists, wood products and technology industry representatives, all from BC. Highlighted was the long history of white pine blister rust (WPBR) breeding in the U.S. and our more recent efforts in BC including a tour of our MFR Bailey seed orchard near Vernon. A 3-stop field tour the second day concentrated on realized genetic gain trials (Plate 9/Figure 8) and a long-term pruning trial. Approximately 90 field foresters and forest managers attended the workshop. The general consensus among participants was that we now have sources of white pine seed that can be trusted to deliver disease resistance/tolerance levels of approximately 65% at rotation (eg. we can expect 65% of trees planted today to survive to rotation age less other non-rust causes of mortality).

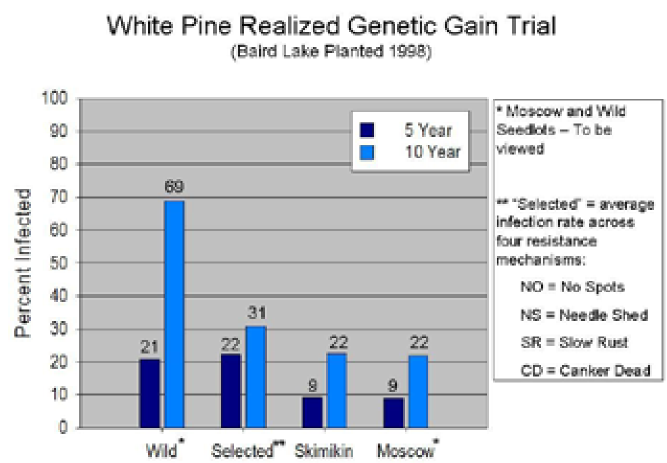


Figure 8. White Pine Blister Rust resistance/tolerance Realized Genetic Gains at Baird Lake site at 10 years.

Plate 9. Western White Pine Workshop field stop at Baird Lake Realized Genetic Gain Trial.

Paper and Silver Birches

Fill-in grafting for both our native paper birch and the silver birch from Finland was completed at Kalamalka and paper birch seed orchards (southern interior SPU to be determined) are now planted at Kalamalka and Skimikin sites. Location of the silver birch SO(s) is to be determined.

Hybrid Cottonwoods

In 2005 as part of the Cottonwood Genecology Trial (see Chang-Yi Xie Coastal broadleaved report) we planted 75 hybrid cottonwood clones at the Red Rock Nursery site (Plate 10) near Prince George. The first three years growth has been modest including some early fall frost damages with nearly all trees surviving but with growth compromised to some extent. In the fourth field season (2008) the hybrids as a group have accelerated with seasonal height growth averaging 1.5m+. The 2008 season was wetter than the previous three and roots possibly reaching into a moister soil profile are thought to be the reasons for this growth jump. This excellent growth, some of which was probably due to shoot extension late into the season, will provide us a good opportunity to evaluate frost tolerance. 24 of these 75 clones have one or two northern latitudinal parents which should confer some measure of frost tolerance not seen in clones with south of 50 degrees parents. These 24 clones may hold promise for those exploring biomass for energy options among willows, cottonwoods, and aspens at north temperate and beyond latitudes.

Plate 10. Vicky Berger at the Red Rock Cottonwood Genecology trial site with Northern Hybrid Poplars in the background and Fort Nelson Native Cottonwoods in the foreground.

3.13 Assisted Migration Adaptational Trial (AMAT)

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

The Assisted Migration Adaptation Trial (AMAT) team switched into high gear this year. The 12 test sites for the first planting series have been confirmed, with several requiring repeated visits to satisfy statutory obligations (thanks Mike!). Fencing and site preparation have been completed on those sites where it is required, and all sites have been layed-out in preparation for planting in spring 2009. Seedlings of the 49 experimental Class A seedlots and 24 local Class B control seedlots were sown and grown at Landing Nursery in Vernon. In November 2008 the AMAT team, led by Vicky Berger, and assisted by a crew from Future Forest Inc., labelled, lifted, sorted, bagged and boxed the 53 000 seedlings that will be planted in spring 2009 (Plate 12). In preparation for the second planting series, 12 sites have been identified and experimental and control seedlots stratified.

The 2008/09 fiscal year has seen considerable extension activity for the AMAT. The project was presented or discussed at the following meetings or tours:

- Canadian Tree Improvement Association - Quebec (Aug 2008)
- Pest Vulnerability workshop hosted by PCIC – Victoria (Nov 2008)
- Kamloops Future Forest Strategy workshop – Kamloops (June 2008)
- Chief Forester - Victoria (May 2008)
- Okanagan TSA Public Advisory Group field tour - Summerland (Sept 2008)
- Cariboo TSA field foresters – Williams Lake (Sept 2008)
- Northern Silviculture Committee winter workshop – Prince George (Jan 2009)

As a result of our extension activities, the AMAT team is collaborating with researchers at UNBC on a Douglas-fir and lodgepole pine mycology project, and opportunities for collaborating on a multi-species silviculture project are being explored with researchers from UBC.

The AMAT team is looking forward to sowing the seed for the second planting series in April 2009 and working closely with our many industrial collaborators who generously continue to provide seed and assist us in finding test sites.

Plate 11. 16 tree species to be planted for the AMAT in 2009.

Plate 12. Assisted Migration Adaptational Trial species diversity.

Plate 13. A wide range of BEC zones for the AMAT in 2009 - Pyxh to the ESSFwc.

4.0 Seed Transfer Technical Advisory Committee (STTAC)

Lee Charleson

The newly developed Seed Transfer Technical Advisory Committee (STTAC) supports genecology research and seed transfer policy development with an initial emphasis on commercial tree species. The STTAC was initiated following FGC's Genecology and Seed Transfer Subprogram review which recommended a separate committee to carry out genecology and seed transfer work. The Ministry of Forests and Range Tree Improvement Branch (Lee Charleson) leads the committee. The STTAC is comprised of representatives with science-based to operational backgrounds: genetics, academia, gene conservation, licensees, decision support and orchard operations.

The main tasks of the fall meetings were to prepare a vision statement and performance indicator, and to develop protocols and structure for a call-for-proposals.

The vision statement of the committee is:

> "By 2020, high-quality genecology research information will guide operationally efficient climate-based seed transfer policy and practices for all trees planted in BC."

Key elements of the call-for-proposals were: i) development of an eligibility list, ii) ranking the criteria, iii) development of a proposal package, and iv) convening a review committee. A sub-committee, headed by John Russell, was formed to address and finalize the eligibility list and ranking of criteria. The call-for-proposals package, compiled by Keith Thomas, was provided to interested parties via email and was posted on-line in mid-January 2009. A review committee was assembled through invitation by the Chair of the STTAC.

Proposals were received, reviewed and ranked by the review committee. A list of accepted proposals along with the funding level agreed to by the review committee was compiled.

The committee accomplished a great deal in its first year. Future work will include streamlining the call-for-proposals process and ensuring the relevance of genecology projects to inform and guide seed transfer through the use of value, resilience, conservation and climate-change criteria.

5.0 Genetic Resouce Decision Support Subprogram (GRDS)

Leslie McAuley

Decision support activities of the GRDS subprogram this year comprised 5 project areas: 1) Strategic Planning and Analysis, 2) Resource Information Management, 3) Monitoring and Evaluation, 4) Genetic Resource Information Management Systems, and 5) Training and Extension.

Supporting decision-makers with data, knowledge and tools

A decision support system (DSS) is defined as *the integrated system of tools (machine and human) that serve to support the process of decision-making*. As the global community transitions into the 21st century, business transformations are taking place that are moving us from an 'age of information' to one that is 'knowledge-based' and informed by decision support tools. In February of 2008, to acknowledge the importance of supporting decision-makers with data, knowledge and tools, the subprogram name was changed from Genetic Resource Information Management to Genetic Resource Decision Support (GRDS).

Subprogram Highlights

This year, subprogram highlights included decision support for the development (review) and implementation of interim policy measures for climate-based seed transfer. Proposed changes to upward elevation limits for the majority of natural stand and orchard species will be implemented in April of 2009 as amendments to the *Chief Forester's Standards for Seed Use*. Updates to seedlots registered on Seed Planning and Registry (SPAR) and Seed Planning Units, including spatial geometry were also undertaken at that time. For more information on Climate-based Seed Transfer Interim Policy measures, including impact maps by Seed Planning Unit, see http://www.for.gov.bc.ca/hti/climate_based_seed_transfer/nov08-maps.htm.

A second highlight was the presentation of *GIS-based Forest Seed Deployment Tracking over Time and Space*, at the ESRI (Environmental Systems Research Institute, Inc.) International 2009 User Conference. This presentation is based on a collaborative project (and MSc Thesis) with GRDS and the University of British Columbia to develop a GIS-based approach for evaluating seed deployment of natural stand and orchard seedlots based on planting activities annually reported through the Reporting Silviculture Updates and Landstatus Tracking system (RESULTS). TIB (L McAuley) participated as a member of the thesis defence committee. For more information on the 2009 ESRI UC, see http://www.esri.com/events/uc/index.html.

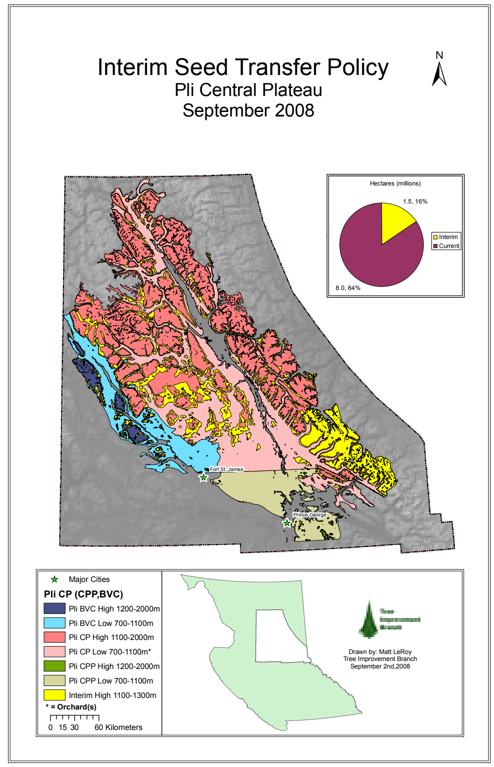


Plate 14. Extent of interior lodgepole pine seed deployment area impacted by climate-based seed transfer interim policy measures for the Pli Central Plateau seed planning unit (including zones/units of overlap). September 2008.

Continuous Improvement

A key objective of GRDS is to seek opportunities for continuous improvement in the form of enabling technologies, human-based knowledge and insight, and extension and communication tools. This year GRDS continuous improvement included:

- Liaison with MFR Forests Analysis and Inventory Branch (FAIB) for the purposes of incorporating Genetic Resource Management (GRM) data and map themes into *Impact and Opportunity Mapping* such as the Mountain Pine Beetle (MPB) Forest for Tomorrow (FFT) Footprint Mapping and Commercial Forest Reserves projects.

- Provision of decision support in response to emerging issues and key priorities such as *Climate Change Adaptation* including participation, review and input on the Future Forests Ecosystems Initiative (FFEI) Technical Team and Vulnerability Assessment Working Group; and at the FFEI Climate Change Monitoring Workshop (Jan 09, Genetic indicators), FFEI Policy 'Scenario Building' workshop (Mar 09; Genetic scenarios), and the FFEI Tree Species Landscape Scoping workshop (Mar 09; GRM linkages).
- Development of a 'mock-up' web-based *State of GRM Report* for reporting out status and trends, scenarios, indicators and performance measures at the regional and species level.

GRDS accomplishments in 2008/09 included the following:

Building Forest Genetics and GIS Capacity

Collaboration continued with the UBC Forest Management and Forest Sciences Departments to research GIS-based GRM evaluation and monitoring methods and approach, and to build GIS and Genetics capacity. In March 2009, Chen Ding, UBC graduate student (MSc Thesis candidate) defended, "Evaluating Interior Spruce Genetic Resource Management Practices through GIS-based Tracking of Seed Deployment over time in British Columbia". A poster was accepted for presentation at the 2009 GEOIDE Conference in Vancouver, BC. The project was also accepted for presentation at the 2009 ESRI International User Conference in San Diego, CA. For more information on the 2009 ESRI UC, see http://www.esri.com/events/uc/index.html; Sessions - Papers and Panel Discussions, Forestry, Wildlife and Fisheries Management (FOR), Forest Management Decision Support, page 18; GIS-based Forest Seed Deployment Tracking over Time and Space; *Michael Meitner, Department of Forest Resource Management, UBC;* http://www.esri.com/events/uc/docs/papers_panel_discussions.pdf.

Climate Change, Seed Transfer and Spatial SPU Updates

Completed spatial data updates (changes in upward elevation limits) to the Seed Planning Units (SPU) in support of the development of climate-based interim policy for seed transfer. Interim policy SPU impact maps (8 ½ x 11" pdfs) were also developed to support the review process. In each map, the bright yellow indicates the additional area to the SPU due to an increase to the upper elevation limit. SPU updates were loaded into the GeoBC, Land and Resource Data Warehouse (LRDW) in April, 2009. SPU spatial data can be discovered, downloaded and viewed at: http://www.lrdw.ca/. Information on climate-based seed transfer interim policy changes can be viewed at: http://www.for.gov.bc.ca/code/cfstandards/amendmentNov08.htm. Thumbnails of the interim policy SPU 'pdf' impact maps can be viewed at: http://www.for.gov.bc.ca/hti/climate_based_seed_transfer/nov08-maps.htm.

Sustainable Forest Management Reporting of GRM

Indicators for Genetic Diversity and Silviculture (select seed use and genetic gain) were first reported in the 2006 State of the Forest (SOF) report. Updates are currently underway for inclusion in the SOF 2010 Report (Genetic Diversity indicator team is co-led between MFR Tree Improvement and Research Branches). GIS-based analysis,

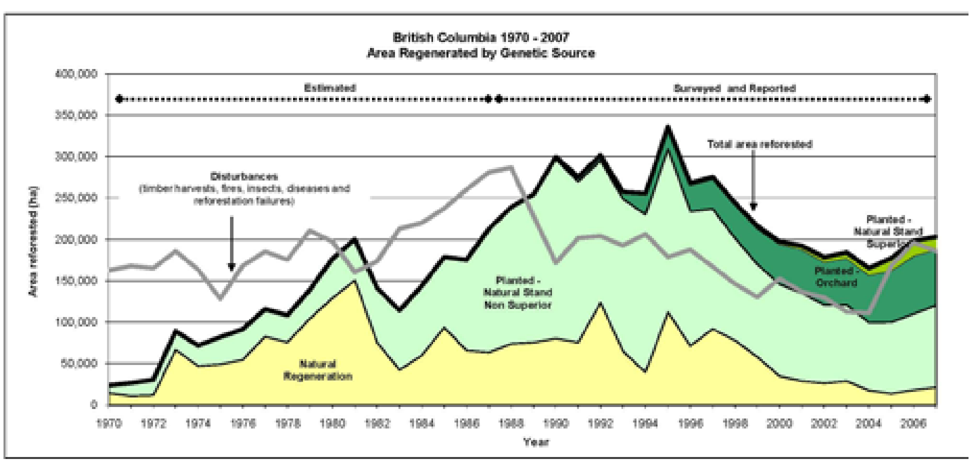


Plate 15. Area disturbed, naturally regenerated, planted with natural stand non-superior provenance seed, planted with superior provenance seed, and planted with orchard seed, 1970-2007.

data summaries and mapping have been completed. Four indicator measures were updated: 1) How well conserved are the genetic resources of trees? 2) What is the level of genetic diversity in regenerated forests? 3) What is the proportion of forest regeneration by genetic source? and 4) What is the extent and source of genetic variation in forest regeneration across the province?

Updates were based on a GIS analysis and data summary of seed selection, use and deployment based on forest (silviculture) opening data reported in the Reporting Silviculture Updates and Land Status Tracking System (RESULTS) from 1970 to 2007. Regeneration data is also tracked spatially at the forest (silviculture) opening level using RESULTS and the Vegetation Resources Inventory system (VRI). For more information on State of the Forest reporting, see http://www.for.gov.bc.ca/hfp/sof/.

Mapping of Seedlot Genetic Source

Enhancements to the Seed Planning and Registry (SPAR) system and SeedMap were completed this year, including development of: 1) a new seedlot 'Collection Area' data capture and mapping tool, 2) multi-year SPAR seed use reports, including a new charting feature, 3) a new 'Feature Search' tool, 4) the Seed source and Seed Use query, and 5) registered seedlot updates as per the climate-based interim policy for seed transfer (changes to upward elevation limits).

Supporting Timber Supply Analyses and Future Forest Strategies

Decision support for strategic and operational planning, forest estate and timber supply analysis included support of the provincial Timber Supply Review process, Future Forest Strategies, the Forests for Tomorrow program, and FGC species plans. Decision support services included verification of seed use and genetic gain assumptions and provision of data (current management – seed use and genetic gain history) and information summaries (forecasts - species plan timelines) for the provincial Timber Supply Review (TSR), including: 3 Timber Supply Areas (PG, Soo and Golden) and 5 Tree Farm Licenses. Evaluation and decision support was also provided for the proposed Strathcona TSA Second Growth Pilot (Coast Forest Action Plan, Future Forest Strategy) tree improvement strategies (sensitivity analyses).

6.0 Operational Tree Improvement (OTIP) – the Twelfth Year in Review

Keith Thomas

The Forest Genetics Conservation and Management Program has the ability to meet future seed demands due to key investments in breeding, testing, seed pest management, seed orchard quality and quantity boosts, and in orchard development through Council-owned SelectSeed Ltd. Over the years the Operational Tree Improvement Sub-program (OTIP) has provided the focus for investing in our orchards for the purposes of increasing genetic gain as well as seed yields. This sub-program continues to be an important mechanism for investment in existing orchards to help them support provincial objectives for the use of high-quality select seed operational reforestation. With the deployment of replacement stock from the breeding programs, the genetic worth of orchards continues to climb. In addition, our program utilises a system of performance management to monitor progress and set reasonable targets for project success. Orchardists and researchers have responded to these approaches and in many instances have achieved beyond planned targets.

Although 2008-09 was a moderate year for most orchard crops, considerable work continues with stock replacement and studies on seed supply issues. There are still numerous insect-related problems that reduce seed yields.

For budget and OTIP business details, please refer to the FGC Annual Report 2008/9 http://www.fgcouncil.bc.ca/FGC-Annual-Report-0809-26Jan10a-Web.pdf

Technical support within the OTIP sub-program is an integral part of tree improvement in general and provides an excellent avenue for operational problem-solving.

6.1 Orchard Projects

6.1.1 Saanich Forestry Centre (WFP)

Annette van Neijenhuis

Western Forest Products manages production tree seed orchards for Seed Planning Units in the Maritime zone at the Saanich Forestry Centre. These orchards include low elevation Douglas-fir, low elevation western redcedar, low and high elevation western hemlock, and low elevation Sitka spruce seed orchards and yellow cypress hedge orchards. 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 with replacement of 161 ramets in orchards 166 and 405. Average genetic worth of these orchards are 16 and 19 respectively. Additional copies of forward selections were received from MFR surplus; these, together with additional on-site (Plate 16) and ordered grafts provide 313 ramets for future mortality replacement.

The 2008 cone crop was very small at 13.4 hl; thus minimal management was warranted. As only the older, large trees contributed to the crop and the within-orchard pollen contribution was low, its genetic worth is 10. Seed set and germination for this crop were likewise poor, resulting in an estimated 47 k plantables.

Plate 16. Cathy Cook prepares rootstock for grafting of Douglas-fir orchard replacement stock.

Girdling treatments were applied to 43 ramets in Fdc 166 to induce more cone buds for the 2009 crop. Early surveys for reproductive buds, in March of 2009 (Quarter 4), demonstrated positive response of pollen production to girdling treatments. Final girdling treatment analysis will be completed after 2009 cone harvest.

High-elevation Douglas-fir Replacement Orchard

The replacement orchard for coastal Douglas-fir orchard 116 is now established (Plate 17). Orchard 406 contains 220 ramets, with an additional 27 vacancies to be filled with further grafts as they are available. This orchard is projected to produce crops of 13% volume gain at rotation.

Plate 17 . The high elevation Douglas-fir seed orchard is projected to produce seed for reforestation with volume gain of 13% at rotation.

Western Redcedar Orchard and Crop Enhancement

The 2008 western redcedar crop was high-graded; 5.9 hl of cones were harvested in two crops to yield an estimated 159 k plantables of 7% gain seed, and 484 k plantables of 14% gain seed. A portion of the crop was not harvested in Cw orchard 189.

Though no induction was applied, a good 2009 crop was evident in the fourth quarter. To improve the quality of the 2009 crop, 84 ramets representing 20 parents were rogued from Cw orchard 198 prior to pollen flight. Supplemental mass pollination (SMP) was applied to 112 ramets in Cw 198 (Plate 18), using pollen of breeding value 18. Incidence of western redcedar cone midge was below treatment threshold levels. Midge counts in Cw 189, where a portion of the 2008 crop was not harvested, and in Cw 190 (QCI orchard) where no crops have been managed or harvested, are significantly higher.

Plate 18. Pollen is extracted and applied to western redcedar crops to reduce inbreeding and to reduce the success of local wild pollen.

Low-elevation Western Hemlock Crop Enhancement

The 2008 western hemlock crop was managed in orchard 170 in 2008. Supplemental mass pollination deploying high breeding value pollen (19% gain) was applied to 265 ramets in the first quarter. Additional pollen was stored for future crop management. Crop harvest yielded 8 hl of cones with a genetic worth of 14%; germination on this seed lot is high, resulting in estimates of plantables of 1.9 million plantables.

High-elevation Western Hemlock Orchard and Future Crop Enhancement

A small crop was managed in western hemlock orchard 187 in 2008. Supplemental mass pollination was applied to 31 ramets, deploying pollen with a breeding value of 7. Additional pollen was stored for future crop management. This crop yielded 0.2 hl of cones; as the effective population size was less than 10, this crop will be mixed with another high elevation crop to make the required standard for effective population size.

No ramet replacement due to mortality was required for western hemlock orchard 187 in 2008. Replacement stock to reach the planned orchard parental balance, together with back-up stock, was grafted and maintained.

Sitka Spruce Orchard and Crop Enhancement

The 2009 crop in the weevil-resistant Sitka spruce orchard 172 yielded 3.5 hl of cones. The crop was managed with supplemental mass pollination: pollen of breeding value 91 was applied to the orchard. The seed yield was good, and germination tests are at species average, thus the crop is estimated to produce 290.6 k plantables of resistance of 88%.

Orchard ramets of adequate size that had not produced significantly to date were included in an induction treatment trial. Combinations of root pruning and girdling treatments were applied to 102 ramets, with an additional 39 ramets identified as untreated controls. Pollen and cone production in 2009 will be examined to determine the efficacy of the treatments.

Yellow Cypress Production Hedges Enhancement

Enhanced management of the yellow cypress hedges included fertilizer treatments, pest control, and shoot pruning was carried out. The average genetic worth of this A-class material is 20.

6.1.2 Sechelt Seed Orchard (CanFor)

Patti Brown

Douglas-fir

749 ramets from orchard #177 were injected with $GA_{4/7}$ in June of 2008 to produce a crop in 2009 with a GW of 17. 165 ramets from the high elevation fir orchard, orchard #116, were injected with $GA_{4/7}$ in June of 2008 to produce a crop in 2009.

Western Redcedar

The maintenance of 2000 redcedar ramets from test series 4 through 6 in the holding beds at Sechelt continued. 200 ramets were rogued from series 4 based on 7 year results. 40 crop trees were removed from orchard #186 upon completion of the 10 year data. The remaining 60 were sprayed with GA_3 in late July to produce a crop in 2009 with a GW of 12.

Western White Pine

MGR pollen was collected from the MGR identified trees in the Robert's Creek test site and applied to all female cones produced in 2008 in orchard #174. 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. 22.8 kg of MGR seed was produced in 2008.

6.1.3 Mt. Newton Seed Orchard (TimberWest)

Tim Crowder

Douglas-fir

SPU 0106 covers activities in four Fdc M low orchards: 134, 154, 183 and 197. Orchards 134 and154 are mature orchards that are being rogued and upgraded as new ramets are available. Orchard 183 is a younger orchard that is in full production, while orchard 197 is in establishment phase.

We applied SMP to 210 early- and late-flowering clones, in the young orchards, to ensure adequate pollination when orchard pollen counts were low. 6.5 litres of pollen with GW 16+ was collected and 2.5 litres of this year's pollen was mixed with 3.5 litres of stored pollen and re-applied. The remainder of the collected pollen was dried, vacuum-sealed and frozen for use in future years.

650 ramets were induced by stem injection of $GA_{4/7}$, and an additional 381trees were treated with a double overlapping stem girdling treatment to produce a crop in 2009. All four orchards were fertilized by injection through the irrigation system, and newly planted trees were top-dressed with a granular fertilizer and hand-watered as necessary.

The crop was monitored for the presence of cone and seed pests and as these were high enough to cause economic losses, 660 crop trees were sprayed twice to limit the insect damage. Transplanting of 455 young grafted ramets into empty spots in the orchards occurred in the fall and winter, and 281 trees were maintained in a holding bed. 1305 new ramets of with an average GW +20% were grafted for future upgrading of the Douglas-fir orchards.

54.87 kg seed was produced in two seed lots that are capable of producing 2 million trees at +12% gain and 0.5 million seedlings at 7% gain.

Western Redcedar

SPU 0205 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. Both of the cedar orchards contain large original ramets as well as small high-gain ramets from test series one and two.

92 ramets in orchard #152 were induced by spraying with GA_3, for a crop in 2009. 1935 grafted ramets from test series 1 - 6 were maintained in a holding bed awaiting

the field test results, at which time the top performing clones will be transplanted to orchard positions and the remainder will be removed.

2.27 kg seed was produced in two seed lots. This is enough to produce 225,000 seedlings with GW 15% and 110,000 with GW 7%.

Monitoring for *Mayetiola* midge and other pests was carried out, however this year's infestation levels were low and no control was required.

Western Hemlock

SPU 0310 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 ramets, SMP was carried out on 117 trees to ensure adequate seed set. 2.54 kg of seed were collected from this orchard, which is enough for 612,000 trees with GW 14%. All ramets were fertilized by injection through the irrigation system, and were pruned to increase the surface area for cone production. 68 low producing trees were treated with stem injected $GA_{4/7}$ in order to increase flowering. Pest monitoring was carried out on all 454 orchard trees as was fertilization and irrigation.

6.1.4 Saanich Seed Orchard

Carolyn Lohr

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

Orchard 181 was a 95-clone, 1000-ramet, first-generation SM, mid-elevation, Fdc orchard. Fdc breeders planted progeny test plots in spring of 2005. An initial rogue of the orchard took place over the fall/spring 2008/2009 season based on improved early survival data from progeny plots. 43 clones with 416 ramets were rogued. The final composition of orchard 181 will be 25-30 clones from both forward and backward selections.

Management operations included surveys for the health and vigour of the ramets as well as graft maintenance, rootstock pruning, mortality replacement, fertilizer and irrigation application, foliar nutrient sampling, and pest surveys for foliar and cones. *Contarinia* levels were low in 2008 – no treatments were applied.

Crop management included phenological and bud surveys, pollen collection, and SMP on early and late ramets. Production for 2008 was 37.4 hl of cones and 14.433 kg of seed.

6.1.5 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. This is the sixth year of the project.

SPU 0110

Clones with breeding values of less than 11 were rogued from both orchards, 314 ramets in total: 216 ramets from orchard #162 and 98 ramets from orchard # 149.

Pollination bags were placed on 489 branches of 28 high BV ramets in orchard #162. Pollen mix of average BV 20.8 was applied at minimum twice to each bag.

Seedlot #63164 yielded a collection of 1.6 hectolitres (approximately 4100 cones), 399 grams of seed with GW of 19. Seed yield per hectolitre was 0.249 kg.

Ninety-nine 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 55 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*.

6.1.6 Kalamalka Seed Orchards

Chris Walsh

In 2008/2009, Kalamalka Seed Orchards received OTIP approval for 10 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, planting rootstock for future grafting, transplanting the older higher-value ramets to the orchards, and roguing lower-value ramets from the orchards;

- Improving orchard seed quantity and quality through pollen management, including 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 2008, we produced approximately 468 kg of western larch, lodgepole pine, interior spruce, and western white pine seed equivalent to over 69 million seedlings with an average GW of +17. Large areas of the interior of the province are using Kalamalka seed.

Project	Species	SPZ	Orchard	Roguing	Grafts Made	Maintained	Rootstock	Transplants
SPU0401	Sx	NE	305	29		77		33
SPU0502	Sx	NE	306	21		49		23
SPU0701	Pli	NE	347			1478		1673
SPU1302	Lw	NE	332	37	40	8	40	83
SPU1501	Pw	KQ	335			185		17
SPU1708	Pli	BV	230	79				
SPU2201	Fdi	NE	324					22
SPU3501	Sx	BV	620			12		14
Totals				166	40	1809	40	1865

Table 3. Orchard Composition Activities by Project.

Project	Species	SPZ	Orchard	Pollen Collected (litres, dry)	Trees Pollinated
SPU0401	Sx	NE	305	2.0	547
SPU0502	Sx	NE	306	2.0	484
SPU0701	Pli	NE	307	3.0	1,656
SPU1501	Pw	KQ	335		1,916
SPU1708	Pli	BV	230	5.0	1,000
SPU2201	Fdi	NE	324	2.0	1,363
SPU3201	Pli	EK	340	3.0	1,337
SPU3501	Sx	BV	620	2.5	434
SPU4401	Sx	NE	341	2.0	400
Totals				21.5	9,137

Table 4. Pollen Management Activities by Project.

6.1.7 Vernon Seed Orchard Company (VSOC)

Dan Gaudet and Tia Wagner

The Operational Tree Improvement Program (OTIP) funded sixteen projects at Vernon Seed Orchard in 2008/2009 (Table 5).

Pollen Management

SMP is standard procedure for good orchard maintenance. Pollen collection is done efficiently and effectively with backpack vacuums, decreasing the picking and processing time and cost.

Plate 19. Collecting Fdi pollen by vacuum.

Induction

All three mature Douglas-fir orchards were administered $GA_{4/7}$. Results in Douglas-fir continue to be positive. We've collected and compiled five years of data allowing for clone based $GA_{4/7}$ injection prescriptions. This makes the process more efficient while maximizing the efficacy. To amplify $GA_{4/7}$ results orchards were drought stressed.

Orchard Health

Each year we continue to diligently monitor orchards for pests that either effect cone and seed quantities or tree health. Early detection and control is vital to minimizing adverse effects to ramets. The appearance of mountain pine beetle in interior seed orchards in 2006 heightens the necessity for sound pest management plans. To ensure continued health and high vigour of ramets, pest and disease management have become routine practiced at VSOC. Weekly monitoring allows for early detection of pests and implementation of control strategies if necessary.

Orchard Activities

- Pollen collection and application in Sx, Fdi and Pli were big spring projects this year.
- Pruning side branches of trees for tractor access and to promote better growth traits was completed in late fall.
- All local seed orchards benefited from new hobo weather stations. These weather stations will allow all seed orchards to keep consistent and comparable weather and degree-day data. A weather station with updated software was installed in the Prince George lodgepole pine orchard. New software automatically calculates and plots degree-day accumulation during the season. Data collected can assist in determining the effect of temperatures on seed set, insect control timing and calculating trends over time.
- Foliar sampling and analysis was completed in all orchards. Sample results aid in determining nutrient application levels in the following seasons.
- This year was the first big production from the weevil-tolerant Sx orchard #211 with 232 kgs produced.

Available funding has a positive effect on the ability to achieve the Forest Genetics Council's goals of 12% gain and 75% use of Class A seed.

SPU Project	Species	SPZ	Orchard	Pest Monitoring and Control	Induction	SMP - Ramets Treated	Pollen Collected (L)
1201	all		site		Nutrient Analysis		
1208	Pli	PG	236				5
1706	Pli	BV	234	2927			5
1801	Pli	CP	218	4142		12	
1701	Pli	BV	219	5455		12	
1202	Pli	PG	222	3746			
4102	Fdi	PG	225	510		244	5
3702	Fdi	QL	226	351		261	
4301	Fdi	CT	231	1050		406	3
1403	Sx	PG	214	2500			
1403	Sx	PG	211	3500			
1421	Sx	PG	Hold-bed	maintenance of 2.0 generation holdbed (2600)			
4057E32	Pli	All	All Pli	Spraying Sevin on all Pli for MPB protection			
4057E33	Pli	Trial	219/218/222	Cone collection for Pli seed set trial			

Table 5. Summary of Vernon Seed Orchard 2009 OTIP activities.

Plate 20. Cone picking crew VSOC.

Plate 21. Cone picking VSOC.

Plate 22. Cone picking VSOC.

6.1.8 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.

In 2008/09, 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, rogueing, insect and disease monitoring and control, rodent control, crown management, foliar analyses, pollen monitoring and distribution, pollen collection, flower induction, and supplemental mass pollination (SMP). In addition to the individual orchard projects, two incremental projects were funded.

Pli Orchards

To improve the quality of the older Pli orchards 210 grafts were made in 2008 and maintained in holding beds. In the spring of 2009, 209 grafts from the holding area were planted out to fill vacant orchard positions. One hundred and fourteen 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.

Plate 23. Rogueing unproductive ramets.

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. Whole pollen buds were collected both manually and by 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. After processing, samples of the pollen were tested for viability at the Vernon Seed Orchard Company lab before going into freezer storage for future use.

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 that measures were taken to protect ramet health and developing cones. Insecticide sprays were applied to control *Leptoglossus* seed bug. Poison baits were used to control rodents feeding on tree roots, and *Sequoia* pitch moths were removed by hand. In the fall of 2008, pruning was done in the larger orchards to open up the crowns, restrict ramet height, and maintain tractor access down the rows.

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. Approximately five litres of pollen were collected, processed, and put into freezer storage after viability testing at the Vernon Seed Orchard Company lab.

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 smaller population of *Dioryctria* in the Fdi orchard in 2008, we had little to no damage evident at the time of cone harvest.

For inducing the crop for 2009, we applied gibberellic acid (GA) to 523 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 2009.

Grandview Seed Orchards Incremental Projects

Mountain Pine Beetle – Pli Ramet Protection

Drawing from experience in 2006 and 2007, a prophylactic insecticide spray program was continued in 2008 with the assistance of OTIP funding. Taking a proactive approach to the MPB problem, we applied 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.

Plate 24. Setting up MPB traps at PRT.

Trap monitoring indicated that the orchards were exposed to high populations of beetles during the summer of 2008. 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 high level of exposure to beetle attack (as observed by high trap catches), 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.

All projects were completed as planned in the 2008/09 season. In the Pli Thompson Okanagan Low, we collected 13.54 kg of seed with the potential to produce 2.7 million seedlings. In the Pli Nelson Low, we collected 7.85 kg of seed with the potential to produce 1.56 million seedlings. The Fdi Nelson Low orchard suffered a substantial loss of cones due to a late spring frost that killed approximately 50% of the receptive flowers in the orchard. As a result, despite a large number of flowers initially, a small crop was harvested. The Fdi orchard yielded 1.77 kg of seed with the potential to produce 80,000 seedlings.

The activities conducted in 2008/09 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 25. PRT cone picking crew 2008.

6.1.9 Eagle Rock Seed Orchards (Tolko Industries)

Greg Pieper

Tolko Industries manages 5 seed orchards for the Thompson Okanagan region. There are 2 older orchards and 3 younger orchards.

We have an older Sx seed orchard soon to be phased out; as well as an older Pli orchard also entering it's final time. We established a low and high Thompson Okanagan Spruce orchard in 2003, and a high elevation Thompson Okanagan Lodgepole Pine in 2003 through SelectSeed funding.

SPU16 Thompson Okanagan Pli High Orchards 310 (Tolko) and 339 (SelectSeed)

- 18 hl collected in 2008 from 339 (SelectSeed/Tolko)
- 10 liters of pollen (collected in 2007) was applied to 339 in 3 applications using spritzers.
- 2 litres of pollen was collected from 310 for SMP application next year in 339.
- Leaders and branches were clipped to enhance future cone sites and keep branches more accessible in the new SelectSeed orchard.
- *Leptoglossus* required 4 sprays for control in both Orchard 339 and 310.
- *Sequoia* pitch moths and *Dioryctria* were removed by hand from the base of the trees.
- Orchards were mowed, sprayed and fertilized to maintain optimum health.
- Pocket gophers were controlled with treated bait.
- Foliar samples were collected and sent for analysis.

SPU28 Thompson Okanagan Sx High and Low Orchard 303 (Tolko) and Orchards 342 and 343 (SelectSeed)

- In the young SelectSeed orchards (342 and 343) all trees were topped to keep ramets short and accessible and increase potential cone sites.
- Basal branches were clipped to facilitate herbicide spraying.
- Pollen collection from orchard 303 resulted in 5 litres from the low and 6 litres from the high for future use in orchards 342 and 343.
- 34 hl of cones (303) were collected in the mid-high elevation to accommodate seed demand
- Trees were topped to reduce picking costs.
- 140 ramets in 342 (Low TO Sx) and 282 ramets (High TO SX) received GA stem injections in 2008. These trees are now large enough to begin producing a crop.
- Pest monitoring was done on a weekly basis for *Leptoglossus*, *Dioryctria*, and adelgids.
- Pocket gophers, a never ending concern were controlled with treated bait.
- Foliar samples were collected and sent to the lab for analysis.

Plate 26. Vacuum collection of Pli pollen at Eagle Rock Seed Orchard Corry Stuart and Noni Campbell.

Plate 27. Pollen application at Eagle Rock Seed Orchard SelectSeed Pli orchard - Sue Olson.

6.1.10 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 (PGTIS) in 2008-2009.

Phenology surveys were completed to keep track of receptivity periods, which can vary considerably from year to year. As well, some extremely late flowering clones received SMP. Pollen flight was monitored both inside and outside the orchards. No outside pollen flight occurred, due to the mountain pine beetle's efficiency in large-scale pine eradication.

October foliar samples were taken for nutrient analysis. Fertilizer applications were increased to ensure maximum ramet health for yet another bark beetle season.

Significant damage to branches was caused by pesticide equipment, large hydraulic lifts, and heavy wet snow. Extensive tree maintenance was carried out to ensure that damaged trees will not serve as beetle attractants.

Surveys for western gall rust, *Lophodermella* needle cast, 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 (MPB) 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 2007, mountain pine beetle presence at PGTIS has decreased drastically in 2008. 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 in early July. More adjustments/changes were made to our custom-made, tractor-mounted application equipment, resulting in increased spray height and ability to spray large branches As in the previous year, secondary bark beetle attacks required some tree removal in orchards #223, #220 and #228.

Despite the largest ever cone crop in 2007, all three orchards produced another large crop (Table 6). The three provenance orchards yielded 59.073 kg of seed, the equivalent of approximately 11.77 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 to 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 central 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.

250 grafts were transplanted into the clone banks to replace missing/dead trees.

Frequent rototilling and hand weeding was required in

PRINCE GEORGE TREE IMPROVEMENT STATION - 2008 CONE CROP DATA									
Orchard Name	**Orchard No**	**% Gain**	**Hl Cones**	**Total kg Seed**	**kg Seed/hl**	**Seeds/Gram**	**Total No. of Seed**	**Potential Mill. Seedlings produced**	**Germination %**
Willow-Bowron	220	6	53.7	23.202	0.432	258	5,986,116	4,788,893	97%
Central Plateau-Finlay	223	6	34.1	15.552	0.456	246	3,825,792	3,060,634	92%
Bulkley	228	6	44.7	20.319	0.455	254	5,161,026	4,128,821	97%
Total			**132.5**	**59.073**			**14,972,934**	**11,978,347**	

Table 6. PGTIS 2008 Crop Statistics.

the holding area due to the wet weather.

Similar management activities were carried out in the 12,000-tree clone banks. All clone banks were inventoried. Irrigation maintenance, fertilization, mowing, and weeding/ brushing were required to ensure ramet survival. Extensive headland mowing was necessary to control weeds and prevent brush from moving in.

Foliar sampling was carried out. Insect (root collar weevil and spruce leader weevil) and disease monitoring was carried out to ensure ramet health. Ramet labelling was continued, replacing old, damaged tags and labelling newly planted trees with more permanent tags.

Plate 28. Mower at PGTIS.

Plate 29. SMP at PGTIS.

6.1.11 Skimikin Seed Orchards

Keith Cox

Summary for Projects 404, 411, 501, 1503, 3502, 4002, 4057E13, and 4201

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 2008.

The West Kootenay (Nelson mid and high) spruce orchards had 173 replacement grafts made in the spring, another 224 grafts were maintained in the holding area and 325 were transplanted into the orchards. The orchards were surveyed for insects and disease, 10 rust brooms (*Chrysomyxa Arctostaphyli*) and 29 weevil attacked tops were removed, rodents were baited, and the orchards were sprayed for spruce budworm and spruce cone maggot. The crop from orchard 301 yielded 12.082 kg and the crop from orchard 302 yielded 16.459 kg.

The white pine orchard (#609) was monitored extensively because of the mountain pine beetle and the pine cone moth, resulting in 45 trap counts being done over the season, plus many visual surveys. The orchard was sprayed for mountain pine beetle. No trees were attacked.

In the three spruce orchards for the Bulkley Valley Low the crop was sprayed for spruce cone maggot and cone rust. Repairs were done where the ground had again settled from previous roguing. Another 127 replacement grafts were made, 224 grafts were maintained in the holding area, and 243 were transplanted into orchard 208. The crop was 123.3 hectolitres and yielded 124.488 kilograms of seed.

In the spruce orchard for the Peace River mid elevation zone (#212) the 2793 trees were monitored for insects, disease, and rodents. A total of 63 weevil damaged tops were removed, the young orchard was baited extensively for rodents, and it was sprayed for *Leptoglossus*. The 2007 cone induction was very successful, with the first crop yielding 90.389 kg.

In orchard 206 for the PG High Sx SPU, the last crop was picked yielding 74.613 kg. The trees were monitored for insects and disease, sprayed for cone rust and cone maggot, and rodents were baited. The orchard, planted in April 1979, was removed in the fall.

The on-site research plantations were also monitored for insects and disease and baited for rodents. The newest spruce plantation was sprayed for weeds and spruce budworm, and the grass ground cover was seeded in the early fall. Seven rows of white pine seedlings were also planted, as part of a rust resistance screening trial. The *Ribes* garden was maintained and white pine seedlings were inoculated in September. Three plantations and 32 rows in the white pine blister screening area were removed in the fall by pulling them out with an excavator. The larger trees were shipped to the Salmon River for bank stabilization.

Extensive monitoring was done for the mountain pine beetle, orchards 345 (Py) and 609 (Pw) were sprayed with Sevin, and two more areas were cleaned up, to reduce the fire hazard, by hand-piling and burning or mulching.

6.1.12 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 2.0 litres of pollen for SMP in young Pli Orchard 238 to increase the production of Class A seed to 500,000 plantables by summer 2008.

Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Results

• We collected 1500 ml of pollen, vacuumed at Kettle River, purchased 1000 ml of pollen from Vernon Seed Orchard, and collected 755 ml of pollen at Kalamalka Seed Orchard. We applied approximately 1900 ml of pollen to approximately 2000 ramets, which produced female conelets from May 22 to June 1, 2008 the receptivity period. Of the remaining pollen, we retained 2355 ml in cold storage for SMP use in spring 2009.

• We inspected developing cones for the presence of *Leptoglossus* and observed endemic levels of adults and nymphs. However, because the risk to the seed crop was negligible, we didn't need to apply pesticides.

Output and Deliverables

• We conducted a conelet survey to determine the BV contribution to the GW of the seedlot. The numbers of cones available for harvest have been tabulated, but information regarding total hl, seedset, and seed quantity will not be available until after the 2009 harvest and seed processing activity. Estimates totalling 16 hl of cones is forecast for harvest 2009, which is a significant increase from the 2008 crop. SMP has prevented these conelets from aborting due to lack of sufficient pollen in the young Pli orchard.

• By manually isolating approximately 10-20 *Comandra* blister rust bole infections, we were able to prevent the spread of spores and the subsequent infection of adjacent ramets.

• We removed approximately 150-200 pitch moth larvae manually from the boles of infested ramets. This activity will reduce the girdling impact and slow the spread.

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 2009.

• Minimize filled seed losses from predation by *Leptoglossus* through pesticide applications.

Output and Deliverables

• We purchased 1.0 litre of pollen from Vernon Seed Orchard Company, vacuum collected 500 ml. of pollen at KRSO, and collected 295 ml of pollen from Kalamalka Seed Orchard. We applied approximately 0.5 litres of pollen to approximately 1700 ramets producing female conelets from May 21 to June 3, 2008, the receptivity period. Of the remaining pollen, we retained 2.295 litres in cold storage for SMP use in spring 2009.

• We inspected developing cones for the presence of *Leptoglossus* and observed a few adults and nymphs, but the population and risk to the seed crop was deemed to be negligible and therefore we didn't need to apply pesticides.

• We identified the presence of *Comandra* blister rust and treated it as well as pitch moth.

• We conducted a conelet survey to determine the BV contribution to the GW of the seedlot. The numbers of cones available for harvest based on this year's SMP activities are unknown at this time. Information regarding total hl of cones, seedset, and seed quantity will only be available following the 2009 harvest and seed processing actiivity.

• By manually isolating approximately 20-30 *Comandra* blister rust infections we were able to prevent the spread of spores to adjacent clones in the orchard.

• We removed approximately 200-300 pitch moth larvae by hand from the boles of ramets in the orchard to prevent further development of the larvae and subsequently reduce the incidence of future attack.

6.1.13 Sorrento Seed Orchards OTIP 1707 and 1803

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 2008/09 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 is established. Pollen was collected for the BV orchard at VSOC, and the Kalamalka Research Centre (KFC). This pollen was applied three 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.

For 2008, it was determined by orchard survey that the ramets were slightly under the diameter at which Mountain Pine Beetle would attack. Therefore, the protective pesticide spray was not required for this season. However, MPB pheromone traps were set up and monitored for the season, indicating a small population of beetles in the area around the orchards. Also, the orchard ramets were monitored for any sign of MPB attack and no ramets were affected.

Cones harvested in the BV orchard yielded 67 grams of seed, or 13,350 plantables in 2008. In the CP orchard, the 2008 harvest yielded 59 grams of seed or 11,750 plantables.

Early seed production in these young orchards directly supports the FGC's goals by making more genetically improved seed available for use in BC's forests.

Plate 30. Pollen application in the BV orchard at Sorrento.

6.2 Technical Support Programs

6.2.1 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 hedges occurred in early 2008, and fertilizing of both the soil-based and field-based container-planted hedges with 34-0-0, 19-18-18, and 12-51-0 continued throughout the growing season. The media for the greenhouse-grown container-planted donor plants contained APEX 16-5-11, augmented by weekly applications of hi-sol.

In the autumn of 2008, there were 7173 donor plants in the operational hedge. Analysis of the nine-year measurements were completed and based on field performance, 29 clones were rogued from the main production greenhouse. This was done to create space for the genetically improved material, as well as increase the genetic worth of our greenhouse stock. Many of these rogued clones were later added to the unimproved SSM hedge.

Also based on the results on the nine-year measurements, some 27 clones from the series two collections were selected to bulk up the hedge. A total of 4356 new cuttings were set from this collection.

In an effort to increase the rooting success of the clones in the hedge, some 4368 cuttings were set to test hedge rootability. A sampling of every clone from series 1, 2 and 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.

6.2.2 Estimating Pollen Contamination in Coastal Seed Orchards

Joe Webber

SPU 0113

Introduction

Annual estimates of pollen contamination for all seed orchard species are required by the *Chief Forester's Standards for Seed Use* where orchards are at risk. On the coast, this includes Douglas-fir, western redcedar, western hemlock and Sitka spruce. Over the past three years, pollen monitoring data has been collected for all four species. Regional pollen loads for Sitka spruce are so low that this species is not at risk. This report summarizes data collected for Douglas-fir and western hemlock (2008) and western redcedar (2009) and reports their corresponding contamination levels.

Procedures

Pollen monitoring, used 7-day recorders for both regional and orchard monitoring. The magnitude of pollen contamination was estimated as the ratio of non-orchard pollen load (regional monitoring) to orchard pollen load (which includes regional pollen) over the duration of seed orchard receptivity. Two pollen monitoring stations within each orchard (ORC) and three regional stations located at a distance from the orchard (REG) were used. For each pollen monitoring station, daily pollen catch was counted and expressed as grains/mm^2/24h. Orchard and regional pollen loads for the orchard receptivity period was then calculated as the sum of the daily pollen catch. No orchard adjustment factor was used.

Highlights

The three regional sites used were Puckle Road, Saanich Peninsula Hospital and Mount Newton Cross Roads. Monitoring began when orchard shedding was first observed (20% orchard shedding) and continued until orchard pollen shed had passed (>80% complete). The two Douglas-fir orchards monitored for contamination were TimberWest (183) and Western Forest Products (166) orchard. The two western hemlock orchards monitored were TimberWest (130) and Western Forest Products (170) orchards. The The two western redcedar orchards monitored were TimberWest (140) and Western Forest Products (198). All pollen grains were identified and counted at x100 using a compound microscope.

Western hemlock pollen is distinguished from the Douglas-fir pollen by size (60 µm vs 85 µm, respectively) and by exine sculpturing (Douglas-fir is smooth and western hemlock is warty). Western redcedar pollen is about 20 to 30 µm in diameter with some warty structures (orbicules) on the excine. The only species that confounds redcedar pollen counts is red alder. Red alder is slightly smaller (20 to 25 µm in diameter) with pores. It looks very similar to redcedar at x100 magnification but with smaller orbicules. Separation of redcedar pollen from red alder is done on the basis of shape and phenology. When dry, redcedar pollen is irregularly shaped and at x100, the orbicules appear as bright spots on the excine. Red alder is, in general, pentagonal and does not have the bright spots from the orbicules.

Results

Contamination levels for 2008 in Douglas-fir at Western Forest Products (WFP 166) and TimberWest (TW 183) orchards were 14.9% and 11.2%, respectively. Western hemlock, contamination in Western Forest Products (WFP 170) and TimberWest (TW 130) was 11.2% and 17.3%, respectively. Contamination for western redcedar were 72.2% and 69.8% respectively for WFP (198) and TW (140) orchards (see Table 7).

Conclusions

Douglas-fir and western hemlock had moderate to low values for contamination in 2008 and western redcedar had high values. This is the first time contamination values were calculated using consistent monitoring technique for western hemlock and western redcedar. The values for Douglas-fir were expected since 2008 was a relatively light flowering year both within the orchard and regionally. Western redcedar pollen loads for 2008 were the highest recorded for any coastal orchard species. Although variations in redcedar pollen loads vary from year to year, they remain higher than any other orchard species. Since the redcedar orchards are either young (WFP) or small (TW), we can expected contamination levels to remain high until orchard pollen production increases or orchard numbers are expanded.

While the potential contamination in western redcedar is large it may not have as great an impact on a seedlot's GW as it may in Douglas-fir. In fact, the effect of contamination may even be positive since it would reduce the level of selfing in western redcedar. Wang and Russell (2006) suggest that an approximate 1% increase in volume occurs for each 10% reduction in selfing (orchard pollen). Whether these results also apply to contaminate pollen is not known but the negative effect of contamination applied to Douglas-fir may not apply to western redcedar.

Contamination levels in western hemlock may not be high enough to seriously affect a seedlot's GW. As orchards mature, the orchard level pollen production is expected to increase. Equally so, as higher breeding value orchards are established, the effect of contamination will also increase. Until higher breeding value orchards are established, orchard managers may be justified in not monitoring western hemlock contamination. However, orchard managers are responsible for assessing this risk and will have to make that decision themselves.

Wang, T. and Russell, J. H. (2006). Evaluation of selfing effects on western redcedar growth and yield in operational plantations using TASS. For. Sci. 52:281-289.

		Pollen Load (PL)	
Douglas-fir		WFP-166	TW-183
	Regional PL	7.3	3.2
	Orchard PL	48.9	28.6
	%Contamination	14.9	11.2
Western hemlock		WFP-170	TW-130
	Regional PL	1.5	1.7
	Orchard PL	12.7	9.8
	%Contamination	11.2	17.3
Western redcedar		WFP-198	TW-140
	Regional PL	84.3	51.0
	Orchard PL	116.7	73.0
	%Contamination	72.2	69.8

Table 7. Pollen load and percent contamination values for Douglas-fir and western hemlock (2008) and western redcedar (2009) from each of Western Forest Products (WFP) and TimberWest (TW) orchard sites.

6.2.3 Metabolomic Snapshots of Douglas-fir Cone Induction Treatments

Patrick von Aderkas & Lisheng Kong

Drastic cone shortfall requires drastic measures. To increase cone numbers per tree, a number of treatments can be tried. Tree abuse - pruning, girdling, or water stress – works well on Douglas-fir. Another popular method is stem injection of gibberellins. We know that cone induction is related to changes in plant growth regulating substances, but do these various treatments and mistreatments induce common hormone responses, or does each treatment bring about a unique hormonal response?

To answer these questions, we took a metabolomics approach, profiling four hormone classes and their metabolites. Typically, a set of buds at a particular stage are collected and their hormones extracted. Then we apply a methodology known as multiple reaction monitoring or MRM. The hormones and a certain number of their metabolites have also been manufactured in the lab, then altered with the addition of a deuterium ion, which makes them just a tad heavier. These deuterated hormone metabolites provide internal standards when the extracted hormones are blown through a mass spectrometer. This allows absolute quantitation of the real compound compared to the standard. In other words, we can measure the exact amount of not only one hormone, but as many as 20. And that's all from the same sample. This is thanks to the chemical wizardry of Dr. Sue Abrams and her team of chemists at the National Research Council of Canada's mass spectrometry lab in the Plant Biotechnology Institute in Saskatoon.

MRM methodology was carried out on a shopping list of physiologically important hormones and their related compounds. In this way, it was possible to see where pathways accumulated their breakdown products, which provides a snapshot of hormone pools and pathways. The hormones investigated included the following: gibberellins (GA_1, GA_3 GA_4 GA_7), abscisic acid (ABA) and some of its catabolites (phaseic acid, dihydrophaseic acid, 7'-hydroxy ABA, neo-phaseic acid, and abscisic acid glucose ester, ABA-GE), cytokinins and related metabolites (zeatin, zeatin riboside, zeatin-O-glucoside, dihydrozeatin, dihydrozeatin riboside, isopentenyl adenine, isopentenyl adenosine), and indole acetic acid (IAA) and its conjugates (indole-3-acetic acid aspartate, indole-3-acetic acid glutamate).

Gibberellin injection

Douglas-fir trees at PRT's seed orchard in Armstrong, BC were injected in early May, a time when trees were forming next year's cones. We injected gibberellin into the stems of ramets of selected genotypes in one of four concentrations per injection (0, 4, 40, and 400 mg).

Gibberellin treatments led to cone induction, as samples collected the following spring verified (Kong et al. 2008). Mass spectrometric analysis showed that gibberellin levels rose quickly compared to controls, then fell a few weeks later (Figure 9). Similarly, IAA rose in weeks 2 and 3 following GA treatment, implying an indirect effect of GA on localized growth resulting in IAA metabolic changes.

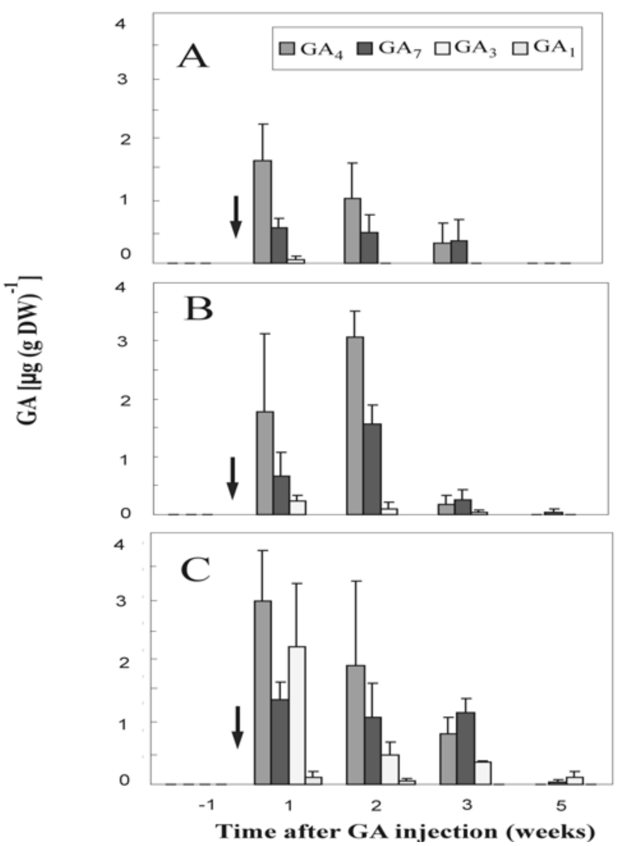


Figure 9. Changes in GA concentrations in Douglas-fir long-shoot stems after stem injection with GA on May 24, 2006, which is indicated by the arrows. Mean ± SE, n=3. Each tree injected with (A) 4 mg GA, (B) 40 mg GA and (C) 400 mg GA. (From Kong et al. 2008)

A very different pattern was seen in ABA and its major conjugate ABA-GE. ABA steadily declined, whereas ABA-GE remained stable. From other MRM studies that we've carried out on nine different genotypes of Douglas-fir, we know that such an ABA profile in May is seasonal and does not represent a response to induction treatments (Kong et al. 2009).

Physical treatments: Girdling

We girdled two genotypes (3 ramets each) and compared them with controls (3 ungirdled ramets each). Girdling did not influence profiles of auxins, cytokinins, or ABA. Although girdling had no effect on ABA concentration, significant differences between genotypes were seen in ABA concentrations and profiles (Figure 10). The only metabolite
to show an effect of girdling was the breakdown product of ABA, its glycosyl ester ABA-GE (Figure 11). Girdling clearly influences hormone metabolism differently than GA injection.

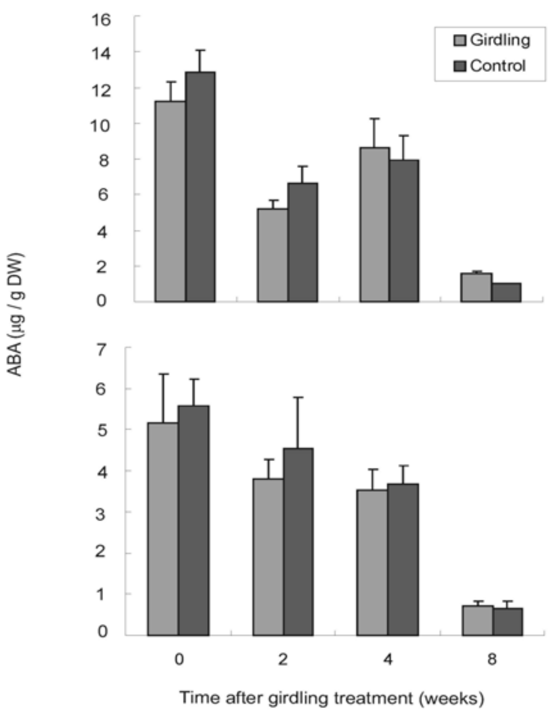


Figure 10. Changes in concentrations of ABA in Douglas-fir long-shoot stems following girdling treatment in clone 9550 (upper) and clone 9137 (lower), mean ± SE, n=3.

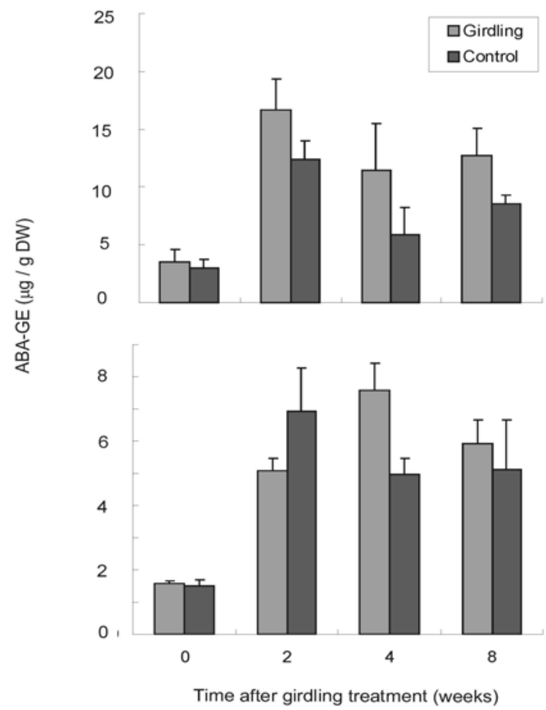


Figure 11. Changes in concentrations of ABA-GE in Douglas-fir long-shoot stems following girdling treatment in clone 9550 (upper) and clone 9137 (lower), mean ± SE, n=3.

Overall conclusion

Cones can be induced by various treatments. Looking at just two of those treatments it appears – from a metabolomics angle at least – that they elicit very different responses in Douglas-fir's hormone physiology. We have only presented the most cursory selection from the vast amount of data that flowed in from this MRM study. The power of the method lies in its ability to distinguish simultaneous effects on various hormone pools. We are continuing this work with a variety of other cone induction treatments of both Douglas-fir and lodgepole pine. This work was supported by FIA-FGC MPBE04 contract.

References

Kong L., S.R. Abrams, S.J. Owens, H. Graham, P. von Aderkas. 2009. Phytohormones and their metabolites during long shoot development in Douglas-fir following cone induction by gibberellin injection. Tree Physiol. 28: 1357-1364.

Kong L., S.R Abrams, S.J. Owen, A. van Niejenhuis, P. von Aderkas. 2009. Dynamic changes in concentrations of auxin, cytokinin, ABA and selected metabolites in multiple genotypes of Douglas-fir (*Pseudotsuga menziesii*) during the

6.2.4 Testing the Effects of Upgraded Irrigation Delivery Systems in an Interior Spruce Seed Orchard, an Interior Lodgepole Pine Seed Orchard and a Western Larch Seed Orchard

Gary Giampa
SPU 0412

Objectives

- To determine how the broadcast delivery irrigation system impacts orchard performance.
- To compare the portion of each orchard treated with the upgraded system to the portion of each orchard that continues to be watered by the old drip system.
- To make the results of this study available to other seed orchard managers.

Activities

In the summer of 2003 broadcast irrigation systems were installed in a portion of Sx orchard 305 and Pli orchard 307. Permanent sample trees were chosen in each orchard (82 trees in orchard #305 and 80 trees in orchard #307). Five rows in Lw orchard 332 were converted to the microsprinkler irrigation system in 2006 and 80 permanent sample trees were selected.

The sample trees were chosen in pairs based on establishment date, one tree in the area irrigated with the micro sprinklers and the other in the drip irrigated area. Three major branches on each sample tree were chosen at random and marked with metal tags. Shoot elongation is measured annually on each sample branch. Stem diameter below all branches is also measured annually on each sample tree.

In the summer of 2008 these measurements were repeated. Flower production was surveyed in the orchards and cones were collected from the sample trees. Foliar samples were also collected in the orchards and nutrient uptake has been analysed.

This trial will not be continued in 2009. Please see the results section for our conclusions.

Results

Vegetative Growth

The broadcast irrigation regime has been in effect for five growing seasons in orchards 305 and 307 and two growing seasons in orchard 332. The spruce and pine appear to grow better vegetatively in the broadcast irrigated areas. The larch does not seem to respond as well. Table 8 illustrates the differences in annual shoot growth.

Irrigation Treatment	All years average shoot growth
Pli 307 broadcast	16.1
Pli 307 drip	14.4
Pli 307 difference	1.7
Sx 305 broadcast	14.7
Sx 305 drip	11.4
Sx 305 difference	3.3
Lw 332 broadcast	15.3
Lw 332 drip	15.9
Lw 332 difference	-0.6

Table 8. Different annual shoot growth.

Seed Set

Seed was extracted from cones collected from equivalent sample trees and x-rayed. The broadcast irrigation did not seem to have a consistent positive effect on seed set as shown in Table 9.

Irrigation Treatment	All years FSPC average
Pli 307 broadcast	14.37
Pli 307 drip	12.73
difference FSPC	1.64
Sx 305 broadcast	68.45
Sx 305 drip	68.6
difference FSPC	-0.15
Lw 332 broadcast	62.6
Lw 332 drip	57.7
difference FSPC	4.9

Table 9. Filled seeds per cone.

Flower Production

What effect does broadcast irrigation have on flower production? Cones were counted on the permanent sample trees and compared. Table 10 indicates that broadcast irrigation lowers flower production in the spruce and larch. However, the Pli sample trees in the micro sprinkler rows produced more cones than equivalent trees in the drip section.

Irrigation Treatment	Average cones per tree 2008
Pli 307 broadcast	418
Pli 307 drip	353
Sx 305 broadcast	239
Sx 305 drip	331
Lw 332 broadcast	86
Lw 332 drip	113

Table 10. Average cones per tree.

Nutrient Uptake

Nutrient uptake is another area where broadcast irrigation seemed to have an effect. When the foliar samples were processed higher levels of aluminum, boron, calcium, manganese, nitrogen and phosphorus were observed in the samples collected from the portions of the orchards watered with the broadcast delivery system.

6.2.5 Crown Pruning Technique for North Okanagan Lodgepole Pine Seed Orchards

Chris Walsh
Prepared by Joe Webber

Project SPU 0720
Introduction

The design and management of most lodgepole pine seed orchards require some form of crown management as orchard trees mature. Lodgepole pine seed orchard 230 at Kalamalka was chosen for this pruning trial since the tree age (12-15 years) and height (4-6 m) in 2004 were such that crown management may be beneficial.

This project is testing three levels of height control and two levels of lateral pruning: Control (no topping), Moderate (3.5-4.0m) and Severe (2.5-3.0m) and two levels of lateral pruning: Tractor (remove only laterals extending into the row) and Picker (remove extending and upper crown laterals to improve crown access). Tree response to crown pruning treatments was measured as the number of cones per tree and cone seed yields on 20 randomly selected trees for each of the three top and two lateral pruning treatments.

Results

A complete analysis of all data is available in the final report for OTIP SPU0720 for the year 2008. This report summarizes the data from 2004 to 2008 for cone counts (whole tree and branch counts, cone dry weights) and seed yields (with and without insect protection).

Cone Count

Figure 12 shows the mean whole tree seed-cone counts (determined by total tree cone weights) for each of the three top and two lateral pruning treatments. Cone estimates for 2004-2006 are not shown because they were assessed visually. Cones harvested in 2007 were initiated and differentiated in 2005 (the year following pruning treatments) and the response clearly shows that cone production in both the Moderate and Severe top pruned trees equaled or surpassed cone production in the Control trees.

Access to the cones for management (harvest) also improved with pruning. Figure 13 shows the time (minutes) to pick 1000 cones. In 2007, cone harvest with ladders was faster in the topped trees and substantially faster in the lateral-pruned Tractor trees. In 2008, cone harvest was by machine and there was no difference in harvest times.

Cone Mass

Figure 14 shows dry cone weights for each of three top and two lateral pruning treatments. Cone dry weights did not change the year after pruning but did increase in pruned trees two years after pruning. Cones from the Tractor pruned trees showed the highest dry weights for 2006 and 2007 but again in the fourth year after pruning (2008) the differences in cone dry weights were similar across all treatments but slightly larger in the two Picker pruned treatments.

Data collected for dry cone weight also suggests that crown vigour improves in the topped and lateral pruned trees. Although cone dry weights varied between the blocks before treatments (2004 data), the data does suggest a trends to higher cone weights from the pruned blocks in the three years following pruning.

Seed Yields

Figures 15 and 16 show the mean total seed per cone (TSPC) and filled seed per cone (FSPC) in each of the three top and two lateral pruning treatments. There was no difference in yields across all blocks the year following pruning. We would expect this since the number of pollinated ovules was determined prior to pruning. There is a small, positive indication that TSPC in the Moderate and Severe pruning blocks were higher in 2006 and 2007. However, in 2008 the improved seed set values observed in 2006/07 were not apparent. This result may indicate that re-invigorating crowns by top pruning improves seed set for two or three years after pruning but then treatment effects begins to decline.

Similar results were observed for FSPC (Figure 16). Again, FSPC values were slightly better in the top pruned blocks for two or three years after pruning but as for TSPC, the effect was less apparent four years after pruning (2008).

Finally, Figure 17 shows the differences in seed yields for insect protection from each of the three top and two lateral pruned blocks for the four years following treatments. Seed loss to insect predation is not associated with a specific pruning treatment (data not shown) but the data does show that seed loss is affected by year. The highest losses were observed in 2006 in the order of 10 FSPC. In 2008, seed losses from unbagged cones was about 6 FSPC.

Conclusions

Four years after top and lateral pruning treatments were applied, cone numbers, cone weights and seed yields have equaled or exceeded those from the control block. The Tractor pruned blocks were easier (faster) to harvest in 2007 where ladders were used. However, in 2008 where machines were used, all blocks took about the same time to harvest. On average the 2008 cone crop took abut 25 minutes longer to harvest 1000 cones albeit, there were fewer cones spread over a similar crown volume.

It is also important to note that the lateral pruning for cone access (Picker) did not improve either seed yields or picking times. Cone and seed results suggest that cone response in lodgepole pine orchard trees is generally on the surface (closest to light) of the crown. Simply topping trees and pruning back lateral branch extending into the row only slightly improves production but does improve access for management.

Fourth year data suggests the decline towards lower yields may have begun in the third year after treatments. Fifth year results for 2009 will confirm trends and with statistical analyses, crown pruning recommendations can be made. However, it appears that a three year cycle of crown pruning may be a practical approach for managing crowns in KAL 230.

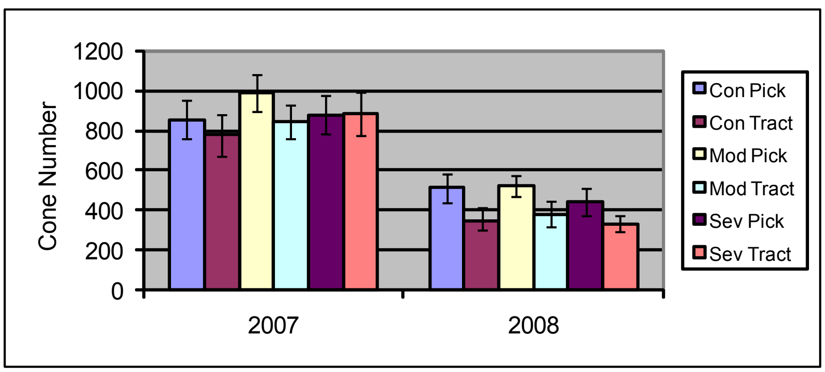


Figure 12. Mean (±standard error) whole tree seed-cone counts (calculated by whole tree cone weights) for 2007 and 2008 for each of the three top and two lateral pruning treatments – KAL 230.

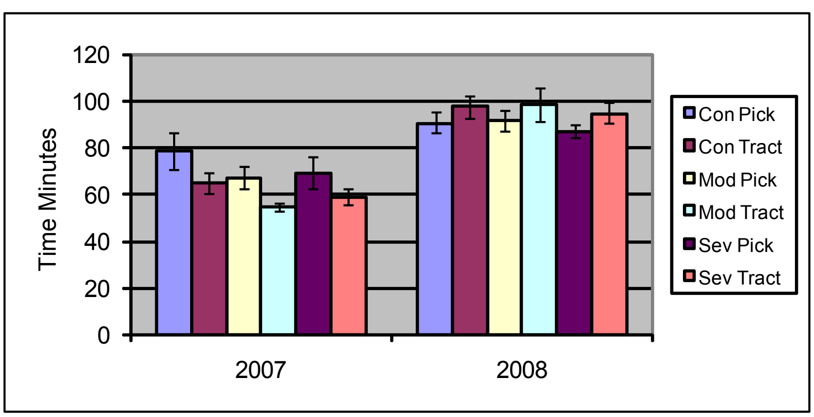


Figure 13. Time (minutes ±standard error) to pick 1000 cones for each of three top and two lateral pruning treatments for 2007 and 2008 - KAL 230.

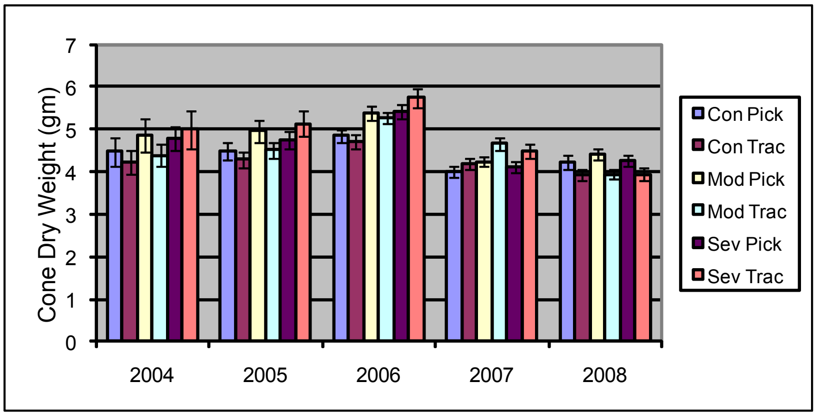


Figure 14. Mean (±standard error) seed-cone dry weight for each of the three top and two lateral pruned treatments for the period of 2004 to 2008 - KAL 230.

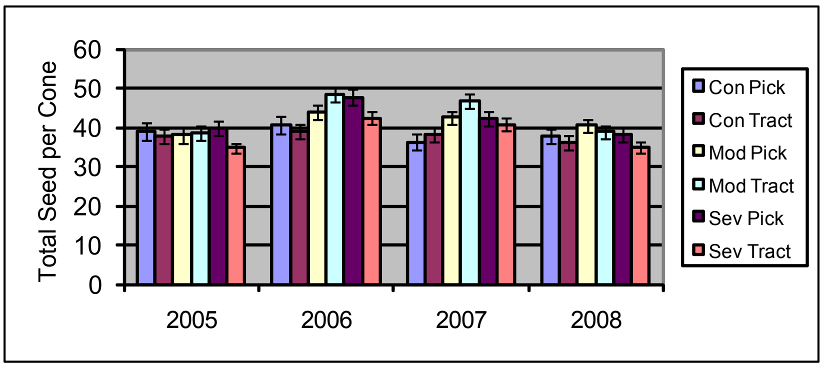


Figure 15. Mean (±standard error) total seed per cone (TSPC) for each of the three top and two lateral pruned treatments for the period of 2004 to 2008 - KAL 230.

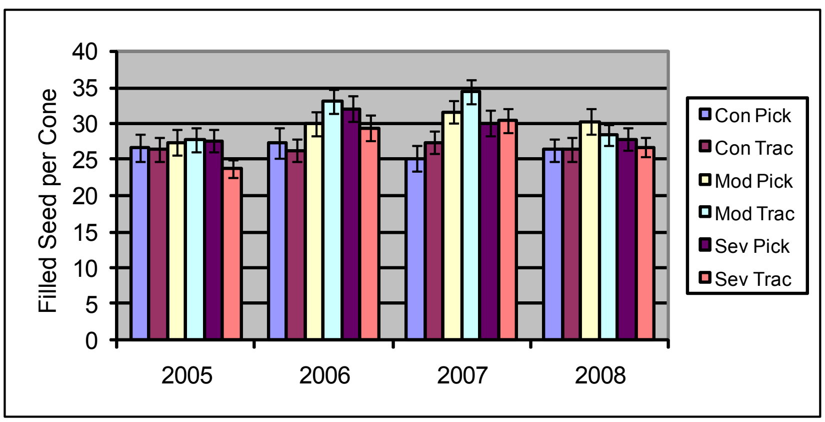


Figure 16. Mean (±standard error) filled seed per cone (FSPC) for each of the three top and two lateral pruned treatments for the period of 2004 to 2008 - KAL 230.

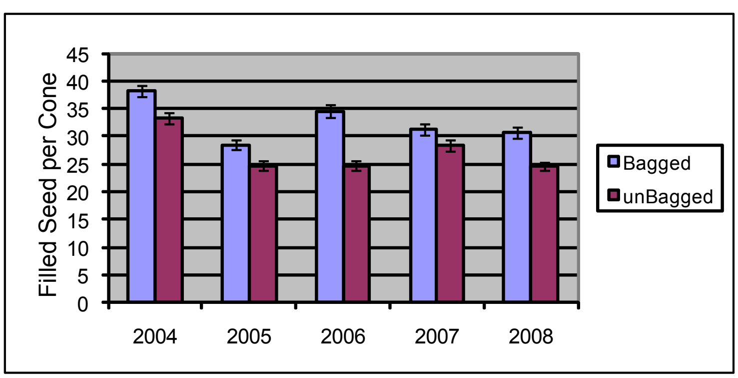


Figure 17. Mean (±standard error) filled seed per cone (FSPC) from cones protected from insects (bagged) and without insect protection (unbagged) for the period of 2004 to 2008 - KAL 230.

6.2.6 Lodgepole Pine Seed Set: North Okanagan Seed Orchards

Chris Walsh
Prepared by Joe Webber

SPU 0719

Introduction

Seed yields are declining in Kalamalka Orchard 307 to about 7-8 filled seed per cone (FSPC) compared to the highest yields observed in 2002 (16 FSPC). Since regular top pruning was halted a few years prior to 2002, tree height has increased and, in general, a loss of shoot vigour in the lower crown has occurred partially attributed to shading. Trees are about 6-7 m tall and crown width extends well into the row. In 2006, three treatments were applied to improve light intensity throughout the crown and increase lower crown vigour: basal pruning, row thinning and fertilizer application. Response from these three treatments was assessed by measuring cone numbers and seed yields. Seed loss from insects bagging (*Leptoglossus*) was also determined.

Basal pruning (Prune) removed branches at 1.5 m and lower. Selective branches in the mid crown were also pruned to increase light intensity. Increasing light to the lower crown was also achieved by removing trees in every second row within a block (Thin). No within-crown pruning was done on these trees. The two crown pruning treatments were completed in 2006.

A third treatment monitored the effect of two years fertilizer treatments applied in late June and late August during the approximate period of seed cone initiation and differentiation. Treatments began in 2006 and response in 2008 was measured as whole tree cone counts. The design for the fertilizer treatment was as follows: two reps of five-tree row plots in each of three treatments and two treatment dates:

Control (C) – no fertilizer

N-only (N) - applied as ammonium nitrate, and

Combo (Co) - a balanced fertilizer adding N, P, K and micro nutrients

A fourth treatment, applied in 2008, to increase light intensity in the lower crown, was achieved by creating a checker-board design of about 180 trees where every second tree within the row was removed.

Results

Whole tree cone counts, cone dry weights and seed yields were completed in a sub-sample (20 trees) of the two crown management treatments (Prune and Thin). Only whole tree cone counts from the fertilizer treatment was completed. Insect damage was assessed on Prune trees only.

Light Intensity on Cone Yields

The effect of basal pruning (Prune) and removing trees from every second row (Thin) was measured by cone wet and dry weights, cone numbers (first- and second-year) and cone yields (total and filled seed per cone). Figure 18 shows the mean cone (second-year cones) numbers per tree. Cone numbers declined in both the Prune and Thin trees. We expected to see fewer cone numbers in years one and two following pruning since many cones differentiated and first-year cones from 2006 would have been removed. There was a small increase in cone wet weight at harvest for both the Prune and Thin treatments over the adjacent Controls. However there was no difference in cone dry weights (data not shown).

For seed yields, there was about 3-4 TSPC and FSPC fewer from the Prune and Thin trees (Figure 19). We expected similar yields from the Prune and Thin trees to those from Control trees but both Prune and Thin trees had fewer TSPC and FSPC. We may infer from this data that cone yields vary by orchard location.

Figure 20 shows the first-year cone counts on each of four major whorl branches in the Control, Prune and Thin trees. Figure 20 also shows first-year cone counts from unpruned trees in the same rows as the Prune trees. Since first-year cones were differentiated the year following treatment, we can infer that higher cone numbers indicate that both treatments improve crown vigour leading to higher first-year cone numbers. Figure 21 shows the results for first-year counts from each of the mid- and lower-crown positions. Compared to unpruned tree, Prune trees produced about the same number of first-year cones as the Control trees. However, Thin trees produced the highest number of first-year cones in each of the two crown positions.

Fertilizer Effects

Figure 22 shows the 2008 whole tree cone response from each of the two fertilizer types and times of application. There was little effect of fertilizer on cone wet weight (data not shown) but late fertilizer application of ammonium nitrate did show a substantial increase in whole tree cone numbers: 626 cones for late N application versus 344 for late Control trees. There appears to be no effect of applying a balanced fertilizer either early or late. No data was collected for cone yields in this trial.

Insect Damage

Figure 23 shows the results of insect bagging on Prune trees only. Bagged cones produced 9.1 and 7.3 more TSPC and FSPC, respectively than unbagged cones. Seed loss due to insect predation continues to be a major source of seed loss.

Conclusions

One approach to increasing orchard seed yields in lodgepole pine is to increase the number of cones per tree. This project looked at two different methods to increase crown vigour and the number of potential flowering sites by improving light access and applying fertilizer during the period of seed cone differentiation.

Increasing light access did not substantially increase cone numbers two years after treatments. However, we would not expect to see treatment differences until three years after treatment. Both differentiated shoot buds (future seed cones) and first-year cones were pruned in 2006 and this explains the fewer cones per tree observed in 2008. First-year cone production (differentiated in 2007) was not affected by basal pruning but did show an increased number within the Thin trees. Experience from this trial and 0720 (crown pruning in KAL 230) suggest that pruned crowns do respond with higher cone and seed yields. Although it appears that improved cone response to increase light occurs, the data from both 0719 and 0720 will have to be analyzed statistically before specific recommendations are made.

Seed yields or cone dry weight did not improve with increased light. Both TSPC and FSPC values were slightly lower in the Prune and Thin trees and the dry weights for all three treatments was similar (4.5 gm).

Two consecutive years of fertilizing with ammonium nitrate applied in late August did increase cone numbers two years after treatments began. An early application of ammonium nitrate only marginally improved cone yields and the balanced fertilizer had no affect applied either in late June or late August. According to Mahalovich and Naffin (USDA For. Sci. Lab, Moscow, ID, 2002) late application of ammonium nitrate (September) was an effective cone enhancement treatment in ponderosa pine but only after three years treatment. If this response also occurs in lodgepole pine, then we can expect a further increase in coning response in the late application of ammonium nitrate in 2009.

Insect predation (bagging) continues to be an important factor affecting seed loss. Protected cones had about 10 and 9 more TSPC and FSPC, respectively. In general the meteorological conditions for seed production in 2008 were moderate. It was neither excessively hot nor dry during any of the critical periods of reproductive development (pollination, early and late embryo development). However, the trend for lower seed yields continues. Why seed yields across all north Okanagan lodgepole pine seed orchards continue to be less than expectations is not known. Certainly insect damage is a major contribution but there are still about 10-15 TSPC and 5-10 FSPC fewer seed that can not be accounted for.

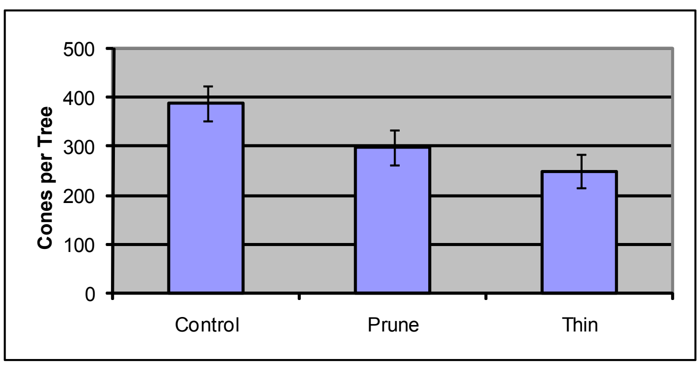


Figure 18. Mean (±standard error) total number of cones harvested from each of the three treatments (Control, Prune and Thin) to improve light penetration throughout the crown - KAL 2008.

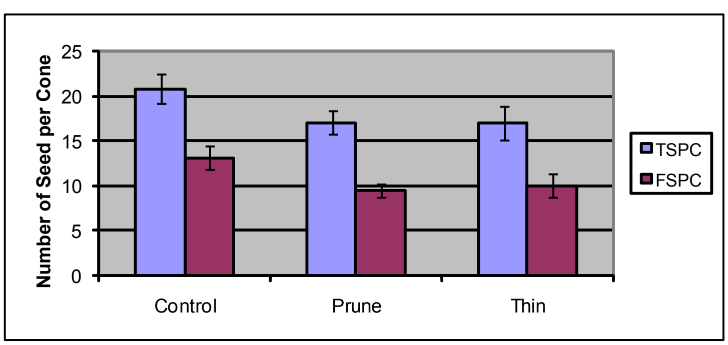


Figure 19. Mean (±standard error) total seed per cone (TSPC) and filled seed per cone (FSPC) for basal pruning (Prune), tree removal (Thin) and no treatments (Control) to improve light penetration throughout the crown - KAL 2008.

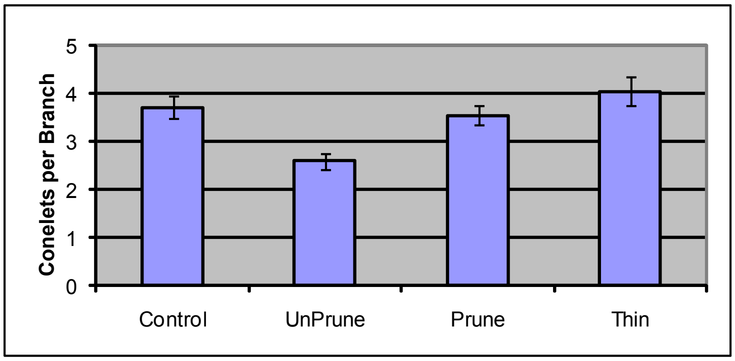


Figure 20. Mean (±standard error) total number of first-year cones counted from four major whorl branches from each of four treatments (Control, UnPrune, Prune and Thin) to improve light penetration throughout the crown - KAL 2008.

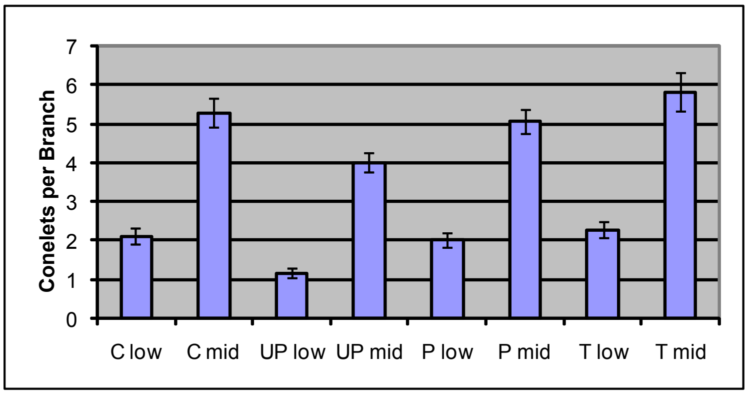


Figure 21. Mean (±standard error) total number of first-year cones counted from two major whorl branches in the lower and mid crown from each of three treatments: Control (C), UnPrune (UP), Prune (P), and Thin (T) to improve light penetration throughout the crown - KAL 2008.

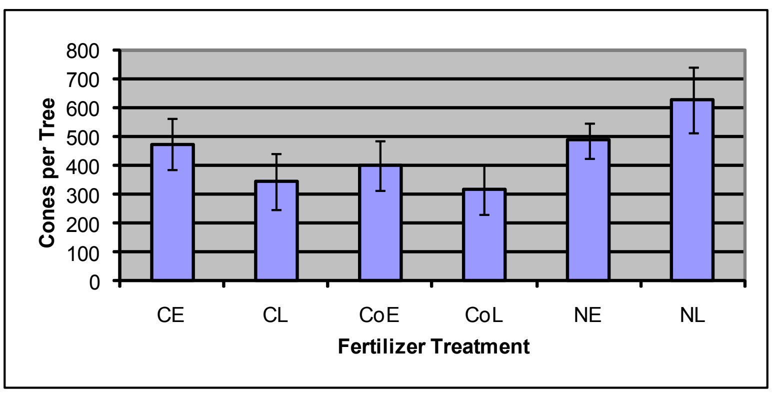


Figure 22. Mean (±standard error) total number of cones harvested from each of three fertilizer treatments and two applications times (June and September) - KAL 230.

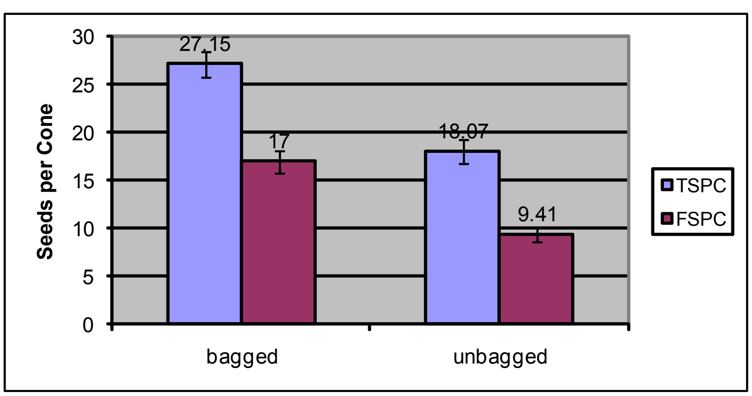


Figure 23. Mean (±standard error) total seed per cone (TSPC) and filled seed per cone (FSPC) for upper crown cones protected from insects (bagged) and not protected (unbagged) from prune block trees - KAL 2008.

6.2.7 Quantifying the Impact of Exclusion Cages on Yields of Viable Seed from Trials in Lodgepole Orchards in the Okanagan

Gary Giampa

Introduction

This work was intended to determine whether the use of mesh exclusion bags significantly affects results from investigations into the poor seed set obtained in lodgepole pine seed orchards in the Okanagan. In particular, the effect of exclusion bagging of the first year conelets was investigated.

Activities

Mesh exclusion cages were used to cover Pli cones through different phases of their development from pollination to maturity. The four treatment regimes were: i. Never bagged; ii. Bagged through the first growing season; iii. Bagged through the second growing season, and iv. Bagged through both growing seasons.

Samples will be harvested and processed when the cones reached maturity in the fall of 2009. Numbers of filled seed per cone (FSPC) will be recorded for each sample, and this parameter will be compared across the different exclusion treatments used in the experiment.

All work is being done in consultation with Jim Corrigan, Interior Seed & Cone Pest Management Biologist.

Results

Cones were selected for specific treatments immediately after pollination in the spring of 2008. The sample cones were identified with coloured flagging and metal tags. Phase ii and iv bags were installed as soon as the flowers were no longer receptive. These bags remained in place until the end of October and were removed for the winter. Phase iii and iv bags will be installed in the spring of 2009.

Output and Deliverables

Results should suggest ways to improve seed set in north Okanagan Pli orchards. In particular, we hope to show whether bagging protection of first-year conelets has an effect on seed yields. This would then indicate whether operational protection of first-year conelets is warranted (e.g. by spraying insecticides). A report will be produced and distributed to all interested parties.

6.2.8 Collection of Crop Statistics for Interior Lodgepole Pine Orchards

Michael Carlson
Prepared by Joe Webber

SPU 0722
Introduction

Seed production from north Okanagan orchards is significantly less than expected. To determine the source of these losses and make recommendations for orchard management practices to improve seed production, the Lodgepole Pine Task Force (January 2006) suggested that standardized orchard statistics be collected for all producing orchards. This project developed standard methods for estimating the number of cones per tree based on cone weight and for estimating cone yields (filled seed per cone, total seed per cone, seed weight), and seed losses due to bagging effect (insect predation). As these data are collected over several years, trends in yearly variation in cone numbers and seed yields will help determine why seed set in the north Okanagan lodgepole pine seed orchards is chronically low. This report summarizes some of the data collected for OTIP Project 0722 over the past three years. The detailed final report for SPU0722 (2008) is available from the OTIP coordinator.

Results

In the spring of 2006, 15 single tree ramets (clones) were selected to include both early, mid- and late-flowering phenology periods for each of nine north Okanagan and three Prince George lodgepole pine orchards. The number of cones per tree was estimated by whole tree cone weights. This method removed a source of error that resulted from estimating cone numbers by volume.

Figure 24 shows the mean (± standard errors) whole tree cone numbers for the 15 selected trees from each of 12 lodgepole pine orchards for the monitoring period of 2006 to 2008. Kalamalka consistently produced the highest number of cones (both orchards) and Prince George, as expected, produced the fewest. However, any further comparison would be difficult because we do not have data for crown volume and tree age.

The mean (± standard errors) yields for FSPC (filled seed per cone) and TSPC (total seed per cone) based on a 30 cone samples for each of the 12 orchards are shown in Figures 25 and 26, respectively. In some orchards and years, data was not collected. Seed yields were substantially lower in 2008. Both FSPC and TSPC were the lowest observed for the period of 2006 to 2008. We expect about 35-40 potential seed from lodgepole pine but in 2008 we observed only 10-12 TSPC and about 8 FSPC (excluding KAL 230 and PG orchards).

Figure 27 shows seed yield production for the whole tree. Data were not calculated from cone (Figure 24) and seed yields (Figure 25) for whole tree seed production. Mean tree seed yields were down substantially in 2008 across all north Okanagan orchards and with the exception of KAL 230 and PRT 311, none met planning estimates of 1500 seed per ramet.

Seed cones protected by bagging (insect protection) produced about 8.7 FSPC (Figure 28) more than those cones without bags. This represents the largest loss of seed in the three years observed (for bagging effect). Seed losses for TSPC were about 10 per cone (data not shown). Bagging effect is a principle factor in accounting for seed losses proving seed production for 2008.

Cone size also varied across all sites and orchards. Figure 27 shows the mean (± standard errors) cone dry weight for each of the 12 orchards. Prince George produced the largest cones (averaging around 8.5 gm dry weight) and the mean cone dry weight of north Okanagan orchards was 4.7 gm ranging from 4.1 (PRT 308) to 5.8 (PRT 313). Mean lodgepole pine seed weights is about 3.8 mg (data not shown) for both north Okanagan and Prince George sites. Lower seed yields from north Okanagan orchards only accounts for a small difference in dry cone weights from the two sites.

Figure 30 shows the mean number of filled seed per gram of dry cone weight. This data may help us quantify the relationship between cone seed yields and cone size. Although cone size varies by orchard, they are similar for each of the three years observed (Figure 30). However, seed yields are down substantially in 2008 resulting in a lower number of seed per gram dry cone weight.

At PGTIS, about 3 filled seed per gram cone dry weight were produced in each of the three years. The highest number of seed per gram cone dry weight was recorded at KAL 230 with values of about 4-5 in each of the three years. The lowest values of seed per gram cone dry weight were observed at KAL 307 and the three VSOC orchards (all less than 1). PRT had the highest number of seed per gram cone dry weight for the north Okanagan orchards (except KAL 230) at about 2.5. Averaged across all north Okanagan orchards (except KAL 230), the number of seed per gram dry cone weight in 2008 (see Figure 28) was about half the value observed in 2007.

Conclusions

The purpose of collecting orchard statistics is to standardize the methods to estimate cone and seed production in all producing lodgepole pine seed orchards. The method to estimate cones per tree (based on cone weight) made comparisons between orchard sites and individual orchards more meaningful. This is also true for estimates of cone analyses (FSPC, TSPC and seed weight) for general orchard production and bagging effects (insects).

While the Prince George orchards produced the highest seed yields (FSPC), they also produced the fewest cones per tree. This made production from the north Okanagan orchards compared to those from Prince George more equitable.

In general, Okanagan orchards produce more cones per tree but fewer filled seed per cone. Overall production of filled seed per tree from Okanagan orchards still lags behind that of Prince George but if losses attributed to bagging effects (insect damage) were mitigated, then production from the north Okanagan orchards would be similar or even greater than those from Prince George.

Over the three years data have been collected, production from most north Okanagan orchards is considerably lower than we expect (potentially). Cones not protected by bagging (insect predation) remain a significant factor. Assuming that seed loss is due to insects and control measures could eliminate this effect planning estimates for ramet production could be met.

Even if we could increase seed yields from about 6 FSPC (mean 2008 values with KAL 230 and PG excluded) to 14 FSPC (eliminate bagging effect), yields would still be substantially lower than the number of potentially fertile ovuliferous scales predict. In the north Okanagan, we still can not account for about 8-10 FSPC which are observed in Prince George (mean yields around 21-30 FSPC).

This report did not include comparisons between orchard management practices (i.e., SMP and cultural). In general, however, where these practices were applied, they may have helped protect against even further losses had they not been applied but equally so, they did not result in yields at or near planning estimates for lodgepole pine in the north Okanagan.

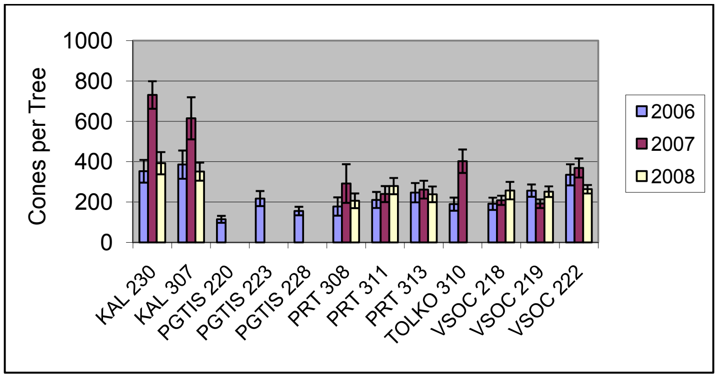


Figure 24. Mean number of seed cones (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

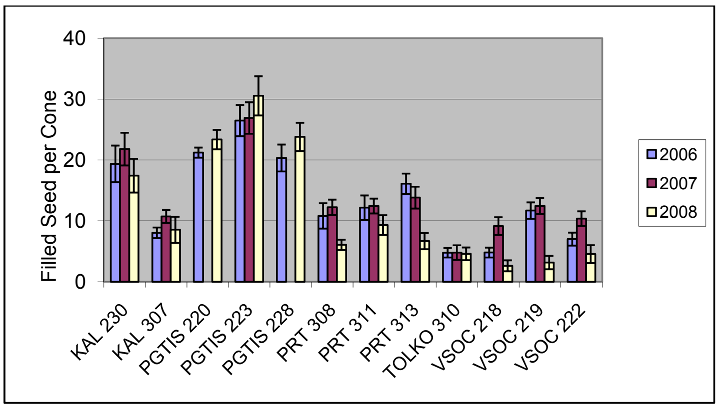


Figure 25. Mean number of filled seed cones (FSPC) (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

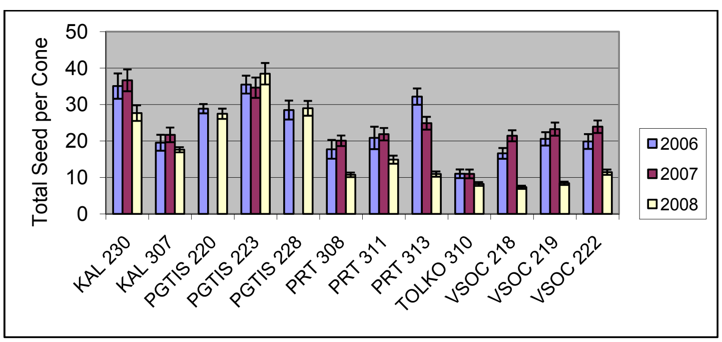


Figure 26. Mean number of total seed per cone (TSPC) (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

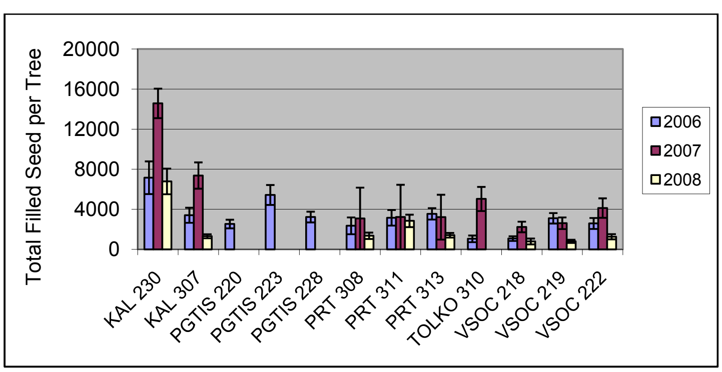


Figure 27. Mean number of filled seed per tree (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

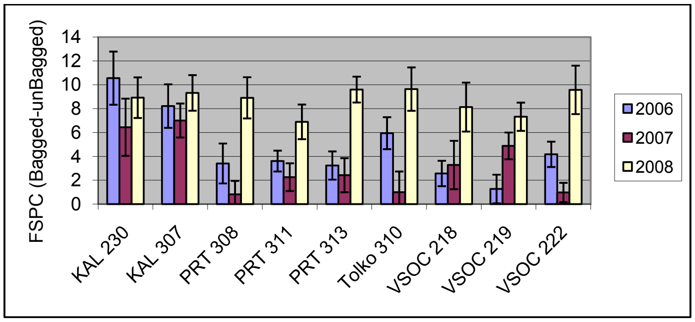


Figure 28. Mean difference number of filled seed per cone (±standard error) between insect bagged cones and unbagged cones from each of nine north Okanagan orchards. 2006-2008.

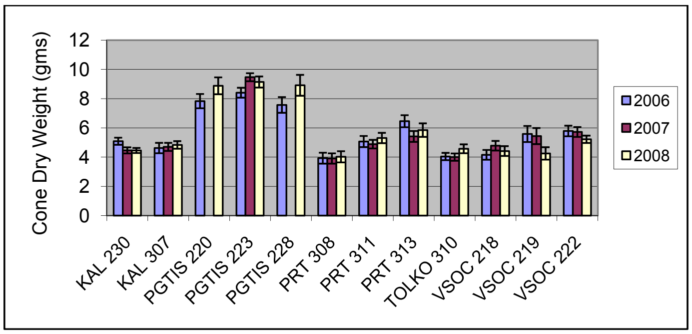


Figure 29. Mean dry cone weight (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

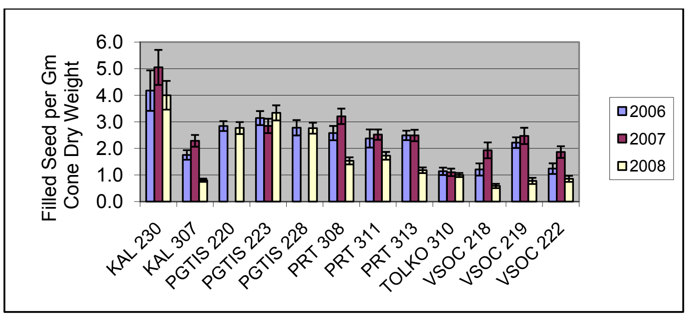


Figure 30. Mean number of filled seed per gram cone dry weight (±standard error) from each of five orchard sites and twelve lodgepole pine seed orchards, 2006-2008.

6.2.9 Competitive Effects of Selfing and Outcross Pollen on MGR SMP Efficacy in White Pine

Joe Webber
Michael Stoehr

SPU 0814
Introduction

The resistance of white pine seedlings from orchard seed is partially dependent of the incorporation of major gene resistant (MGR) pollen from Dorena Lake populations through SMP. Since mature orchards can produce large orchard pollen loads including self pollen), the efficacy of SMP is uncertain. Currently, orchards (all species) are awarded a blanket 25% efficacy value but this has never been tested for white pine.

The problem of incorporating the MGR pollen is further exacerbated by a propensity of white pine to self. In fact white pine is an oddity in the Pinaceae family. Selfing in other species is limited to a few clones (10-15%) that produce a few seeds. However, white pine can produce high quantities of seed when selfed.

Since the seed potential in white pine is about 150-200 FSPC, the ability of both outcross orchard pollen and self to out compete MGR pollen makes improvement of Pw resistance an added challenge. Before developing alternate orchard strategies for producing seed with the highest resistance genetic worth (GW), we need to determine the selfing ability of selected clones in competition with orchard and MGR pollen sources (outcross) using current operational SMP technique. SMP efficacy was determined by comparing seed set from bagged and SMP treatments as well as molecular (DNA finger printing) technique. This report provides a summary of the seed yields and paternity analyses. A more detailed report is available from the final report for project 0814 (2008).

Procedures

Pollination Treatments

CanFor white pine seed orchard 174 has about 40 clones of which 20 were producing heavy crops in 2007. Two ramets from each of 10 top resistant parents were selected. Five pollination treatments were completed. On each of the two ramets, three control pollinations were completed. On one of the two ramets either MGR (poly-mix of ten clones) or self pollen was applied using orchard SMP technique. The number of treatments is as follows: Pollen was applied using spritizer type applicators and each bag and SMP cluster were treated between 3- 5 times.

Self	10
MGR	10
50/50 self/MGR	10
Self SMP	10
MGR SMP	10

Cones were collected in the fall of 2008 and cured in a growth chamber at 30°C for two weeks. All cones from each of the five lots from each of the 10 clones were hand extracted and total seed per cone (TSPC) and filled seed per cone (FSPC) determined by x-ray analyses.

Paternity Analysis

Seed from each of the five crosses and 10 clones were analyzed by Dr. Craig Newton, ATG Genetics Inc. The previously identified hypervariable region of the white pine chloroplast genome was used to establish baseline genotypes of orchard clones and seed resulting from control crosses and SMP. Since the chloroplast DNA (cpDNA) is inherited paternally in conifers, i.e., through the pollen, it is an ideal genetic marker to determine the pollen parent of a wind-pollinated seed. A total of 14 possible hypervariable regions are located in white pine cpDNA. Each region was tested using 10 parental genomic DNAs. Between 4 and 6 of the most informative (polymorphic) cpDNA regions were selected for orchard parents and seed analyses.

Results - Seed Yields

		Bagged			SMP	
Clone	Tree	Self	MGR	50/50	Self	MGR
47	1	0.7	122.8	82.0		44.3
47	2	na	109.0	54.4	na	
65	1	35.7	na	55.0		72.7
65	2	na	93.0	100.0	97.2	
114	1	43.0	37.0	64.0		na
114	2	56.0	63.7	53.5	55.3	
139	1	27.4	69.8	63.8		93.1
139	2	24.7	48.3	69.5	48.3	
145	1	34.1	86.3	69.0		80.4
145	2	66.0	113.8	68.0	71.4	
180	1	5.0	57.4	37.0		34.0
180	2	na	56.6	28.7	23.5	
407	1	na	64.0	na		80.8
407	2	24.7	58.7	na	66.3	
408	1	38.0	38.5	31.0		42.7
408	2	35.5	37.7	42.5	27.3	
640	1	16.0	97.6	46.3		58.6
640	2	10.0	53.0	30.7	40.0	
21139	1	11.8	122.0	75.8		103.4
21139	2	10.0	na	85.7	32.3	
	Means	**25.8**	**73.8**	**58.7**	**51.3**	**67.8**

Table 11. The number of filled seed per cone (FSPC) for each of ten clones and two ramets from the MGR/Self SMP Treatments 2007 - Sechelt 174.

Table 11 shows the filled seed per cone (FSPC) for each of the 10 selected clones and 2 ramets per clone. All control crosses (bagged) were completed on two ramets. SMP treatments were completed on single ramets (to avoid confounding effects of self and MGR SMP treatments on the same ramet). Figure 31 shows the mean seed total seed per cone (TSPC), filled seed per cone (FSPC), and percent filled seed per cone (ratio of FSPC to TSPC) for each of the five pollination treatments. Mean seed yields from self only pollen was 25.8 FSPC with a range of 0 to 66 FSPC for the 10 clones and 2 ramets. Mean seed yields from MGR only pollen was 73.8 FSPC with a range of 37.7 to 122.8 for each of the 10 clones and 2 ramets per clone. The mean seed yields from the 50/50 mix of self and MGR pollen was 51.3 FSPC with a range of 28.7 to 100. The mean seed yields for the two SMP treatments (self and MGR) was 51.3 and 67.8 FSPC, respectively The range in seed yields for the two SMP treatments was 23.5 to 97.2 for self and 34.0 to 103.4 FSPC for MGR.

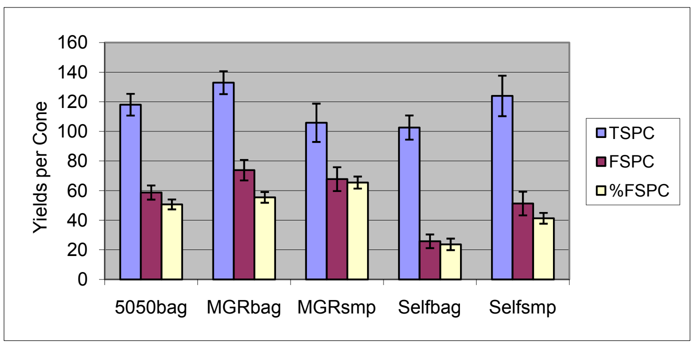


Figure 31. The mean number (±standard error) of total seed per cone (TSPC), filled seed per cone (FSPC) and percent filled seed per cone (%FSPC) for each of five pollinations treatments - Sechelt 174.

Clearly white pine self yields are significant but still about 40% less than outcross, MGR pollen (bagged results). The mean seed yield (FSPC) calculated from control cross self and MGR pollen is about 50 FSPC. Seed yields from a 50/50 mix of self and MGR pollen is 58.7 FSPC. This suggests that MGR pollen does out-compete self pollen but self pollen in the polymix does lower seed yields (by about 8-10 FSPC).

Seed yields from self SMP are about twice that of self bagged yields. Based on this data, about 50% of seed in the self SMP is sired by outcross orchard pollen. Seed yields from MGR SMP are about 10% greater than the MGR bagged yields suggesting the SMP efficacy of MGR is about 90%. However, if the potential outcross yield from self SMP is about 50%, then the 90% SMP result from MGR SMP is too high (not accounting for orchard outcross pollen).

Paternity analyses suggest the MGR efficacy ranges between 76 and 84% (Table 12). This data shows the mean frequencies of the two unique MGR genotypes (M2 and M10) from the number of seed analyzed. M10 does not occur in either of the nine other MGR sources or the orchard population. M2 also does not occur in the other MGR sources but it does occur in low frequencies (0.04) in the orchard population. The frequencies of M2 from both bagged and SMP seed were higher than those from M10. While we would expect somewhat higher frequencies for the M2 SMP results (M2 also occurs in the orchard population), we would not expect it to be any higher than the M10 frequency from bagged seed. This suggests that the fertility potential of the two unique MGR parents (and the remaining 8 other MGR parents) are not equal even though the poly-mix was prepared with equal volumes of the 10 lots.

MGR-2			MGR-10		
Observed Frequency SMP	Expected Frequency Bagged	SMP Efficacy %	Observed Frequency SMP	Expected Frequency Bagged	SMP Efficacy %
0.114	0.150	76%	0.078	0.093	84%

Table 12. Mean frequencies of occurrence of MGR sources M2 and M10 in the SMP MGR seed lots with estimates of SMP efficacy from the 10 clones of white pine orchard 174 Sechelt.

Conclusion

SMP efficacy in white pine is the highest (about 75-80%) determined for any BC conifer species. White pine has a large receptive flower and the distance between ovuliferous scales makes access to pollen more efficient. In this trial, applying pollen with a hand spritzer and multiple visits was very effective and self pollen did not compete significantly with outcross MGR pollen. Data suggest SMP is an effective tool in white pine to improve blister rust resistance in planting stock and the current flat rate of 25% applied to SMP efficacy in other BC species may not apply to white pine.

6.3 Mountain Pine Beetle Incremental Projects

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

Gary Giampa

Objectives

To protect 4832 pine trees in three seed orchards from MPB attack and preserve seed production capacity.

Activities

In consultation with the Interior Seed Orchard Pest Management Biologist, we applied insecticide to tree stems in seed orchards 230, 307 and 335 prior to the 2008 MPB flight. An Integrated Pest Management (IPM) 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.

Orchard trees were basal pruned in order to expose the boles. Improved spray access to the boles resulted in better insecticide coverage.

Results

Monitoring data indicated that all mature Interior pine seed orchards were exposed to potentially harmful population levels of MPB in the summer of 2008. The prophylactic spray provided total protection. We did not lose any of the 4382 susceptible trees to MPB in 2008.

Output and Deliverables

Results from the 2008 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.

7.0 Extension and Communications

7.1 ETAC Activities

Diane Douglas

Workshops and Meetings

A White Pine Workshop was held in Vernon, BC, June 17 & 18, 2008. It was co-sponsored by ETAC, RSI Forest Health and a workshop fee facilitated through Jack Woods and SelectSeed Ltd. The organizing committee consisted of Vicky Berger, Michael Carlson, Michelle Cleary, Diane Douglas and Stefan Zeglen. 90 BCTS, MFR and industry folks participated. Speakers included Rich Hunt, Stefan Zeglen, Michelle Cleary, Det Vogler, John King, Mary Frances Mahalovich, Stan Hadikin and Les Jozsa. A field component of the workshop was held on the second day.

Plates 31 & 32. Western White Pine Workshop, June 2008 - field tours to Baird Lake realized genetic gain trial site and Bailey Seed Orchard Site.

Coastal Tree Improvement History get togethers were held in Vancouver and Victoria to honor the pioneers in the forest genetics/tree improvement at the coast; work initiated 50 years ago

Plate 33. 50 Year Celebration of History of Tree Improvement at the Coast - Vancouver, fall 2008. Simon Orr-Ewing, Grant Ainscough, Don Grant, Sven Rasmussen, Gerry Burch, Alvin Yanchuk, John Barker, Alec Orr-Ewing, Jack Woods, Brian Barber, David Reid.

Plate 34. 50 Year History Celebration of Tree Improvement at the Coast - Victoria, spring 2009. Rob Bowden-Green, Brian McCutcheon, Keith Illingworth, Vlad Korelus, Bill Dumont, Gerry Burch, Dave Wallinger, Chris Heaman, Mike Meagher, Jack Woods, David Reid, Brian Barber.

A UBC extension session was held March 4 & 5, 2009 with 36 people in attendance and the opportunity to hear presentations by UBC students.

Publications

The bulletin "Whitebark Pine – Conserving a Species at Risk" was developed and web published at: http://www.for.gov.bc.ca/hti/whitebark/WhitebarkPine_Bulletin-July08.pdf

"Developing Sitka Spruce Populations for Resistance to the White Pine Weevil (Summary of Research and Breeding Program- Technical Report 050 by John N King and Rene I Alfaro was published in 2009. ETAC contributed to the desk top publishing of this report. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr050.htm

TIC*talk*, Volume 9 (December 2008) consisting of 31 pages featured articles varying from "Tree Seed Centre celebrates 50 years of Excellence" to "Estimating Pollen Contamination". http://www.fgcouncil.bc.ca/tictalk_2008-final2-web.pdf

"The Forest Genetics Council Extension Technical Advisory Committee Continuous Improvement Report and Recommendations for Program Evaluation" was produced by FORREX in the spring of 2009.

A Forest Genetics Council display unit draft is being developed.

8.0 Seed Orchard Pest Management

Robb Bennett

The Seed Orchard 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 and Dr. Robb Bennett) deliver 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 2008-09 fiscal year, the PMTAC administered projects on conifer seed bug, fir cone worm, *Fusarium* fungi, conifer adelgids, 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	2nd year of work based on our discovery that seed bugs use infrared wavelengths to find hosts showed that: cone IR profiles have clonal basis; seed bugs also respond strongly to green/blue wavelengths.
Conifer seed bug (*Leptoglossus occidentalis*): Mark/release/recapture	All Pinaceae	This new project's objectives are to determine spring immigration patterns, within orchard dispersal, and population abundance and test a visual monitoring system. Interesting preliminary results support bug attraction through infrared wavelengths to Pli and Sx cones as well as clonal susceptibility due to terpenoid differences
Fir coneworm (*Dioryctria abietivorella*): Life history and reproductive behaviour	Fd, Sx, Lw, Pw	The 2nd year of this 3-year project produced these results: females multiply, mate during flight period and apparently do not disperse until mated; male flight period is much longer than female period (determined by light and pheromone trapping); female "calling" behaviour occurs throughout the night and is dominated by "middle-aged" and older females.
Fusarium fungi: Reducing infections in orchard seed & determining infection mechanisms	All species	Research completed. Summary report encapsulating results of several related projects is under revision prior to publication.
Conifer adelgids (*Adelges* & *Pineus* spp.): Species composition, gall formation, and life history	Sx, Lw, Fd, Pw	Project completed & M.Sc. defended. Conclusions: susceptibility to galling is genetic and heritable; fundatrices induce and gallicolae complete gall formation; presence of fundatrices and gallicolae are both required for gall production; management should target fundatrices; gall morphology is distinctive for genera and for some species.
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 culmination of pesticide trials using new formulations and novel injection hardware produced inconclusive results. New trials using new chemistries applied as broadcast sprays are being tested in 2009/10.
Cone and seed insect field guide	All species	New images of a variety of cone and seed insects have been made. Fact sheets for 13 high priority insects have been drafted and are under review prior to publication.
Interior pest management extension operations	All interior species	In its 1st year of administration by PM-TAC this project 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 13. Seed Orchard Pest Management Projects.

Plate 35. Infrared image of white pine cone: *Leptoglossus* find cones by sensing infrared. (photo W. Strong)

Plate 36. *Leptoglossus* marked E86 - one of those that was recaptured the year after marking. (photo W. Strong)

Plate 37. "Bug dorms" used to contain *Leptoglossus* in mark-release-recapture experiments. (photo W. Strong)

Plate 38. Babita Bains sets up a 4-way Malaise trap to intercept flying adult Adelgids. (photo W. Strong)

Plate 39. Grad student Caroline Whitehouse checks a *Dioryctria* pheromone trap. (photo W. Strong)

Appendix 1 FGC Seed Planning Unit

SPU Unit (OTIP)	Seed Planning Unit (SPU)	Species	Seed Planning Zone (SPZ)	Elevation Band (metres)	
		Common name		Min	Max
1	FDC M LOW	Douglas-fir	M	1	700
2	CW M LOW SOUTH	Western redcedar	M	1	600
3	HW M LOW SOUTH	Western hemlock	M	1	600
4	SX NE MID	Interior spruce	NE	800	1500
5	SX NE HIGH	Interior spruce	NE	1500	1900
6	SS M LOW SOUTH	Sitka spruce	M	1	500
7	PLI NE LOW	Lodgepole pine	NE	700	1400
8	PW M LOW	Western white pine	M	1	1000
new	PW M HIGH	Western white pine	M	1000	1400
9	BA M LOW	Amabilis fir	M	1	700
10	PLI TO LOW	Lodgepole pine	TO	700	1100
new	PLI TO MID	Lodgepole pine	TO	1100	1400
11	YC M ALL SOUTH	Yellow-cedar	M	1	1100
12	PLI PG LOW	Lodgepole pine	PG	700	1200
13	LW NE LOW	Western larch	NE	700	1400
14	SX PG LOW	Interior spruce	PG	600	1200
15	PW KQ ALL	Western white pine	KQ	500	1200
16	PLI TO HIGH	Lodgepole pine	TO	1400	1600
17	PLI BV LOW	Lodgepole pine	BV	700	1200
18	PLI CP LOW	Lodgepole pine	CP	700	1100
19	FDC SM LOW	Douglas-fir	SM	200	1000
20	PLI NE HIGH	Lodgepole pine	NE	1400	2000
21	FDI NE LOW	Douglas-fir	NE	400	1000
22	FDI NE HIGH	Douglas-fir	NE	1000	1600
23	SX SM ALL	Interior sitka hybrid	SM	1	1800
24	HW M HIGH SOUTH	Western hemlock	M	600	1100
25	SX EK ALL	Interior spruce	EK	750	1700
26	PLI PG HIGH	Lodgepole pine	PG	1200	2000
27	CW SM ALL	Western redcedar	SM	200	1000
28	SX TO HIGH	Interior spruce	TO	1300	1900
29	PLI EK HIGH	Lodgepole pine	EK	1500	2000
30	SX TO LOW	Interior spruce	TO	700	1300
31	FDC M HIGH	Douglas-fir	M	700	1200
32	PLI EK LOW	Lodgepole pine	EK	800	1500
33	CW M HIGH	Western redcedar	M	600	2000
34	LW EK ALL	Western larch	EK	800	1500
35	SX BV LOW	Interior spruce	BV	500	1200
36	BG M LOW	Grand fir	M	1	700
37	FDI QL LOW	Douglas-fir	QL	700	1200
38	HW M LOW NORTH	Western hemlock	M	1	600
39	FDI EK ALL	Douglas-fir	EK	700	1400
40	SX PR LOW	Interior spruce	PR	450	650
new	SX PR MID	Interior spruce	PR	650	1200
41	FDI PG LOW	Douglas-fir	PG	700	1000
42	SX PG HIGH	Interior spruce	PG	1200	1550
43	FDI CT LOW	Douglas-fir	CT	600	1200

Source: Ministry of Forests, Tree Improvement Branch (SPU, Version 3.0; April, 2005)

Appendix 2 Tree Species

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

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

Appendix 3 Author Contact List

CONTRIBUTOR	AFFILIATION	TELEPHONE NUMBER
Aitken, Sally	UBC	604-822-6020
Ashley, Valerie	MFR	250-260-4753
Barber, Brian	MFR	250-356-0888
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
Crowder, Tim	TimberWest	250-652-4211
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
Hayton, Lisa	MFR	250-387-5443
Hooge, Bonnie	MFR	250-963-8416
Hunt, Rich	CFS	250-746-7259
Jaquish, Barry	MFR	250-260-4766
King, John	MFR	250-387-6476
Krakowski, Jodie	MFR	250-749-6811
Kolotelo, Dave	MFR	604-541-1683
Kong, Lisheng	UVic	250-721-8926
Lohr, Carolyn	MFR	250-652-5600
McAuley, Leslie	MFR	250-356-6208
Noshad, David	MFR	250-363-6003
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
Ponsford, Dave	MFR	250-387-1058
Reid, David	MFR	250-652-5600
Russell, John	MFR	250-749-6811
Stoehr, Michael	MFR	250-356-6209
Thomas, Keith	MFR	250-356-1127
Ukrainetz, Nick	MFR	250-260-4761
van Neijenhuis, Annette	WFP	250-652-4023
von Aderkas, Patrick	UVic	250-721-8926
Wagner, Rita	MFR	250-963-8416

CONTRIBUTOR	AFFILIATION	TELEPHONE NUMBER
Wagner, Tia	VSOC	250-542-0833
Walsh, Chris	MFR	250-260-4777
Webber, Joe	ProSeed Consulting	250-537-8871
Woods, Jack	SelectSeed	604-734-5778
Xie, Chang-Yi	MFR	250-387-8911


2008 / 2009

Forest Genetics Council of BC

Tree Improvement Program

Project Report






FGC Forest Genetics Council of British Columbia

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Forests and Range

FOREST SERVICE BRITISH COLUMBIA