FGC Forest Genetics Council of British Columbia

Tree Improvement Program

Project Report 2002/2003

Forest Service · British Columbia

Front Cover Interpretations

Breeding for resistance to the white pine or terminal weevil has been the key element in the Sitka spruce tree improvement program and is also an important feature of the interior spruce program. Fortunately strong natural resistance has been found in some of our native populations and this is being incorporated in our full-sib breeding program as well as in our seed orchards. A strong collaborative research effort with the BC and Canadian Forest Services, Simon Fraser University, UBC and our industrial collaborators especially Western Forest Products has definitely been an important part of our successes to date. The next phase in this effort is to more fully understand the mechanisms behind this genetic resistance and how it is inherited.

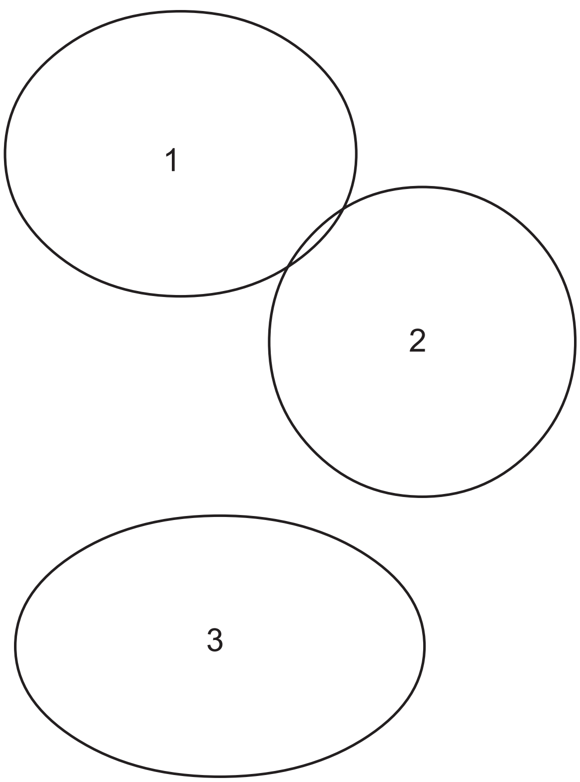

Plate 1.

Investigating weevil damage on full-sibs of interior spruce at Kalamalka. Interior spruce and especially eastern populations of white spruce are more resistant than Sitka spruce. Understanding why this is so may help in identifying strong and durable genetic resistance to the weevil

Plate 2.

Caging experiments have been important in understanding questions emerging about weevil resistance. What drives weevil preference? What makes certain trees more attractive to the weevil whilst other trees bear natural resistance?

Plate 3.

View of Skeena river- This is a transition area where interior (mainly white) spruce hybridizes with Sitka spruce. Strong environmental gradients affect susceptibility to weevil as well as to frost. The program in the North West is designed primarily to establish sound transfer rules in this environmentally complex area but it may also help us in our understanding of the interaction of genetics and the environment in weevil resistance.

Forest Genetics Council of BC

Tree Improvement Program

Project Report 2002/2003

Coordinated and compiled by:

Brian Crown,
Island Eyes Images,
and
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Tree Improvement Branch

British Columbia Ministry of Forests

Acknowledgements

Roger Painter, Tree Improvement Coordinator, Forest Genetics Council of British Columbia

The Tree Improvement Program's financial and industry support from external sources has been a large reason for its success over the past six years. The Forest Investment Account has also recognized the value of this program and continues to invest in our industry. There is little doubt that this support has provided our Program with the resources to put together a vibrant and robust program. The Forest Genetics Council (FGC) has also become a co-operative model for multi partner organizations. It has brought together the efforts of Government, Industry and the intellectual community and is anchored by a strong business approach to tree improvement in BC. It includes annual business plans and budgets based on performance management with targets assigned for annual projects. Our continued financial support has led to the realization that working together in true cooperation has positioned our industry for future opportunities.

Thanks once again this year to the Project Leaders for completing their contributions to this report. This publication is a successful reflection of our combined work and as a publication it is well received. My congratulations to all and I hope that you enjoy this sixth annual report. I would like to acknowledge the hard work of our editorial review team for taking the time to look over our submissions. They include: Diane Goertzen, Joe Webber, Jack Woods, Don Summers and Michael Stoehr.

The front and back covers of this year's report highlight the work of John King, the Ministry of Forests Breeder for Sitka Spruce and Western White Pine. John has been a strong contributor to coastal tree improvement for years and it is a pleasure to be able to showcase his programs.

As I write this message, spring is in full bloom and our program is off and running with another positive year, supported by the Forest Investment Account. This is indeed good news and I look forward to working with you again on your projects. My thanks all those who have worked on this program with me through the Tree Improvement Program. You have made the job of administering the various parts a relatively problem free process. We will continue to work on your behalf in providing the Forest Investment Program with good sound reporting and accountability while allowing projects leaders to get on with the work at hand.

To all the Project Leaders I hope 2003/2004 shows great success.

Introduction

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

This report marks the sixth year of the Forest Genetic Council's (FGC) tree improvement program and the first full year of support received under the auspices of the Forest Investment Initiative (FII). Since 1997 FRBC has been a major partner and funding source for forest genetics in British Columbia and we are pleased that FII has maintained this initiative and support for:

- Doubling genetic gain (genetic worth) of select materials
- Increasing the use of select seed to 75% by year 2007
- Managing a gene conservation program to maintain genetic diversity in commercial species, and
- Supporting the long-term seed production capacity needed to meet the priorities of the FGC business plan.

Over the 6-year period of this program the average genetic worth of planted material rose from 6.5% to 11% and the province wide use of select seed rose from 29% to 44%. The estimated additional volume expected at rotation age (65 years) is over 2.1M cu m based upon 2002 select seed use.

The FGC recognized the long-standing contributions of Dr. J. Barker this year with the presentation of the 2002 FGC Achievement Award. John's pioneering work in tree improvement is widely acknowledged both provincially and nationally. Our best wishes go to John in his continued endeavours.

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

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

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

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

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1.0 Tree Improvement In British Columbia

1.1 Ministry of Forests

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

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

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

1.2 FGC Forest Genetics Council of British Columbia

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

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

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

1.3 FIA - Tree Improvement Subprograms

The Forest Investment Account, (FIA), Tree Improvement Program is consistent with the provincial strategy for forest gene resource management developed by the FGC. The TIP goals are to increase the growth rate, wood quality, and pest resistance of seedlings, and to preserve the genetic diversity of tree species across the province. TIP activities are organized into six subprograms (Figure 1).

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

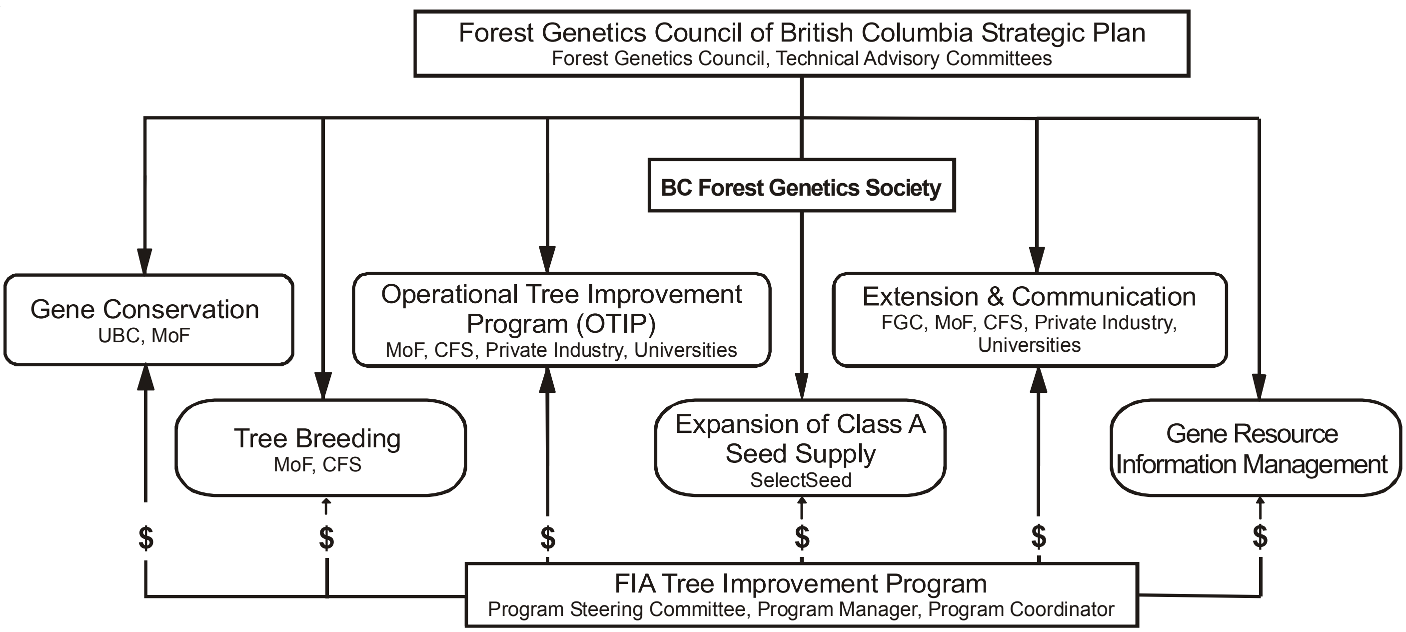


Figure 1. Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest gene resource management areas

1.3.1 Expansion of Orchard Seed Supply Subprogram

SelectSeed Ltd.
Jack Woods

The Subprogram for the Expansion of Orchard Seed Supply is in place to ensure there is sufficient orchard capacity to meet FGC objectives. Species planning directed by the Coastal and Interior Technical Advisory Committees of the FGC estimates total seed orchard capacity needs within each seed planning unit (SPU). Where there is a need to expand existing orchards or to establish new orchards, and where these needs are not being met by the private or public sector, SelectSeed Company Ltd. (SelectSeed) is mandated to develop orchard capacity on behalf of all stakeholders.

SelectSeed is wholly owned by the BC Forest Genetics Society (Figure 2), an entity under the direction of the FGC. SelectSeed is operated by a Board of Directors appointed under the FGC structure.

As SelectSeed is controlled by stakeholders, and not aligned with any single agency, it also provides program management services to the FGC. Funding is provided through a Multi-Year Agreement (MYA) originally set up with Forest Renewal BC, and now transferred to the Provincial Government. FIA funding is used by the Provincial Government to meet their obligations under the MYA. As SelectSeed-developed orchards begin production, seed sales will displace funding provided under the MYA.

SelectSeed's annual business plan and investments are based on species plans prepared by FGC TACs and Species Committees. The SelectSeed business plan must be reviewed and approved by the FGC each year. The SelectSeed Board of Directors is responsible for meeting objectives and programs set out in the business plan, and is guided by the terms of the SelectSeed MYA. A single SelectSeed staff member carries out program work and acts as Program Manager for the FGC. SelectSeed also reports at mid-year and annually to the FGC. To date, long-term orchard development agreements for 14 seed orchards have been entered into between SelectSeed and private sector interests.

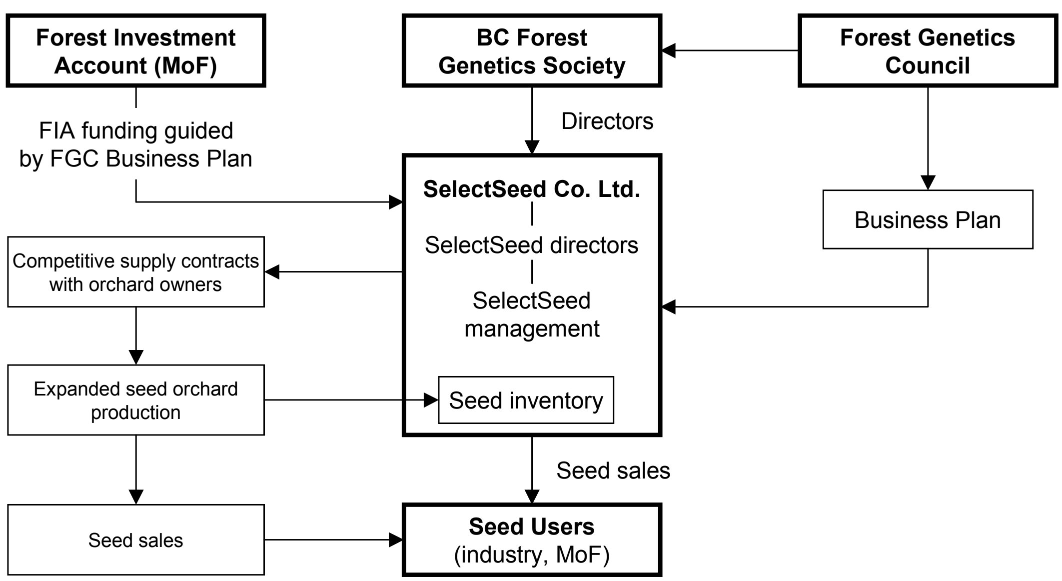


Figure 2. Schematic of organizational relationships among FGC, FIA, SelectSeed and seed users.

2.0 The Sixth Year In Review

Roger Painter

The2002-3 season proved to be another successful year. For most orchards 2002-3 has proved to be an excellent crop year. With the added investment through the Forest Investment Account this has resulted in improvements to available seed supplies, both in the quality and quantity of seed crops produced leading to healthier stronger forests for our province. The value of these faster growing trees will result in greater stability for our forest industry and a stronger long-term economy over time.

The Tree Improvement Program has now been in place for 6 years. Through that time the Forest Genetic Council has developed a strong program and identified key elements for achieving its long-term goals. The Tree Improvement Program contains five sub-programs to direct the operational side of tree improvement. They include Operational Production (OTIP), Tree Breeding, Extension and Communication, Gene Conservation, and Gene Resource Information Management (GRIM). The Forest Genetics Council has five working committees that provide technical direction for the sub-programs. This includes the Coastal and Interior Technical Advisory Committees (CTAC and ITAC), as well as Extension and Communication and Gene Conservation Technical committees. These Committees are responsible for developing goals and priorities specific to those areas. The FGC has also enacted a strong performance management system to ensure that the overall program goals are met. This system focuses project leaders on meeting specific performance targets in order to ensure they have met the goals of their projects. Species committees (sub-committees of the TAC's) have also been initiated. Their roll is to review progress and provide priorities for future investment by species.

The Operational Tree Improvement Program issues a call for proposals each year. In 2002-3, a total of 88 requests for funding in OTIP were reviewed. The technical review committees recommended that 79 of the proposals be accepted. The total amount of proposals received was approximately $1.60 million with a little over $1.1 millions in proposals being approved. The OTIP is reviewed separately by Coastal and Interior technical committees. The Coast represents a smaller area overall however it's tree improvement activities are more advanced and diverse. The interior programs cover a greater proportion of the province with larger seed needs. It received the substantial portion of funding with considerable work being targeted towards Lodgepole Pine. A sub-committee formed in 1999 reviewed and made recommendations on seed-set problems in Lodgepole Pine orchards in the Okanagan. Seed yields had not been at projected levels and a number of approaches have since been investigated to improve production. This work was initiated through the committee and done through a series of projects, which identified solutions to the seed yield problem. The breakdown of investment by region for all of OTIP is as follows:

Number of projects and funding by region		
Interior projects	51	$835,256
Coastal projects	28	$298,799
Overall Total	79	$1,133,955

Council has a strong program for developing annual project priorities through annual species committee reviews. Both Tree Breeding and the Operational Tree Improvement Program receive their direction from these reviews. Similarly the Extension and Gene Conservation TAC have developed its own priority review procedures and a steering committee provides oversight for GRIM sub program. Tree Breeding, as a Ministry of Forests responsibility is not part of the original Operational Tree Improvement Program "Call for Proposals" process. Priorities for the Tree Breeding sub-program are still developed through the Species sub-committees but decisions on projects to be undertaken are reached through co-ordination with the Tree Improvement and Research Branches of the Ministry of Forests and the FGC Program Manager. Considerable support is needed in this sub-program and will continue to receive strong levels of funding to ensure that development of new production stock is achieved for new orchards. These new orchards will provide seed for the various Seed Planning Zones where production capacity is low and/or where priorities for genetic quality seed are high. It will also help produce stock to replace older less advanced orchards. Work in Tree Breeding has already provided much of the genetic material to establish these new orchards. The development of a long-term investment program through Select Seed Ltd. has produced over 25,000 grafts for new orchard establishment so far.

Although not a specific sub-program, technical support is an integral part of tree improvement in general and provided an excellent avenue for operational problem-solving through the OTIP process. The Lodgepole Pine seed-set issue is an excellent example of focussed investigations that allow the tree improvement program to develop better methods for operational delivery of its product. A project breakdown by areas of investment follows:

Number of projects/areas of investment	
Tree Breeding	40
Gene Conservation	8
Operational Production	51
Technical Support	28
Extension and Communication	4
Seed Planning and Information Tools	2

The tree improvement industry represents a broad base of partners. This includes forestry companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies and individuals. In 2002/2003 Tree Improvement Program involved 48 separate proponents from all parts of the industry. With the current structures that include sub-programs and the focus driven TAC's, the Forest Genetics Council continues to provide the direction necessary for making sound investment and guidance for selecting acceptable proposals. The use of performance planning also helps ensure that approved submissions reflect the direction that the Council has set for meeting its goals through centralized planning and review.

2.1 Centre for Forest Gene Conservation

Sally Aitken

Key to any forest genetic resource management program is the maintenance of genetic diversity to allow species to adapt to future biotic and abiotic challenges, and for genetic selection for new traits of economic interest in the future. Most of Council's gene conservation objectives are met through the Centre for Forest Gene Conservation (CFGC) in the Faculty of Forestry at the University of British Columbia. The CFGC has completed three years of a seven-year Gene Conservation Plan that includes developing effective strategies for conserving and monitoring genetic diversity, evaluating current levels of protection of genetic resources, and investigating levels and patterns of genetic diversity in native species.

Accomplishments of the CFGC in 2002/03 included:

- establishment of a range wide study of adaptation and genecology of whitebark pine
- initiation of a study of the relationship between inbreeding and blister rust resistance in whitebark pine
- initiation of a study entitled 'Adapting forest gene resource management to climate change' funded by an NSERC/BIOCAP Canada Foundation Strategic Grant
- completion of a report on *in situ* gene conservation status of eleven commercially important conifers in British Columbia
- revision of species distribution maps for determining *in situ* gene conservation status (phase 1) for an additional 39 'minor' tree species in BC

- completion of Geographic Information System queries to the Seamless Forest Cover Inventory and related databases for the initiation of phase 2 assessment of *in situ* conservation status of tree species in BC
- completion of sampling and laboratory analysis, near-completion of data analysis and preparation of a draft manuscript for a project on efficient sampling strategies for capturing rare alleles in *ex situ* collections
- development of microsatellite markers for western hemlock for a project developing marker-based methods of monitoring and managing co-ancestry in breeding populations
- presentation of ongoing CFGC activities and project results at provincial, national and international meetings, conferences and workshops
- update of the CFGC website (www.genetics.forestry.ubc.ca/cfgc)

2.2 Tree Breeding

2.2.1 *Abies* Provenance Testing

Cheng C. Ying

Amabilis fir

Amabilis fir remains the focal species of the *Abies* provenance testing project. We continue to maintain and closely monitor the short-term tests at Sylvan Vale and Woodmere nursery, and the three newly established long-term tests at Kitimat, Port McNeill and Jordan River. The 'seedling weevil' (*Steremnius carinatus*) caused about 19% and 12% mortality at the Jordan R. and Kitimat tests respectively.

The second phase of the long-term tests will be planted at seven sites in spring 2003. We have somewhat modified the experimental design by reducing the number of replications from 20 to 10 per site and increasing the number of sites from three to seven. This change reduces the land requirement per site to about one hectare. Finding a suitable site over two hectares is increasingly difficult in the coastal region partly due to smaller harvesting blocks. This modification has helped the site selection. One main objective of this second phase testing is to evaluate the adaptability and growth of the seed sources from the species' southern range in a northern environment. We collected seeds from 70 trees in 7 stands in Oregon and Washington.

B^+ seed remains the primary means of achieving genetic gain, either in natural stands or seed production areas. The establishment phase of field tests will be completed in 2003. We will shift our focus to data collection for decisions on B^+ seed sources and seed transfer. A preliminary decision on B^+ seed sources will be made in 2004-05.

Subalpine fir

Two short-term tests were planted in the fall of 2002 at Cobble Hill and Prince George Tree Improvement Station. Long-term testing is not a component of this species. These two additional tests are essential to evaluate provenance variation in adaptability, growth and other traits, and are supplementary to the other two tests at Sylvan Vale and Woodmere nursery established in 1999.

Grand fir

We analysed time trends in geographic patterns of provenance variation in growth up to age 20. Geographic pattern persists from age 10 on, with no major ranking change in provenance mean height after age 10. Natural populations of grand fir along Eastern Vancouver Island are inherently fast growing, e.g. provenances #12040 (Salmon R.), #12041 (Oyster Bay), 12044 (Parksville), and # 12048 (Sooke). These stands are small and in isolation, and also vulnerable to urban expansion. Their conservation and protection ought to receive high priority.

Noble fir

In response to a client request to relax the elevational seed transfer, we updated the analysis of the testing results up to age 16. No elevational pattern is apparent at any of the three sites and no significant change is seen at different ages (6, 10 and 16 years after planting). The results indicate little risk in elevational transfer. There seems to be no reason not to relax the elevational transfer, if the current limit poses difficulty in operational implementation. We recommend expanding elevational transfer to 300 m upward and 400 m downward.

2.2.2 Coastal Douglas-fir

Michael Stoehr, Keith Bird

Background:

In advanced generation seed orchards, inbreeding can accumulate as related parents are selected for inclusion in seed orchards. To avoid this potential problem in third generation orchards of coastal Douglas-fir, subline breeding is used as a breeding strategy. In subline breeding, potential inbreeding is kept within sublines (by crossing related individuals within a subline only) and eliminated in the seed production population (orchard) as only one individual (i.e., the best progeny of the best family) in each subline is forward selected as a seed orchard parent.

Progeny Testing:

After a productive breeding season last year, enough seed was available to raise seedlings for the testing of eight sublines. Subline testing is a two-pronged approach with one part identifying the best parents (the parent with the best general combining ability or GCA) in each subline using a standard pollen mix; and secondly, by selecting the most desirable individual from the full-sib family of the two best general combiners (two parents with the highest GCA). This year, GCA-tests of eight sublines were established on four sites (Jordan River, Cowichan Lake, Port Alberni and north of Campbell River). The full-sib family tests were planted at Jordan River and North Arm at Cowichan Lake. The latter family test is a farm-field test. This completes the establishment of 16 sublines in progeny tests.

Genecology:

The submaritime (interior-coastal transition) zone genecology tests were established in 1996 to help delineate seed zones and seed transfer in this diverse ecosystem. This year the tests were maintained, but not measured. Some high-elevation forward selections will be made in the future, to be included in a submaritime seed orchard. High gain coastal families still perform well, as do the interior-coastal hybrids, even after the leaders are above the snow level.

Realized Gain:

Realized gain trials on five sites (Campbell River, Cowichan Lake, Powell River, Spirit Lake and Norrish) were measured and the results analyzed. Genetically improved families (mid gain and top crosses) performed as expected with realized genetic gains very close to those predicted (see Figure 3 below). Mid-gain families averaged over 10% gain above wild stand controls, while top-cross families approached 17% gain. These realized gain tests were established as 12x12 tree square plots at four different planting densities to evaluate various levels of competition from seedlings of very similar genetic quality. However, to date at age seven, no competition effects were detected.

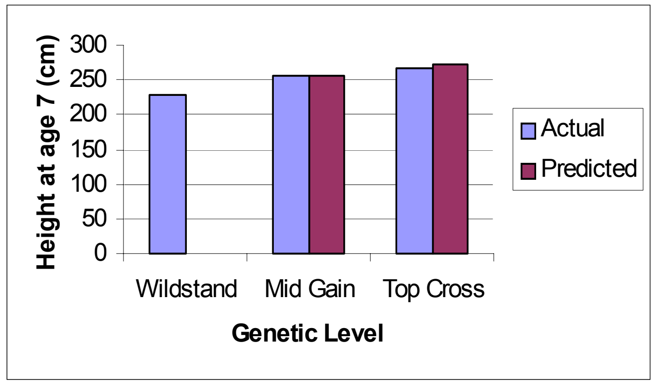


Figure 3. Results from the Realized Gain competition trials

Wood Quality Research:

The goal of this research project (funded by Forest Innovation Investment) is to develop a site index map for relative wood density. For this purpose, 10 full-sib families have been sampled (using increment cores at breast height followed by wood density determination) on 20 test sites of the second generation tests (EP 708). Each family is represented by 12 cores per site. Preliminary results based on 18 test sites show that certain areas are more capable of growing high-specific gravity wood, independent of families or growth rate (site index for height growth). This year, sampling was extended to include an additional 22 sites - producing a site index map of greater density.

2.2.3 Interior Douglas-fir

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

Four 15-year-old sites in the Nelson high elevation SPU were brushed, pruned to 1.5 m., and measured. Results are presented in figure 4. Of interest, the five experimental seedlots from BC's Submaritime zone were, on average, 25 percent taller than six operational control seedlots. Differences in survival and damage between the two seedlot groups were minimal.

In each of the 15-year-old Nass Skeena Douglas-fir seed source/species test and the 6-year-old Submaritime Douglas-fir experiment, three sites were brushed, maintained and measured. Analyses of both experiments are in progress. Increment cores were collected for wood relative density determination for160 o.p. families in the Prince George SPU test at the Prince George Tree Improvement Station. In the second-generation breeding project, 85 controlled crosses were completed and 216 pollen lots were collected for future breeding.

Site	Number of test trees	Site mean height (cm)	Range of family mean heights (cm)	Survival %	Damage %	h2 individual	h2 family
Gold Hill	6445	518	307 - 731	84	19	0.69	0.76
Ranch Ridge *	3662	552	274 - 745	48	2	>1.00	0.81
Erie Ck.	6731	571	355 - 724	88	6	0.58	0.71
Stevens	6556	482	310 - 641	85	13	0.53	0.71

*Ranch Ridge site was systematically thinned in 2000 for wood relative density determination.

Figure 4. Fifteen-year growth summary of four sites in the Nelson high elevation Interior Douglas-fir progeny test.

2.2.4 Western Redcedar

John Russell

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

1. Gene Conservation: Approximately 100 new parents from the East side of the Washington Cascades were cloned and established in the gene archives at CLRS.

2. Genecolgy: Analyses of 10-year measurements on the open-pollinated progeny trials at a southern interior field site have revealed (Figures 5 and 6):

- significant population differences in height and survival
- significant adaptive patterns between major zones (e.g. coast vs. interior)
- minimal adaptive variation within zones (e.g. elevation on the coast)
- GxE related to between zones.

It has been recommended to postpone any changes to seed transfer guidelines pending further information from younger genecological trials.

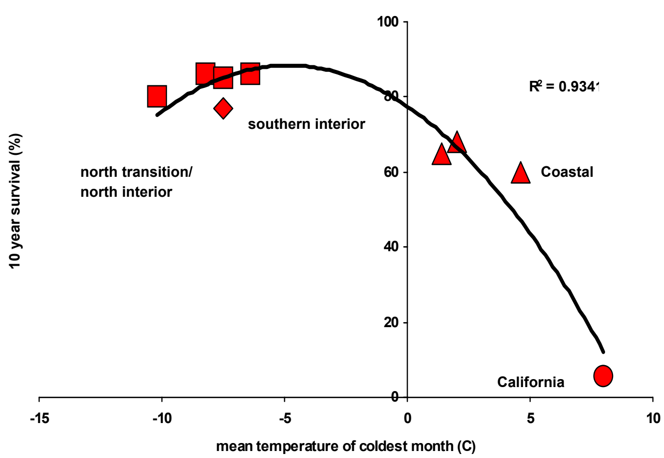


Figure 5. Ten-year survival of western redcedar range-wide populations as a function of population-origin mean temperature of the coldest month.

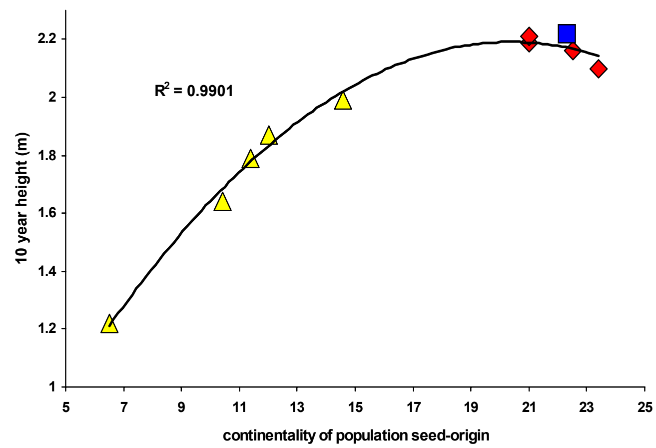


Figure 6. Ten-year heights of western redcedar range-wide populations as a function of population-origin continentality

Breeding:

More than 250 coastal U.S. parent-trees are currently being bred for polycross testing, in addition to the 750 already completed.

Progeny Testing:

To-date, 34 progeny sites testing over 600 polycrossed families have been established. An additional 150 families will be established into trials next year. All sites were maintained to minimise competing vegetation and deer browsing. The first and second series established in 1998 and 1999 were measured for 5-year heights. Breeding values have been officially released for approximately 300 parents.

Technical Support

Selfing studies: 1. *Selfed lines*. Sixty lines (30 random and 30 select) from fifteen F^1 seed-parents have been successfully bred to S4 in eight years. The study was designed to evaluate growth and adaptation differences due to genetic selection and inbreeding, and thus the feasibility of utilizing selfed lines in a recurrent selection program

Wood durability:

The objective of this study is to screen western redcedar trees for enhanced natural durability by analysing wood cores for tropolones, in particular the thujaplicans, and correlating to weight loss in fungal rot tests. It is anticipated that wood durability measures will be developed for 300 clones by the end of this project. To-date, approximately 300 parent-trees that are currently in existing seed orchards have been profiled for 22 known and unknown tropolone compounds. In addition, 100 of these parent trees have been measured for weight loss in the presence of heartwood-attacking fungi.

2.2.5 Yellow-cedar

John Russell

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

Genecology:

Analyses of 10-year height data, at five field sites, indicated significant population differences in growth but no detectable adaptive patterns from both low and high elevation test sites (Figure 7). It has been recommended that seed transfer guidelines for yellow-cedar allow unlimited upward transfer in addition to the unlimited lower transfer already allowed.

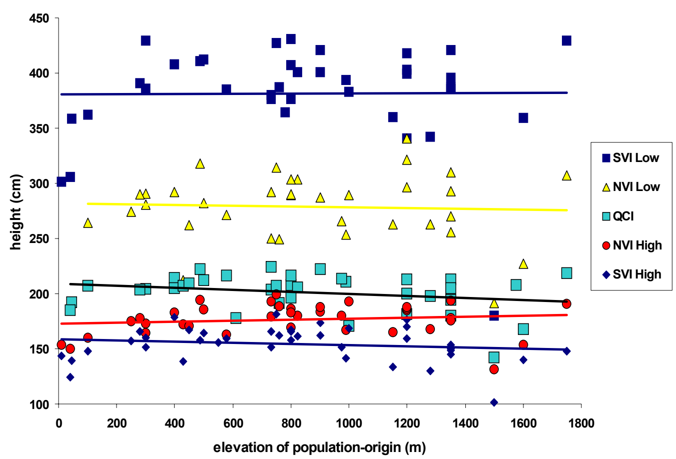


Figure 7. Ten-year heights of yellow-cedar populations as a function of the elevation of population-origin.

First generation clonal testing:

Three annual series of clonal progeny have been established. Over 5000 clones from 400 full-sib families have been planted. Three to four test sites were established at each series. All sites have high survival and are growing well. Five-year data has been collected from the first two series. Clonal values from approximately 3000 clones were developed and officially released. Top selections are currently being repropagated for inclusion into operational hedges and breeding orchards.

Advanced generation breeding:

Approximately 80 selections from earlier MoF genetic trials and Western Forest Products clonal trials have been established in three different breeding orchards (Jordan River, CLRS, and Callahan). New selections will eventually be added to these orchards from MoF clonal trials. A new round of matings/clonal testing will be performed when these selections become of reproductive age.

2.2.6 Western Hemlock

Charlie Cartwright

SPU3 – Low Elevation Maritme

Considerable progress has been made in the low elevation maritime hemlock forest genetics program in 2002/03. Breeding focused upon completing crossing for advanced generation testing of first generation parents tested in the early 1990's. First trials of this material were sown in 2002, but will not be deployed until the spring of 2004. Some plants from these full-sib families were taken and potted as donors for a clonal replicate trial. To do this twenty-four cuttings from each of 16 seedlings for each of 60 of the full-sib families were set. These will be lifted for out-planting in 2004 along with the seedling material. The use of cuttings permits determining family performance while at the same time allowing for efficient within family selection. The seedling trials with the same crosses will act as a check to assure that the family-wise results from a cutting trial are similar. For this fiscal year 4 tests were out-planted on Vancouver Island to confirm the worth of Washington State parents as yet untested in BC. Other activities in 2002/03 include release of new breeding values based on 10 year data of the 1990 tests.

As well as assessments of growth trait performance, some wood research culminated in reports in 2002. Results of how specific gravity and microfibril angle vary in the stems of selected and wild type hemlock were presented at the Western Forest Genetics Association meeting in Edmonton. As well, a paper describing the effect of thinning and fertilizer on best and average parents was reported to an IUFRO conference in the fall. Rankings for wood traits are still under review and are likely to be released in the next fiscal year.

Another facet of the low elevation maritime program has been seed transfer studies. In previous years materials from a wide range of provenances have been deployed around the range of the species in BC, along with tested materials from programs in Washington and Oregon as well as BC. Age 10 data was delivered early in 2002 and are being analyzed for a report in the summer of 2003. As well, 3 new test sites were established, one at Bella Bella, one near Bella Coola and a third at Revelstoke. Some maintenance was required for these sites, as well as the others deployed in the last couple of seasons. The aim of this testing is to better understand how the genome experiences its environment, but the practical spin off is more appropriate seed transfer standards, particularly as regards high gain tested families.

SPU24 - High Elevation Maritime Hemlock

Breeding for a last round of first generation testing has continued and will terminate next year with sowing of trials. This will bring the number of high elevation selections tested to about 325m. Ten-year-old height and diameter measurements were analyzed for 34 parents with revision of breeding values in early 2002. Trials put out in 2001 required some light maintenance and are generally in fine shape. Volume gains in new orchards to be comprised of these tested parents are estimated to be around 15% once production is in full swing. Roguing of older orchards will produce seed of roughly half that gain in the near future.

2.2.7 Sitka Spruce

John King, René Alfaro,
Charlie Cartwright, Dave Ponsford

Figure 8. Weevil Resistant Spruce

Activities this year included the completion of the first phase of the F^1 breeding program. Parents were designated by their phenotypic resistance to the weevil and their source (mainly Haney or Big Qualicum). Some susceptible parents were also used. Seed from this effort has been sown for trials that will be established in 2004, representing the first F^1 series. The breeding to establish future series will continue. The F^1's will replace the clones and families in our research efforts in trying to understand the mechanisms behind this resistance.

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

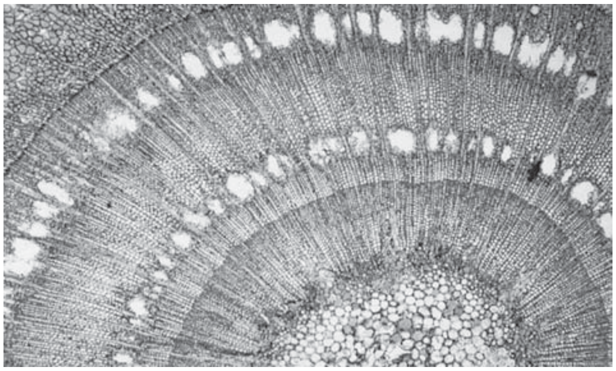


Figure 9. Traumatic resin cells (magnified)

Ongoing trial assessment for weevil attack has continued, reviewing some of the hazard assessment trials. These were a series of trials established to test resistance over a variety of ecological and potential weevil hazard areas. The main objective is to aid in determining deployment guidelines. Some of these guidelines were assessed in the last year to investigate elevational transfer of weevil resistant sources. Based on this work it was recommended under the Species Committee and CTAC that weevil resistant sources could be planted up to 500 m, up 200 m from the previous 300 m.

Figure 10. Measuring high elevation hazard rating site in order to check transferability of weevil resistant sources.

Good progress has been made in the first draft of a report outlining the weevil resistance program. This report shall present many of the details of the program, outlining our scoring system for resistance, ranking all of our parents to date. The report will also present deployment guidelines for resistant material. Two book chapters on this work have also been published and ongoing articles are being submitted.

2.2.8 Queen Charlotte and Coast/Interior Transition Spruce

John King

Details of these programs will also be included in the full report. Basically the Queen Charlotte program allows us to assess Sitka growth free from weevil attack and supports the Seed Orchard program (SO 142 and its replacement). Our major difficulty has been in getting "free-to-grow" conditions in this case not from weevil or brush but from deer browse and a good deal of our maintenance effort is on browse protection.

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

2.2.9 Interior Spruce,

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

Interior Spruce

The BC interior spruce tree improvement program began in the mid-1960's. It has progressed to the point where improved first-generation seed orchards are in full production for most zones, and second- generation full-sib progeny tests are in place for three seed planning units (SPU's). Like many older tree breeding programs, the spruce program has advanced in stages.

Experimental Project (EP) 670 began in 1967 in three SPU's: Prince George (PG), East Kootenay (EK) and Smithers. EP 819 began in 1981 in seed zones not covered by EP 670. These initial seed planning zones were purposely small and subject to review as new information became available. In 1998, the interior spruce SPU's were amended based on an extensive review that considered results from provenance tests, progeny tests and genecology experiments. The new SPU's combined many of the old, smaller seed planning zones into larger zones. The challenge today is to bring together populations from the two programs to accommodate the new SPU's.

In 2002, efforts focused on maintaining and measuring field tests, and second-generation breeding for the new Prince George low elevation SPU. In EP 670, the second-generation test series for the PG, EK and Smithers SPU's (9 sites in total) were maintained, and six-year tree height was measured in the PG and EK series. Thirty year tree height and diameters were measured at two sites in the first-generation PG open-pollinated (o.p.) tests. Data analyses for these measurements are in progress. At the Skimikin seed orchard complex, the terminal leader weevil (*Pissodes strobi* Peck) population in the Shuswap Adams (SA) polycross test was augmented with weevils reared at Pacific Forestry Centre, Victoria. This augmentation will provide a uniform attack rate across the plantation in spring 2003. Top kill and damage will be scored in fall 2003. Two sites in the Bulkley Valley were also brushed and maintained. The 37-year-old Quick and Verdun provenance tests, the oldest replicated interior spruce provenance tests in BC, were brushed, pruned and relabelled. Tree height and diameter measurements will be recorded in spring 2003. Four somatic embling plantings in the Prince George Forest Region were maintained and measured.

In the second-generation crossing program for the new PG SPU, 105 crosses were completed and 42 pollen lots were collected and stored for future breeding. Crossing for the zone is now 54 percent complete and should be finished in about two years. Twenty-one pollen lots were collected from the Riverside Thompson Okanagan spruce seed orchard.

2.2.10 Silviculture and Breeding for Lodgepole Pine Wood Volume, Quality and Value

Mike Carlson

Most tree breeding programs concentrate on increasing stem volume growth rates by selecting for superior height growth in the first generation of selective breeding with only minor emphasis on stem form and/or crown characteristics. In the second selection cycle, wood quality, stem form and stem value traits are often considered in addition to selecting for volume gain.

In the Pli breeding program we are establishing second generation family tests with control pollinated family sets concentrating on stem volume in one line and wood specific gravity in another line for each of five seed planning units (TO,NE,PG,BV and CP, all low elev.). Stem quality, lumber recovery and ultimately lumber value depend upon many factors. Branch size, number, distribution and retention all affect lumber grade, recovery and value. The relative importance of hereditary and environmental factors on these traits are unknown for lodgepole pine.

Ongoing concerns of the interior forest industry with Pli managed stand stocking standards and thinning regimes and their impact on future second growth Pli log and lumber quality and value has stimulated research under the Forest Innovation Investment (FII) umbrella. We have combined efforts with J.S. Thrower and Associates of Kamloops to study the genetic and environmental effects and their interactions on various growth and yield parameters including; height, diameter and stem volume growth rates, wood specific gravity, branching characteristics and projected log and lumber values (see figure 11).

Figure 11. John Murphy and Greg O'Neill of KFC with Jim Thrower and Future Forests contract crew at Pennask Lake Pli progeny test site, planted 1986.

Our 1986 progeny test series in the TO, PG and BV SPUs includes 30 common WP families planted across nine sites. These families were from three provenance sources (10 families each) widely separated geographically in the southern interior. Progeny test sites of differing SI in each, the southern and northern interior (TO and PG SPU's) were chosen for sampling, and the 30 families were measured for a host of stem and branching traits in fall 2002. Data analysis is underway.

2.2.11 Coastal White Pine

John King, Rich Hunt (CFS), Dave Ponsford

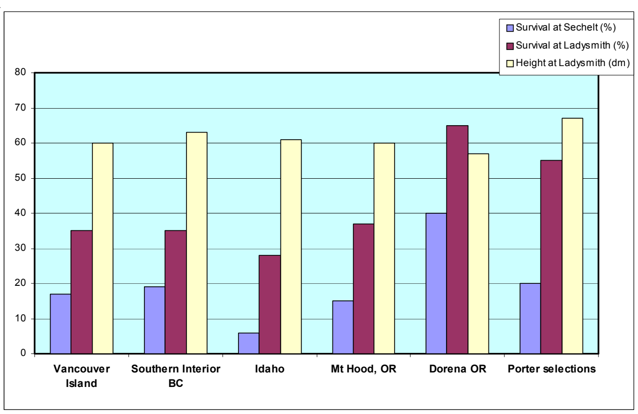
This year's main activity saw the completion of the first phase of the F^1 breeding program. Parents for this effort came from the CFS screening program and were designated as either Slow Canker Growth (SCG) or Difficult to Infect (DI). SCG trees occur more frequently than DI. Also included as parents were some of the best of the Texada trees and some Idaho, Interior and Dorena trees. Seed from this effort has been sown for trials that we shall establish in 2004. These will represent the first F^1 series but we shall continue the breeding to establish future series and also to develop a separate MGR population.

Figure 12. Breeding Program Crosses at CanFor Seed Orchard, Sechelt BC (courtesy R. Sneizko).

The winter of 02/03 saw the collection of the last scions from the CFS selections. Many of the grafts made the previous year did not survive so we made up a lot of these and we also got to some of the trees we had not managed to collect in previous years. Grafting is being done at CLRS and at Mount Newton and grafts will be established in the North Arm clonal archive, seed orchards and a newly established breeding orchard at Puckle Road. Besides the material grafted from the CFS parent trees, some interesting material was obtained from Jim Hargrove, tree improvement forester from the Quinault Indian Nation. Charlie Cartwright helped with this acquisition through his membership in HEMTIC.

Figure 13. Don Pigott collecting from one of the best SCG trees.

Older trials continue to be measured, including provenance trials and root rot trials established by the CFS. These measurements will help us to evaluate the resistance of our seedlots and assess the transferability of these seedlots. Some results of these measurements have been reported in a paper entitled " The Five Needle Pines in British Columbia, Canada: Past, Present and Future" by J. King and R. Hunt to be published as the proceedings of the IUFRO white pine meeting in a special USDA Forest Service Research Report. Figure 14 shows some of these results on two sites: Ladysmith a low infection site and Sechelt a high infection site. It can be seen that the MGR Dorena "Champion Mine" seedlot is the best for overall survival at both sites and at the high infection site is likely to be the only survivor over time. However at the lower infection site of Ladysmith, (figure15), it can be seen that the Porter selections shows up best for height growth and also appears good for survival (55%). This appears to indicate that the type of partial resistance mechanisms, that have been screened for by Porter and then later in the CFS program, should give us substantial benefit. These will work well on their own at the lower levels of infection and when combined with MGR will work well on the high infection sites.



Series 1 = Survival at Sechelt (%)

Series 2 = Survival at Ladysmith (%)

Series 3 = Height at Ladysmith (dm)

Figure 14. Results for growth and survival as reported in King and Hunt 2003

Figure 15. Porter's screening for blister rust resistance by growing *Pinus monticola* ramets from blister rust resistant candidates in a disease (*ribies*) garden at Duncan BC in 1955. (from King and Hunt 2003)

2.2.12 Lodgepole Pine Realized Genetic Gain Trial (5th year)

Thompson-Okanagan SPU, Mabel Lake Site

Mike Carlson

Estimates of rotation age stemwood volume gains from the use of seed orchard seedlots are made from progeny tests of seed orchard parents. Typically, these estimates are made when progeny test trees are 10-12 years old and only beginning to enter into intertree competition for site resources. For most of a rotation, plantation grown trees will be competing with one another. The question has been asked: Will the more rapidly growing seed orchard derived trees continue to express their growth superiority after the onset of competition, on a per unit area basis? This trial is designed to answer the question. The trial has 27 treatments: three levels of genetic quality (wild, orchard run and elite), three plantation espacement levels (1.5 m, 2.5 m, 3.5m), and three levels of site index (low, mid, high).

This Mabel Lake site is one of six in the Thompson-Okanagan SPU Realized Genetic Gain trial series planted in 1999. After four field seasons, the relative height growth performances of wild, orchard run and elite seedlots are: 100: 119: 130% respectively. These estimates are very close to those made from the original progeny tests series (See Figure 16).

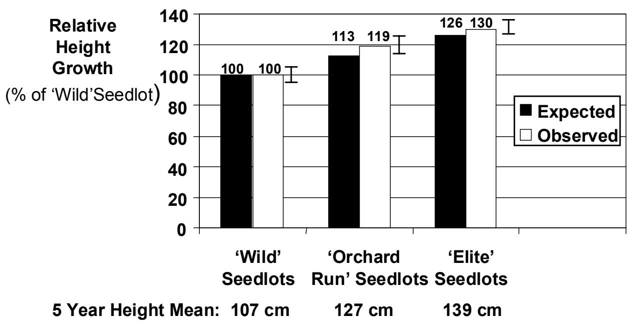


Figure 16. Lodgepole Pine Realized Genetic Gain Trial:Thompson-Okanagan SPU Mabel Lake Site @ 5 years from Seed

These young trees (5 years) are still open grown, even at the 1.5 m spacing and we will have to wait for a few more years to begin estimating their growth rates under competitive conditions and stemwood volume growth rates on a per hectare basis. Ultimately, this information will be used to calibrate stand growth models and in timber supply area planning.

2.2.13 Lodgepole Pine

Realized Genetic Gain Trial: Thompson-Okanagan and Nelson SPU's

Mike Carlson

Lodgepole pine realized genetic gain trials were planted in the Thompson-Okanagan low SPU in 1999 and in the Prince George low SPU in 2000. These trials used sets of control-pollinated Pli families representing two levels of genetic improvement ("orchard run" and "elite") to be compared with wild seedlot controls. One hundred and forty-four-tree square block plots will provide unit- area estimates of tree volume growth for comparisons among and between improved and wild seed sources. Trees used as parents in the control-pollinated breeding sets are a sample of parents in our rogued first generation seed orchards. Orchard bulk seedlots with the majority of orchard parents contributing gametes are the actual improved products for use in reforestation. So, an additional type of realized genetic gain trial is in order, one using actual seed orchard seedlots compared with the currently available wild superior provenance (B+) and B seedlots.

Grafted lodgepole pine seed orchards for the Thompson-Okanagan low and high SPUs (3), and the Nelson low (2) are young and just beginning to produce seed crops with the majority of orchard parents contributing to bulk seedlots.

The year 2001 was the first in which bulk seedlots producing in all five seed orchards for the TO and NE SPUs had 75% or more of orchard parents contributing gametes to seed crops. These seedlots can be considered representative of future orchard seedlots in terms of genetic diversity and genetic gains in wood production. Samples of these five class A seedlots were grown in styro 410s in 2002. Also grown were seedlings from superior provenance (B+) seedlots now commonly used in the TO and NE as well as B seedlots that served as wild controls in the TO and NE progeny test series of the mid 1980s. Seedlings of all genetic entries will be planted on eight field sites in the TO and NE SPUs ranging in elevation from 1,100 to 1,650m. Four of the five seed orchards have upper seed use limits of 1,400m, the remaining orchard (TOHI) is limited at 1,600m. Four sites above 1,400m were chosen to "challenge" our current thinking regards upper elevation use limits. As with this trial, all future Pli progeny and provenance testing (genecology) projects will be designed with climate change implications considered i.e. with seed movements northward and upward in elevation as part of the design strategy.

2.2.14 Western larch

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

Four 10-year-old sites in the Nelson SPU Series 1 open-pollinated progeny test were maintained and measured. New breeding values for each parent were estimated by Best Linear Prediction and will be used to rogue the Nelson seed orchard at Kalamalka. In the western larch second-generation breeding project, 37 and 51 controlled crosses were completed for the East Kootenay and Nelson SPU, respectively. Forty-two pollen lots were collected for future breeding. The second-generation crossing program for both SPU's uses a disconnected factorial mating design with eight parents per factorial. To date, about 25 percent of the crosses have been completed in each SPU. The crossing program is expected to be completed within 2-3 years. Seeds will be sown in spring 2003 to establish realized gain plantations in both SPU's.

2.2.15 A Hybrid Poplar Plantation Irrigated with Reclaimed Wastewater:

Eucalyptus of the North?

Mike Carlson

In 1987, sixteen hectares of Vernon Commonage grassland was site prepared by killing sod grasses with glyphosate and turning with a four-bottom plow. In spring of 1988, a 36 inch 'Rome' gang-disc drawn behind a D-6 Cat made two passes over the land. An above ground irrigation system was constructed and 20,000 hybrid poplar cuttings (35 cm ea.) were stuck in early June at an average spacing of 2 meters x 2 meters. Three interspecific hybrid cross types were planted:

- *Populus trichocarpa* x P. *deltoides*
- *Populus deltoides* x P. *nigra*
- *Populus nigra* x P. *maximowizii*

Today in it's 15th growing season, fully stocked areas are carrying approximately 900 stems per hectare (sph) with an average single tree volume of 0.68 m^3 or a total volume of about 600 m^3/ha for an MAI of 40 m^3 /ha/yr. There are over 25,000 ha of hybrid poplars growing in BC, Washington and Oregon, mostly for pulping fibre. However, there is increasing interest in the use of hybrid poplar for solid wood products: furniture, panelling, trim material, decorative boxes, toys, etc. In August of 2002 a small feller-buncher was used to selectively harvest 31 cubic meters of tree length logs for processing at the Canadian Chopsticks mill in Kelowna (see figures 17 & 18).

Figure 17. Feller buncher harvesting 15 yr old hybrid poplar trees near Vernon.

These logs were milled to produce a variety of lumber grades and dimensions suited to solid wood product manufacture, especially materials for decorative box making at a Vernon plant.

Figure 18. Hybrid poplar log load (31 m3) from Vernon plantation bound for Kelowna mill.

For more information about solid wood product opportunities with this wood see:
http://osu.orst.edu/extension/klamath/poplar/swbc.htm

2.2.16 Private Lands Farm Field 'A' Forestation with Improved Silver Birch from Finland

Mike Carlson

The selective breeding of European silver birch (*Betula pendula* Roth) has been underway for the last 40 years in Finland. In 1992 ten improved silver birch full-sib and wind pollinated families from the Finnish breeding program (compliments of Risto Hagquist, Finnish birch breeder) were planted at three interior sites; Salmon Arm, Prince George and Ft Nelson. These families have proven to be superior in stemwood volume production and stem straightness when compared with local paper birch (*Betula papyrifera*) control seed sources at each site.

In 1999 and again in 2001 the trial planting at the Skimikin seed orchard site (Salmon Arm) was thinned to an average final spacing of approximately 5m between trees to provide for greater crown exposure and to stimulate catkin and seed production. In the fall of 2002 the first collectable seed crop was harvested (see Figure 19).

Figure 19. Vicky Berger of KFC harvesting improved Finnish silver birch from 12 yr old trial plantation at the Skimikin seed orchard site, fall 2002.

Small-scale private woodlot and farm field aforestation projects with silver birch are underway throughout the interior. The Skimikin seed stand is the only known source of improved silver birch seed in North America and could be managed for private woodlot forestry use in BC and elsewhere.

A specialty wood grown in parts of Scandanavia and central Europe is curly or "Carelica" birch, *Betula pendula* Roth var *carelica* (Mercklin). This silver birch genetic variant is found growing naturally in a few stands in southern Finland and is now plantation grown there for the production of valuable veneers and turned wood products. Seed from a curly birch stand was obtained from Risto Hagquist in 1995 and container grown seedlings produced and planted at the Skimikin site in 1996. After 7 field seasons (2002) the original planting was thinned to approximately 50% leaving only the most pronounced curly birch phenotypes (see Figure 20).

Figure 20. "Carelica birdseye" silver birch @ 7 years at the Skimikin seed orchard site.

These trees which exhibit the "lumpy/burly" stem surfaces will produce wood with a striking "birdseye" figure. Commercial curly birch peeler logs are produced on a 30 yr rotation in Finland.

3.0 Orchard Projects

3.1 Kalamalka Seed Orchards

Chris Walsh

Ten projects were approved under the operational production sub-program for 2002/2003 at Kalamalka Seed Orchards. 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 collection of high breeding value pollen from clone banks and the application of Supplemental Mass Pollination; and
- Improving orchard productivity through pest management and other management activities. In addition to collecting, processing and application of pollen, funding also permitted us to purchase blister rust tolerant white pine pollen from the Inland Empire Tree Improvement Co-operative. For all orchards where pollen work was funded, OTIP also funded 25% of the cone collection.

Pest management activities funded included:

- use of Safer's Soap sprays to control galling adelgids,
- removal of weevil infested spruce leaders to reduce weevil populations,
- removal of pine pitch moths damaging orchard tree stems,
- baiting for control of rodents feeding on tree roots,
- sanitation picking of cones in orchards with non-collectible crops to reduce pest populations,
- dormant oil application to control larch adelgids,
- pesticide sprays to control *Leptoglossus*, and

Project	Species	SPZ	Orchard	# Ramets Rogued	# Grafts Made	# Ramets Maintained	Rootstock	Transplants
SPU0401	Sx	NE	305	162	340	471	100	69
SPU0502	Sx	NE	306	243	417	313	100	27
SPU0701	Pli	NE	307	3	42	217		22
SPU1302	Lw	NE	332	133	210	656	300	115
SPU1401	Sx	PG	209	44		100		168
SPU1501	Pw	KQ	335			18	150	99
SPU1604	Pli	TO	310			412		
SPU2501	Sx	EK	304	177		78		138
SPU3401	Lw	EK	333	516	100	711	150	125
SPU3501	Sx	BV	620	139	349	30	50	44
Totals				1417	1458	3006	850	807

Figure 21. Orchard Composition Activities by Project

Project	Species	SPZ	Orchard	Pollen Collected (litres, dry)	Trees Pollinated
SPU0401	Sx	NE	305	4	202
SPU0502	Sx	NE	306	4	185
SPU0701	Pli	NE	307	5	433
SPU1302	Lw	NE	332	2	369
SPU1401	Sx	PG	209	2	82
SPU1501	Pw	KQ	335	1	2321
SPU3501	Sx	BV	620	2	669
Totals				20	4261

Figure 22. Pollen Management Activities by Project

- pesticide sprays to control spittle bugs in lodgepole pine orchards.

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

The OTIP funding was instrumental in increasing both the quantity and quality of seed produced. At Kalamalka in 2002 we produced approximately 500 kg of interior spruce, western larch, lodgepole pine and western white pine seed, equivalent to over 72 million seedlings. Kalamalka seed is being used over large areas of the interior of the province.

3.2 Riverside Seed Orchards

Greg Pieper

SPU 2801

In spruce orchard 303, pollen buds were collected, dried, extracted and stored at Kalamalka for a second generation crossing program which will begin in 2003. This is a project that began in 2001.

Cone induction using $GA_{4/7}$ was done on all healthy, non-producing high b.v. ramets to encourage cone production in 2003.

Safers soap was applied in March using a 1% solution to control adelgids.

A record crop was collected in 2002 producing 76 kg of seed (35 million viable seeds).

Soil and foliar samples were collected for analysis to monitor nutrient status and bud surveys were done to determine quantity, quality and phenology.

SPU 1601

In 2002, micro irrigation was set up in orchard 310 using ¾ inch polyline and mini sprinklers.

This should initiate more root growth and ground moisture should greatly improve. There were18.8 hl of cones harvested, yielding 4.5 kg of seed with genetic worth of greater than ten. Four applications of spray were used to control *Leptoglossus* (western conifer seed bug). Wetern gall rust required one pass and sequoia got two passes to maintain control. Pocket gophers and moles also required two treatments.

Surveys for timing, pollen monitoring, and bud counts were done and samples for soil and foliar analysis were collected.

Results

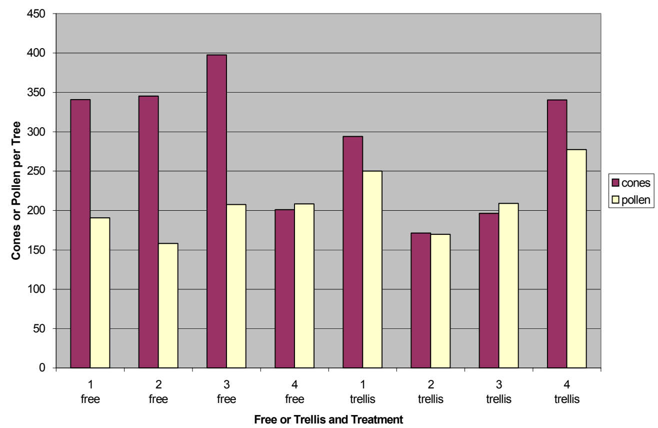


Figure 23. Crown Management Effect on Spruce Crop

In the free standing rows the operational style pruning technique appears to be the most effective in terms of crop production. In the trellis rows the control trees produced the most cones and pollen.

It is apparent that no firm conclusions can be drawn based on one year's worth of observations. Further crop monitoring will be necessary before we can determine which crown management technique is the most effective in this situation.

Conclusion

We will continue to test our refined crown management techniques during the 2003 field season. If a good cone crop is produced in 2003, additional data can be generated that will allow us to more confidently recommend the most effective crown management techniques for these types of orchards.

3.3 Grandview Seed Orchards

Hilary Graham

At the Grandview Seed Orchard site there are three Lodgepole pine orchards and one Douglas-fir orchard which have received OTIP funding for activities to increase the yield and genetic gain of seed produced. Orchards 308 and 311 provide seed for the Pli Thompson-Okanagan low elevation seed planning unit (SPU), orchard 313 provides seed for Pli Nelson low elevation SPU, and orchard 321 provides seed for Fdi Nelson low elevation SPU.

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

In the year 2002, a number of activities were conducted with OTIP funding in these orchards. OTIP projects 0702, 1001, 1002, and 2101 covered activities in orchards 313, 311,308, and 321 respectively. These activities included an irrigation upgrade, phenological surveys, pollen and cone surveys, pollen monitoring, insect and disease control, crown management, foliar analyses, pollen collections, cone harvest, and supplemental mass pollination.

Pli orchards – 2002 activities

The first project to get underway in the spring of 2002 was a major upgrade to the irrigation system in orchard 308. Previously this orchard was irrigated by a drip system which proved over time to be inadequate in providing enough moisture for the entire root system of these mature trees. The new system replaced the drip lines with micro-sprinklers which water the entire root systems evenly. An additional benefit of the micro-sprinklers may be the increase of moisture in the grass panels between trees resulting in higher humidity within the canopy during pollination. The micro-sprinklers worked very well throughout the season, with good soil saturation occurring in shorter watering frequencies. During the pollination period, reproductive phenological surveys were performed in orchards 311 and 313 to determine the timing and order of seed-cone receptivity among seed orchard's clones. The information generated was used to guide pollen management activities, including supplemental mass pollination (SMP), to increase seed set.

A relatively long female receptivity period in 2002 allowed for 4 well-timed applications of pollen (SMP) in orchards 311 and 313 (SMP not necessary in orchard 308). No protandry was observed in any orchard, with the shedding of pollen and flower receptivity coinciding well. The data collected from the surveys was condensed to provide a clone by clone summary of pollen flight and seed-cone receptivity in each orchard.

In all three Pli orchards the amount of pollen and number of cones produced per tree was assessed and recorded. This data will be used to calculate the genetic worth of seed produced in the orchards in 2002/2003.

Pollen monitoring was performed in all three Pli orchards with one-day pollen monitors installed just prior to pollen flight. Data from the monitoring provides information on the amount of pollen within each orchard, between orchards, and in the holding area. Pollen monitoring indicated that there was a substantial pollen supply in orchard 308 and therefore SMP was not conducted in this orchard. However, both orchards 311 and 313 did require SMP as the natural pollen cloud was too small to provide adequate pollination.

During the pollen flight period pollen was collected from orchards 311 and 313 for future use. Whole pollen buds were manually collected by clone and brought into the laboratory for drying and processing. For SMP efforts in 2003, there are 9.8 litres of pollen with an average BV of 20.6 in storage.

Orchards 311 and 313 were pollinated (SMP) in 2002 with stored pollen from a 2001 collection (previous OTIP project). Surveys were conducted prior to each application to indicate the trees with receptive seed-cones. These trees were tagged so that the pollen applicator crew could move quickly from tree to tree and apply the pollen only to receptive seed-cones.

Figure 24. Pollen applicator crew tending to tagged trees.

Four applications of pollen were made to trees in each orchard during the receptive period. It is expected that

SMP will greatly improve seed set by providing pollen in the absence of an adequate natural pollen cloud.

In addition to SMP, additional distribution of the natural pollen cloud in all of the Pli orchards was achieved by running an air-blast sprayer (containing a very fine water mist) through the orchards on calm days during the pollination period.

Figure 25. Enhancing the natural pollen cloud with an air blaster

Cones which had SMP applications in 2001 were collected in orchards 311 and 313 in August.

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

Foliar analyses directed the fertilizer program to ensure optimal nutrition.

A small amount of crown pruning was conducted in each orchard to encourage branching, and to maintain the trees at a manageable height without compromising flower production.

Finally, grafts were made on contract for each of the orchards to fill in empty positions. Many of these grafts were planted in orchard positions at the end of August, and the remainder will be planted in the spring of 2003.

3.4 Prince George Seed Orchards

Rita Wagner

Orchard 220 (Prince George low planning zone), Orchard 223 (Central Plateau Low Planning Zone) Orchard 228 (Bulkley Valley Low Planning Zone).

SPU 1203, 1802, 1702

Three Operational Tree Improvement Projects (SPU 1203, 1802 and 1702) were conducted at the Prince George Tree Improvement Station in 2002-2003. Emphasis was placed on the application of high gain pollen to improve the genetic worth of the seedlots from lodgepole pine seed orchards 220, 223 and 228.

Pollen was also collected from other high gain trees on site for application in future years. Approximately 39 litres of pollen with an average breeding value of 11% is now in storage.

40 hectolitres of cones (kg of seed not yet available) were harvested from the three orchards in Fall 2002. The seed has a genetic worth of 6%.

Some strategies to increase flowering, including crown pruning and hormone application were carried out.

Trees in all orchards were surveyed for western gall rust and lophodermella needle cast.

3.5 Prince George Tree Improvement Station:

Management of Interior Spruce Clone Banks, Ensuring Availability of Scions to Replace Existing Orchard Ramets or Develop New Orchards to Boost Productivity and Gain.

Rita Wagner

SPU 1412

The Interior Spruce Clone Banks at the Prince George Tree Improvement Station provide vital support to the orchard and tree breeding programs in BC The clone banks are a centralized source of scion material for the grafting of new and improved seed orchards. They contain the only copy of many of the interior spruce parent tree selections found in seed orchards and breeding arboreta.

Four hundred ramets (grafted in 2000) were transplanted into the clone banks in the summer of 2002 to fill empty positions.

Five hundred-sixty grafts made in 2001 and held in the holding area until 2003 were weeded, watered, fertilized, pruned and monitored and treated for insects and disease. Similar management activities were carried out in the 12,000 tree clone bank.

Fdi orchard – 2002 activities

Pollen monitoring began at the first flight of pollen in the orchard. Pollen monitors were erected in a number of locations within the orchard, and monitored daily until the completion of pollen flight.

At the same time, phenological surveys were conducted every second day on a sample set of ramets of each clone in the orchard. Pollen shed and female receptivity were monitored throughout the pollination period. Phenological surveys and pollen monitoring provide baseline data for pollen management in this Fdi orchard. Surveys indicated a small amount of pollen was available, and therefore, a small collection was conducted (not a part of this project). This pollen is now available for SMP efforts in 2003.

The volume of pollen and the number of cones on each clone was also assessed. The pollen and cone surveys indicate that a small crop may be harvested in 2003 providing that SMP is used to augment the natural pollen cloud which is expected to be relatively light.

With the early confirmation of OTIP funding and an inventory of pollen from 2001/02 OTIP work, all projects were completed as planned. For the Pli Thompson Okanagan Low SPU, 20.9 kg of seed was produced in 2002, with the potential for 3.38 million seedlings. In the Pli Nelson Low SPU, 6.2 kg of seed was collected with the potential to produce 1.0 million seedlings. A crop was not harvested from the Fdi orchard 321 but is anticipated in 2003.

The activities conducted in 2002 with the assistance of OTIP funding ultimately move us closer towards our goal of increasing the amount and quality of A-class seed for the Pli NE low, Pli TO low, and Fdi NE low seed planning units.

3.6 Skimikin Seed Orchards

Keith Cox

Summary for SPU's 404, 411, 501, 1405, 1503, 3502 and 4002.

Work was funded in nine of the seed orchards at Skimikin in 2002.

The West Kootenay spruce orchards (301 and 302) had 203 replacement grafts planted in April. Another 231 new grafts were also made in the spring and planted in the holding area in the fall.

Figure 26. Augering planting holes in orchard 301, (SPU 404)

Figure 27. Replacement grafts in orchard 301, SPU 404

The orchards were surveyed for insects and disease and conelet samples were taken to monitor for the spruce cone maggot. Both orchards were sprayed to control the cone maggot, and 350 trees were topped while collecting the cones. The two orchards yielded a total of 31 hectolitres of cones.

The white pine crop in orchard 609 was sprayed three times for the white pine cone moth (*Eucosma rescissoriana*) and once for the conifer seed bug (*Leptoglossus occidentalis*). In June 77 litres of pollen buds were collected for future SMP work in orchard 335 at Bailey Road. The 2002 crop of 83 hectolitres yielded 56 kilograms of seed. The 2003 crop is estimated to be 30 to 40 hectolitres.

In spruce orchards 207, 208, and 229 for the Bulkley Valley zone a total of 89 kilograms of seed was produced. Most of the crop trees had been topped and all were sprayed to control the spruce cone maggot. Replacement grafts were made in the spring and 368 were planted in the new holding area in September.

Figure 28. Marking locations in the new Bulkley Valley graft holding area, (SPU 3502)

In October, 259 trees were removed from orchard 208 to make room for the new material when it is ready for transplanting.

Figure 29. Transplanting with an excavator in orchard 208, (SPU 3502)

In orchards 205 and 206, for the the Prince George Low spruce zone, a total of 91 hectolitres of cones were collected with Genetic Worths of 16 and 12. All of the crop trees were sprayed. Seven hundred of the tallest trees were topped, mostly during cone collection in August. In the fall 142 trees were rogued from the two orchards.

Figure 30. Hudson Hope spruce orchard (212) Sept, (SPU 4002)

The spruce orchard for the Peace River mid elevation zone (212) had 349 lower ranked trees removed in the fall, based on 15 year progeny measurements. The 2101 trees in the orchard were monitored for insects, disease, and rodents. The 200 replacement grafts made in the spring were planted in the holding area in September 2002.

Figure 31. Planting replacement grafts in the Hudson Hope holding area, Sept 2002 (SPU 4002)

The on-site research plantations were monitored for insects and disease, baited for rodents, and two young plantations were irrigated. The site where a Douglas-fir plantation had been cut down in 2000 was cultivated to reduce root rot.

The roots and rocks were removed and a cover crop was sown in September to prevent soil erosion.

Figure 32. *Foreground*: the new Bulkley graft holding area, (SPU 3502); *Background*: cultivating for cover crop sowing, (SPU411)

Weevils were collected from the spruce plantations and orchards in June. They were reared in Victoria, along with weevils collected from other sites, then brought back in October and placed on the trees in the east end of the Shuswap-Adams spruce progeny test to provide weevil resistance data. Back-crosses were made in the Ss X Sx plantation and the cones were sent to UBC for analysis. The Ribies garden was maintained and assistance was given as needed to move white pine stock in and out of the garden.

3.7 Vernon Seed Orchard Company

Tim Lee

Vernon Seed Orchard Company (VSOC) established over its' 14-year history, nine 1.5-generation orchards that provide Class A seed for many of the central interior Seed Planning Units. OTIP funding enables VSOC to manage each of the younger orchards for optimal seed production for each SPU and, on occasion, to renew positions within an orchard by roguing and replanting ramets. SPU 1201 fulfils the nutrient analysis required for all the orchards on site. Information gained is a planning tool for fertilizer requirements of each orchard the following year.

Spruce: SPU's 1402 & 1403

Prince George - Spruce #211 - Continued review of families within orchard 211 has identified families with weevil tolerance which is required for parts of this SPU. Orchard 214 covers the bulk seed requirements of the SPU, leaving orchard 211 available to produce the special weevil tolerant seedlings that have been under demand long before we ever started talking about this possibility. A good percentage of the seedlings will be able to overcome the attacks of this pest and will aid in blocks that are now falling short and declared NSR. Funding was required for the removal of 1500 ramets for the replanting of the positions to desired families. Eighteen-hundred grafts were completed and maintained for establishment in the spring of 2003. Monitoring of insects is an annual task that identifies problems populations of mites or aphids. Spraying for control of the pests is required within the orchard most years.

Prince George –Spruce #214 – Using seed germination information gathered over the past 5 production years VSOC has been able to identify one family that historically produces poor germinating seed. A consequence of this poor germination is that when the family is mixed into a seedlot it lowers the germination rate for that seedlot, which in turn causes the over-sowing of other good germinating families. One family was rogued from the orchard for germination reasons. 120 Grafts completed and maintained for orchard planting in 2003. Monitoring and spraying of insects is a part of the annual management activities.

Lodgepole Pine: SPU's 1202, 1701 & 1801

Prince George Low - Pine #222 - 370 rootstock were potted and held for 2003 grafting and re-planting of orchard positions.

Bulkley Valley - Pine #219 – 192 rootstock were potted and held for 2003 grafting and re-planting of orchard positions.

Central Plateau – Pine #218 - 208 rootstock were potted and held for 2003 grafting and re-planting of orchard positions.

Pine Orchard Activities

Pollen work continues to be a large part of managing young pine orchards. Pollen monitoring, picking and processing was required for SMP applications during this production year. Stored pollen picked from late families the previous year was applied to the early flowers in 2002. Diversity of each seedlot is increased by applying pollen of early to late parents and late to early flowering each year, as most cases a portion of the families will be unable to cross otherwise. Data collected is always valuable when applied to crop management. SMP applications consumed 50 liters of pollen annually in the Prince George, Bulkley Valley and Central Plateau orchards and enabled the cone harvest of 19.8 hectolitres in the PG, 92.0 hectolitres in the BV and 20 hectolitres in the CP. A priority processing was given to cones and seed extracted and as soon as seed was weighed, it was registered on SPAR and available to the users. European Pine Shoot Moth, *Leptoglossus* and Pine Pitch Moth continued to be a concern that involved monitoring the population and spraying or hand removal to lower the damaging effect that these pests have created in the past. VSOC staff and a research technician from CFS used pheromone traps to monitor the emergence throughout the adult life cycle. With our efforts in 2002, the Shoot Moth and *Leptoglossus* populations were found to be smaller and the Pitch Moth is growing in numbers over what has been in the past. Further control efforts in 2003 will help to develop the permanent strategy for seed orchards. A full report of the European Pine Shoot Moth work by Rene Alfaro and Tia Heeley of CFS is included as a part of OTIP report booklet. Improved irrigation Bauer spray heads will introduce additional humidity along with the required irrigation water by allowing the angle adjustment of water sprayed higher into the atmosphere within the orchards.

Douglas-fir: SPU's - 3702, 4102 and 4301

Prince George - Douglas-fir #225 is the youngest of the VSOC established fir orchards. Pollen monitoring and collection is an important part in preparing for future seed production. A few female flowers were present in the orchard but no cone quantities were present for seed production to begin. Insect monitoring and spraying was required for the control of aphids and sawfly.

Quesnel Lake – Douglas-fir #226 and Cariboo Transition – Fir #231

The fir orchard ramets are now a mature size and are ready to support a good crop when the production cycle begins in earnest. Pollen production did increase in 2002. The pollen crop required monitoring, picking and extracting for immediate and future use. SMP applications ensured pollen reached the flowering families for proper seed set and cone crop collection. An amount of seed was extracted for future seedlot mixing. All stored pollen will be available for future use. Insect monitoring and spraying was required for the control of aphids and sawfly and we continued monitoring of cone worm that will affect seed extraction percentages. As the fir orchards gain in ramet size, further work is required to understand the interior fir orchards, and then to spur on the start of the fir production cycle. Disease monitoring is an annual management tool for orchards.

3.8 Sechelt Seed Orchards

Patti Brown

The objective of SPU1101 was to increase the long term production of high gain yellow cedar to meet Canfor's annual needs of 300k with a GW of > 12 by 2005. Intensive cultural techniques were applied to the 1,500 donors located at Sechelt, and the 5,000 at Cairnpark Nursery to maintain juvenility and increase the production capacity. Cuttings for 150,000 plantables with a

GW of 11 were taken in the winter of 2003.

SPU0201 targets increasing the GW of red cedar from Sechelt Seed Orchard by preventing selfing in the 2003 crop using physical barriers and SMP techniques. Second generation grafts were maintained and pruned in holding beds for future orchard capacity of high gain genetic seed. 400 ramets from 85 new parents were added to the holding beds in 2002. Approximately 800 (90 parents) were also rogued from the holding beds based on 4 year progeny test results. 1,600 ramets remain in the holding beds at the close of 2002.

The goal of SPU0801 was to: 1) increase the long term rust resistance value of white pine seed from Orchard174 by incorporating clones with slow canker growth mechanisms; and 2) increase the short term resistance value by pollinating with MGR pollen from Dorena sources. New ramets from the Texada source were collected and grafted in 2002 along with parents that had poor survival from the 2000 grafting program. The 375 surviving ramets from the 2000 grafting program were maintained in holding beds in 2002. Future production capabilities were increased by pruning the existing 700 cone bearing trees. *Leptoglossus* numbers were very high in the orchard in 2002 due to no crops in the wild or other susceptible species in the orchard. The adult bugs were killed with a walk through every other day and the juveniles were removed as they emerged. 160,000 plantables were produced in 2002 and a potential 200,000 planatables were pollinated with MGR pollen for havest in 2003.

The main objective of SPU0301 was to increase the genetic worth of our hemlock orchards. Two hundred-seventy ramets were removed from Orchard 133 leaving trees with a GW of 8 or better. The future production capabilities of Orchard 179 were increased by pruning Orchard 179's 300 ramets. 150 replacement ramets were maintained in holding beds.

SPU0604 was for growing and culturing 750 weevil resistant donors at Sylvan Vale Nursery. The donors produced an average of 30 stecklings per plant and therefore enough material to provide 20,000 weevil resistant stecklings for outplanting in the spring of 2003.

SPU0312 provided funds to measure the height and diameter in 5th year growth of cuttings and seedlings outplanted in an operational trial on TFL37. The findings were similar to a concurrent research trial measuring the growth of cuttings and seedlings from top cross families. The trial compared the growth of cuttings with seedlings from two high gain seedlots grown at three nurseries and planted out at two sites. Overall the seedlings grew 6% taller than the cuttings over five growing seasons and the difference was significant if all other factors were ignored. If the cutting vs seedling comparison was made at the site, nursery or seedlot level then the growth differences were not so straight forward. For example if cuttings vs seedlings were compared at the nursery level, the difference was only significant at one of the three nurseries. At the site level, the difference was only significant at one of the 2 sites, and at the seedlot level the difference was only significant for one of the seedlots. Generally though, for all sites and nurseries, the seedlings grew slightly better than the cuttings (except for Seedlot 60377 where cuttings grew more than the seedlings).

3.9 Mount Newton Seed Orchard.

Tim Crowder.

Mount Newton Seed Orchards, owned and operated by TimberWest, carried out three projects under the Operational Tree Improvement Program in 2002/03. Funds were applied only for the portion of the projects that would apply directly to public lands, as projects on a private land base are not eligible for funding.

SPU 0205: Western redcedar Orchards #140 and #152 Crop Enhancement and Upgrading

Thirty-five large trees in Orchard 152 were sprayed with a solution of GA_3 at two different times in an effort to promote the development of both male and female reproductive structures. In Orchard 140, 14.3 hl of cones with a genetic gain of +4% were collected from trees induced in the previous year.

The holding area for clones currently in test was maintained through irrigation, fertilization, pruning, staking and tagging of all ramets. A further 880 grafts were added to the bed this year for a total of 3340 ramets. These trees will be available for transplanting into orchard positions as soon as results from progeny tests are available.

SPU 0901: Maintenance of Abies amabilis Orchard 129

Abies amabilis is BC's ninth most important species in terms of trees replanted and value of the logs harvested, and in the early 1980's an effort was undertaken to start an improvement program for this species. Orchard 129 was one of three planted and is currently the only one surviving undisturbed. Poor flowering and a difficulty to overcome plagiotropic (branch-like) growth has discouraged any further development in a breeding program.

Orchard 129 has been funded by FRBC (now FIA) for the last five years in order that research staff, universities and other interested parties have a set of trees with clonal identities to work on to try and determine methods that will help improve this important species.

Two litres of pollen were collected, extracted, and reapplied to the emerging flower crop, and 1115 trees were treated to control balsam woolly adelgid attack. The orchard was maintained in a healthy and vigorous state by irrigating, fertilizing and controlling grass and weeds.

SPU 1109: Yellow-cedar Donor Hedge Replacement and Upgrading

The yellow-cedar donor hedge at Mt Newton currently produces enough cutting material to set 350,000 cuttings with a genetic gain of +12% volume at rotation. The main portion is used by Weyerhaeuser Canada with any surplus made available to other operators.

The hedge has recently been expanded with the addition of improved clones from the Ministry of Forests program. As well, some of the original hedges are being rogued while others are being bulked up, resulting in hedges of varying ages. This year, one-year-old rooted cuttings of 42 of the best original clones were incorporated into the hedge. As an experiment, 15 copies of each clone were planted in the ground as usual, while another 20 copies were potted and grown in a greenhouse. At the end of the growing season, the greenhouse-grown donors were much larger, yielding 25 cuttings per plant on average, while the outdoor treatment yielded virtually none. The donors grown in the greenhouse also had significantly higher foliar N levels. While it is too soon to evaluate rooting success, this technique appears to be valuable for getting early yields of cuttings from young donor plants of high genetic worth.

3.10 Saanich Forestry Centre

Annette van Neijenhuis

Western Forest Products Limited continues to support the goals of the Forest Genetics Council by aggressively managing our orchards for quality and quantity. Orchard development continued with the incorporation of identified high gain clones from the breeding programs. Crop management delivered high gain seed and stecklings to reforestation programs.

At the Saanich Forestry Centre, nine seed orchards and a hedge orchard produce A-Class seed and stecklings. These orchards are managed by the Company to provide seed for our regeneration obligations in Coastal British Columbia from the North Coast to southern Vancouver Island. Surplus seed and stecklings are identified for sale on the Seed Planning and Registry (SPAR) where other Coastal tenure holders may purchase.

Funds from the Operational Tree Improvement Program (OTIP) provided means for incremental management for improved orchard and seed quality. Quality of orchards was improved through roguing and ramet replacement, including grafting for ramet replacement.

Western Forest Products maintained more than 3,500 western redcedar in test (SPU 0206) in the holding bed. Results from the first series permitted roguing prior to potting. These will be further rogued as test results come available before out-planting in the fall of 2004. Some grafting (93 ramets) was required to replace mortality. This project will result in a quick start to production with larger stock once all test results are received.

Figure 33. Georgina Dampier field-grafting Western redcedar in the "layered"orchard.

Orchard 166, our Douglas-fir orchard, was lightly rogued (15 ramets) to improve the quality of seed produced (SPU 0107). Seed yield in this seed planning unit is still below needs, thus aggressive roguing was postponed until production surpluses exist. Thirty-two ramets replaced those rogued as well as mortality over the past years within the orchard. The average breeding value of the orchard improved from 9.9 to 11.0 through these activities.

Development of the low elevation western hemlock orchard continued with grafting of 159 ramets, roguing of 55 ramets, and planting of 209 ramets (SPU 0304). Although updated breeding values were not published, orchard developments reflect ranking information dispersed by the hemlock breeder.

Grafting, holding bed stock maintenance, and replacement of Sitka spruce continued to improve the quality of orchard 172 (SPU 0601). At present this orchard contains 406 ramets and has an estimated weevil susceptibility of 5.6 per cent. This orchard will be oversized temporarily while further test results are anticipated, and allow aggressive roguing for weevil resistance and volume gain at that time, thereby maximizing production of best quality seed.

Improving the yellow cypress hedge orchards continued with maintenance of holding bed stock and rooting stecklings (SPU 1104). At present efforts are underway to bulk up a number of high-gain clones prior to establishing a replacement hedge of greater gain.

Results from the high elevation western hemlock trials provided by the breeder resulted in review, roguing, grafting, and ramet replacement in orchard 187 (SPU 2401).

Figure 34. Charlie Cartwright measures a western hemlock at a high-elevation trial near Gold River.

Funds from OTIP also supported incremental management for increased production of high gain seed and stecklings. This included support of fertilizer applications, of supplemental mass pollination and controlled pollination, of pest management, and of crop harvest.

Figure 35. High-gain Hw extracted for operational planting program.

Fertilization and pest management occurred in all high gain seed and hedge orchards and was supported, in part, by OTIP funds.

Two small western redcedar crops were produced in 2002. These included a high elevation seedlot which will provide A-Class seed to 800 m and a high gain lot with an average genetic worth of 5 per cent volume gain at rotation (SPU 0206).

Figure 36. Dr. John Russell at Cw trial near Nanaimo.

Various pollination techniques were employed to improve seed set. Moderate levels of midge resulted in below average seed yields in the orchard stock. Potted stock had low midge infestation and high seed yield.

Two Douglas-fir seedlots were harvested and registered in 2002. These were separated due to the presence of cone midge in one portion of the crop. Supplemental mass pollination and cooling were employed to offset pollen contamination from local populations (SPU 0107).

Figure 37. Mal Turgeon harvesting Fdc cones at Saanich Forestry Centre.

Funds were approved for crop management in the low elevation western hemlock orchard (SPU 0304). However, reproductive surveys indicated a paucity of flowers, thus no crop was available. All available pollen from eight top-ranked clones was harvested and processed for future cone crop management.

Controlled pollination resulted in seed for the Sitka spruce bulking up program (SPU 0601). A late frost at the Sayward site killed some flowers; of a total of 946 bags were applied but only 849 were pollinated. This project was combined with breeding for progeny testing, and resulted in more than 75,000 seeds for these two programs.

To maximize the number of yellow cypress cuttings available from young hedges, pruning to discourage lankiness was implemented (SPU 1104). Material shipped to the 2003 stock requests for steckling production averaged above 12 per cent gain.

The Forest Genetics Council's OTIP continues to assist Western Forest Products in delivering maximum gain at earliest dates to reforestation programs in Coastal British Columbia. These efforts have led to improved timber supply predictions. Reduction in harvest constraints will soon be realized with earlier greenup as more high-gain material is deployed. The Company anticipates continued success through OTIP and other cooperative efforts.

3.11 Saanich Seed Orchards:

Establishment and Monitoring of Regional Pollen Monitors on the Saanich Peninsula.

Dan Rudolph

Three projects were carried out at the Ministry of Forests' Saanich site this year.

SPU 0109:

This project involved the establishment and monitoring of seven-day pollen monitors at various locations around the Saanich Peninsula in order to provide Douglas-fir seed producers in the area with consistent estimates of local pollen contamination. In order to quantify the effects of local pollen contamination on the genetic worth of a given seedlot, it is necessary to have an estimate of the amount and timing of the local pollen flight and an estimate of its breeding value. Estimates of the BV's for the local Douglas-fir provenances in Saanich are currently being updated. Estimates of the amount and timing of the local pollen flight are dependent on the monitoring of that flight outside the orchard. This project aimed to provide these estimates so that local Fdc seed producers would have a consistent estimate of pollen contamination for all seedlots produced so that estimates of genetic worth from each could be compared critically.

Work Completed:

Five, seven-day monitors were established at various locations throughout the Saanich Peninsula. Pollen flight was monitored from April 2nd through May 6th. Two fields per day per chart were counted and averaged.

Final Results or End product:

Results were forwarded to local orchardists to be used when calculating GW's of seedlots produced.

SPU 0804: Repair of Vandalism-Related Damage and Enhancing Seed production from rust-Resistant White pine Seed Orchard 175.

This project is an amalgamation of two SPU08 projects that were carried out in Orchard 175 this year. The first part of the project involved the ramet replacement and growing stock management necessary to repair the damage caused to the orchard by vandals in the Spring of 2000. The second part of the project was a continuation of a project initiated in 1999 and involved both the collection of the crop produced by supplemental mass pollination in the Spring of 2001 and the continued use of SMP to enhance seed yields in the crop to be produced in 2003.

Work Completed:

For the part of the project aimed at replacing vandalised trees, scion collection and ramet re-grafting are to be carried out during the fourth quarter.

For the part of the project aimed at enhancing seed yields the following work was done;

- Male and female phenology surveys were conducted on 214 ramets in the orchard four times during the spring pollination period between June 11th and June 24th.
- Pollen was collected from 59 ramets.
- 8.0 litres of pollen was extracted, moisture contents were calculated and all lots were vacuum-sealed in preparation for storage, if needed.
- Pollen was re-applied to receptive flowers on 211 orchard ramets. Each ramet was pollinated at least three times during at two day intervals.
- 17,446 cones, or 46.2 hectolitres, were collected from the orchard.

Final Results or End product:

Seed yields from the 2002 SMP treatment will be calculated following collection in 2003. The 2001 SMP treatment yielded a crop of 33.045 kilograms or approximately 1,520,000 seeds. This represented a yield of approximately 87 seeds per cone which is significantly higher than the expected yield without SMP of 50 seeds per cone.

SPU 1901: Graft Maintenance of Saanich Fdc Holding Area.

Replacement stock for the genetic upgrading and eventual replacement of Sub-Maritime zone seed Orchard 120 has been established in a holding area at the Saanich site for a number of years. The objective of this project was to provide proper maintenance of this stock in order to ensure healthy and vigorous trees for the planned outplanting in the fall of 2002.

Work Completed:

One thousand nine hundred eighty ramets aged three to six years were maintained by pruning rootstock branches, fertilization, irrigation, graft maintenance, identity maintenance, mulching, controlling weed competition, conducting mortality and vigour surveys, mapping and removing cones from smaller ramets to lessen stress.

In the Spring 1037 ramets of 95 clones were transplanted into orchard locations. The remaining 941 ramets were transplanted into new holding area locations adjacent to the orchard site.

Final Results or end product:

All 1,978 ramets of the 95 clones were maintained in a healthy and vigorous condition.

Places and Faces

Tree Improvement Program

2002/2003

4.0 Technical Support Projects

4.1 Cone and Seed Pest Management

INTERIOR OPERATIONS

Robb Bennett

SPU 0405

During 2002/03 the Interior Seed Pest Management Biologist (Dr. Ward Strong) continued to provide the exceptional extension, research, and training services to which we have become accustomed. During this period he provided the following services to the Interior cone and seed production community and others:

- ~250 seed orchard site visits, pest surveys and identification, and damage predictions and assessments.
- Over 50 written pest survey reports to orchard managers and other seed production personnel
- ~30 other pest identification services to Ministry of Forests personnel and others
- Over a dozen extension education presentations to secondary school, college and university students
- One professional presentation to BC Seed Orchard Staff Group
- Numerous "tail-gate" type extension presentations to operational seed production personnel.
- Six in-house seed orchard pest management research projects initiated, continued, or completed.
- Collaborated and cooperated with university, research institution, and other personnel in 5 other research projects

The following publications resulted from these activities:

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

Sopow, S. L., J. D. Shorthouse, W. B. Strong, & D. T. Quiring. 2003. Evidence for long-distance, chemical gall induction by an insect. Ecology Letters, 6: 1-4.

Strong, W. B. 2002. Pest status and control of larch adelgids. Seed & Seedling Extension Topics, 14 (1&2):7-9.

Strong, W. B., S. L. Bates, and M. U. Stoehr. 2001. Feeding by *Leptoglossus occidentalis* (Hemiptera: Coreidae) reduces seedset in lodgepole pine (Pinaceae). The Canadian Entomologist, 133(6):857-865.

4.2 Pheromone-based Monitoring of Douglas-fir Cone Gall Midge,

Contarinia oregonensis in Douglas-fir Seed Orchards

Robb Bennett

SPU 0102

In 2002/03 fiscal year, work concentrated on modifying the Douglas-fir cone gall midge (DFCGM) pheromone (2-acetoxy-(*Z*,*Z*)-4,7-tridecadiene) synthesis methodology by a one-pot double-Wittig approach to allow for less expensive production of the pheromone. This work has resulted in an improvement over the original synthesis methodology published by Gries *et al.* (2002). Although synthetic pheromone yields are low using this approach, the revised methodology is much simpler and faster than the earlier methodology and further improvements are possible. A schematic summary of the work can be seen in Figure 38, (a full description of the synthesis is currently in manuscript form).

Scheme 1

Synthesis of 2-acetoxy-(*Z*)4,(*Z*)7-tridecadiene (5)

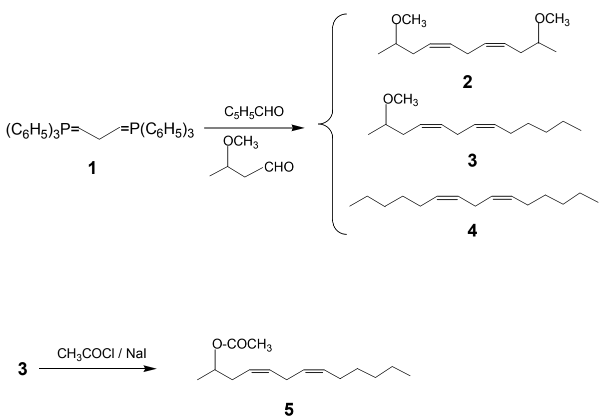


Figure 38. Synthesis of 2-acetoxy-(*Z,Z*)-4,7-tridecadiene

Currently, four scientific manuscripts resulting from the DFCGM pheromone work (pheromone identification & synthesis and pheromone-based population monitoring and control) are in preparation or under review.

DFCGM pheromone identification & synthesis:

- Gries, R., G. Khaskin, G. Gries, R. G. Bennett, G. G. S. King, P. Morewood, K. N. Slessor, and W. D. Morewood. 2002. (Z,Z)-4,7-Tridecadien-(S)-2-yl acetate: Sex pheromone of Douglas-fir cone gall midge, *Contarinia oregonensis*. Journal of Chemical Ecology, 28(11):2283-2297.
- Manuscript on modified synthesis of DFCGM pheromone ("Synthesis of 3-acetoxy-(Z,Z)-4,7-tridecadiene") is in preparation.

DFCGM pheromone-based monitoring:

- Morewood, P., W. D. Morewood, R. G. Bennett, and G. Gries. 2002. Towards pheromone-based monitoring of *Contarinia oregonensis* (Diptera: Cecidomyiidae). The Canadian Entomologist 134(5):689-697.

DFCGM pheromone-based control:

- Morewood, P., W. D. Morewood, R. G. Bennett, W. B. Strong, and G. Gries. *in press.* Last Call™: a tactic for control of *Contarinia oregonensis* (Diptera: Cecidomyiidae)? The Canadian Entomologist.

4.3 Conservation and Management of Grand Fir

Don Pigott

YELLOW POINT PROPAGATION

Grand fir is an important part of reforestation programs in coastal British Columbia at lower elevations. It is a fast growing species; provenance testing showed that 20-year height of the most productive seed sources reached 18m at fertile sites, indicating a potential rotation of 40-45 years at many coastal sites. Grand fir is also very tolerant of flooding and fluctuating water tables. The species has an important role in wood production and ecology.

In the year 2000, approximately 138,000 Grand fir were planted in BC. Less than 2000 of these trees were planted in the Nelson region; the remainder was planted in the Vancouver Forest Region. Minor amounts have also been planted in the Prince Rupert Region, with notable performance from inland sources east of Hope.

Seed demands will likely increase as logging of low elevation second growth stands on the East Coast of Vancouver Island, the Sunshine Coast, and the Lower Mainland accelerates. Seed production in the one grand fir orchard, after 14 years, has been dismal, similar to the experience in other *Abies* orchards. Considering the demand, further investment in seed orchards is unwarranted, and future seed needs must be met through collection from productive natural stands identified according to provenance testing results.

Many of the best Grand fir stands on the East Coast of Vancouver Island, including several recognized B+ stands, have been eliminated or are threatened by urbanization and logging. Conservation measures are necessary to secure long-term access to a seed supply for Grand fir.

The range of Grand fir in the Interior of BC is limited to lower elevations in the Arrow Lakes and Kootenay Lake region in southern BC. Little information is available on the status concerning gene conservation and seed supply potential, however generally the stands are small isolated pockets, which are vulnerable to both human activity and natural disturbance.

In 2001-2002, many of Grand fir stands remaining on the East Coast of Vancouver Island, and the adjacent mainland as far east as Hope, were visited and assessed for suitability for gene conservation and long term seed supply. This information was compiled and evaluated.

Initially, we were concerned about the negative impact of logging and urban development on the stands and trees, particularly on the East Coast of Vancouver Island. One of the more positive findings of this survey was that the species is better represented in a network of provincial, federal, and municipal or regional parks than was originally thought. Although technically this will probably satisfy the needs for gene conservation, these areas are currently not accessible for operational, or even research seed collections in most cases.

It was recommended to the *Abies* Species Committee that management plans to ensure long term seed supply for at least two stands within superior provenances be developed and initiated. The Provenance Forester was asked to make recommendations as to which populations could be designated as superior provenances.

In 2002-2003, the Provenance Forester reviewed the 20-year results of the Grand fir Provenance Tests. Analysis focused on provenance differences in growth and consistency over the testing period. Overall, provenances from Eastern Vancouver Island were the best in growth, with Salmon River, Oyster Bay, and Parksville ranking 1, 2, & 3 across all four test sites. Conclusions were," Natural populations of Grand fir along Eastern Vancouver Island are inherently fast growing. From a utilitarian perspective, these populations ought to receive the highest priority for conservation and protection ".

There are a few stands on Crown land and private forestland in the vicinity of these currently known superior provenances, where there is the potential to manage the species to satisfy our objectives. Consultation is currently underway with the Ministry of Forests, and the private land owners to encourage and develop a management plan which will ensure a long term seed supply. Discussions are also in progress regarding the accessibility of genetic material in several parks and protected areas. (SPU 3601)

4.4 Determining Barriers to Seed Production in *Abies* spp.

Joe Webber,
MoF Research Branch

Don Pigott
YELLOW POINT PROPAGATION

Two objectives of our FRBC *Abies* project were to monitor the flowering and seed production response of amabalis and sub-alpine fir and to develop strategy for inducing flowering in grafted material. Scion collections of amabilis fir were made from the CLRS (Series 1, grafted spring 1994). We also made collections from young and old amabilis fir ortet material (Series 2, grafted spring 1996) from each of two locations on Vancouver Island (Franklin River and Iron River). We also collected two series of sub-alpine fir. The first (Series 3 grafted in 1996) and Series 4 (grafted in 1997), all from the Kalum District. The grafts were maintained at CLRS.

Since we have not had good success with Saanich peninsula seed orchards, we decided to move this grafted stock to a mid elevation site. We were limited to where we could plant this material because the quarantine zone for Balsam Woolly Aphid was still in effect.

Don Pigott located a site on Timber West land near Ladysmith and handled the planting detail. Twelve ramets each of 10 clones from the Series 1 and Series 3 grafting and 12 ramets from each of the two ortet age series (Series 2) were selected. Plantation design used four three row plots randomly assigned. Spacing was 2x3 m. Planting was completed in November 5th, 2002. Details for the plantation and maps are available from Mark Griffin, Research Branch. (SPU0902)

4.5 Estimation of Deleterious Effects of Different Levels of Inbreeding on Western Hemlock Seed Orchard Production.

Oldrich Hak

In forward-selected advanced generation seed orchards and even in first generation orchards, low level of inbreeding has been shown to reduce seed production. Since the use of SMP and of related clones in advanced generation forward selected seed orchards is likely, it is important to gauge the impact of this on orchard production. The size of these effects, except for selfing, for western hemlock is unknown. The objective of this study is to determine the effect of lower level inbreeding in 12 western hemlock parent trees on seed orchard production.

The parent trees in question are being control-crossed to ascertain mean filled seed per isolation and seed production in percent relative to out-crossed seed production. In the first year selfing and out-crosses were done with parent trees in clone banks and seed orchards. Parents and full-sib progeny in the field were induced to secure adequate flowering. In the second year, crosses will be made between parents and their progeny, and among siblings in the field. Further inductions will be done and in the last year as many of the crosses as possible will be completed. (SPU 0309)

4.6 Development of Pollen Management Guidelines for Yellow-Cedar.

Oldrich Hak

Deficiencies in high quality yellow-cedar pollen during pollination may be one of the factors responsible for the failure of low elevation seed orchards to produce sufficient quantities of viable seed. Results up to now indicate that pollen collected from low elevation seed orchards had low viability and low vigor while pollen from high elevation natural stands was of superior quality. If poor pollen viability proves to be one of the main reasons for poor seed production in seed orchards, superior quality pollen could be produced at high elevation orchards then stored and later used to pollinate low elevation orchards.

To date, all assessments of pollen quality were based entirely on vitro testing, using solid media and percentage of pollen germination. These assessments should be therefore interpreted only as an indication of pollen fertility. The actual fertility of low elevation males is being confirmed in this study through control pollinations of females in natural stands using low elevation pollen. Similarly, the level of fertility of low elevation females is not known and is being examined through control pollinations using high quality pollen collected from natural stands. The study will provide more definite answer to the question of whether low elevation males and low elevation females are capable of producing viable seed.

To date, control pollinations at low elevation seed orchard (Mt. Newton), using high elevation stored pollen and orchard pollen as control, have been completed. Control pollinations in natural stands at high elevation (Mt. Washington), using low elevation pollen (Mt. Newton) and high elevation pollen as control, have been also completed. Because yellow-cedar cone development and maturation takes two growing seasons, cone collection, seed extraction, number of filled seed, and seed germination will be completed in fall 2003 and winter 2004. (SPU 1106)

4.7 Improving Seed Production in Yellow-Cedar Seed and Breeding Orchards.

Oldrich Hak

New breeding orchards will be established in the near future to rejuvenate clonal material in hedge orchards. Situating these orchards at low elevation is questionable since previous orchards, planted at low elevations on Vancouver Island, have failed to produce viable seed. Sexual reproduction of yellow-cedar, adapted to cold temperatures and short growing seasons, may be negatively affected when trees are grown in seed orchards and subjected to warmer climate and longer growing season. It has been documented in the literature that extreme temperature conditions during pollen development, with meiosis being the most sensitive part, play a significant role in pollen quality in several species. Comparable effects on yellow-cedar pollen have not been documented in the literature. Examining and comparing pollen development and pollen quality between various geographic and environmental locations, to determine if there is a significant deterioration of pollen viability in low elevation seed orchard when compared to high elevation natural stand, is therefore the first objective of this project. This may provide an insight into which conditions are beneficial for healthy pollen development and maturation. Such information will make it possible to locate suitable sites for production of good quality pollen. The study followed the development of pollen-cones from the initiation stage in the summer of 2001 to the shedding stage in the spring of 2002, as well as pollen viability during specific stages. Three sites Mt. Newton, Mt. Washington, and Whistler Mt., were selected based on the sites mean annual temperatures. The results show that there was a significant trend in the acceleration of pollen development and in the corresponding reduction of pollen quality as the test site elevation decreased. There were substantial differences in pollen development and quality between warm, low elevation sites and colder, high elevation sites (Figures 39 and 40). Pollen-cone development in 2001 was accelerated by approximately one month at Mt. Newton when compared to Mt. Washington, reflecting higher average monthly temperatures at the lower elevation site throughout the year (Figure 1). In general, all early stages of pollen-cone development (i.e. stages 1 to 3) at Mt. Newton occurred when the mean monthly temperatures reached their peak in July and August (15^{0}C and 16.5^{0}C respectively), while only the last two stages, 4 and 5, occurred when the high temperatures started to decrease. The last stage, 6, the shedding stage, will be completed next spring. At Mt. Washington, on the other hand, only the first stage occurred at the peak of the mean monthly temperature in August, while the rest of the pollen-cone development (stages 2 to 4.5) occurred under more moderate temperatures in September and October (10^{0}C and 4^{0}C respectively). Average pollen viability before winter dormancy at Mt. Newton and Mt. Washington was comparable (54% and 55% respectively) but at Whistler Mt., pollen viability during the same period was much lower (26%) (Figure 2). Mt. Washington and Whistler Mt. pollen maintained its viability at the pre-dormancy level throughout the winter, while the viability of Mt. Newton pollen decreased dramatically from 54% to 17%. At pollination time (spring 2002), Mt. Newton pollen viability remained low (22%), while there was a moderate increase in viability at Mt. Washington (from 55% to 63%). The most dramatic change in pollen viability was at Whistler Mt., increasing from 26% to 72%.

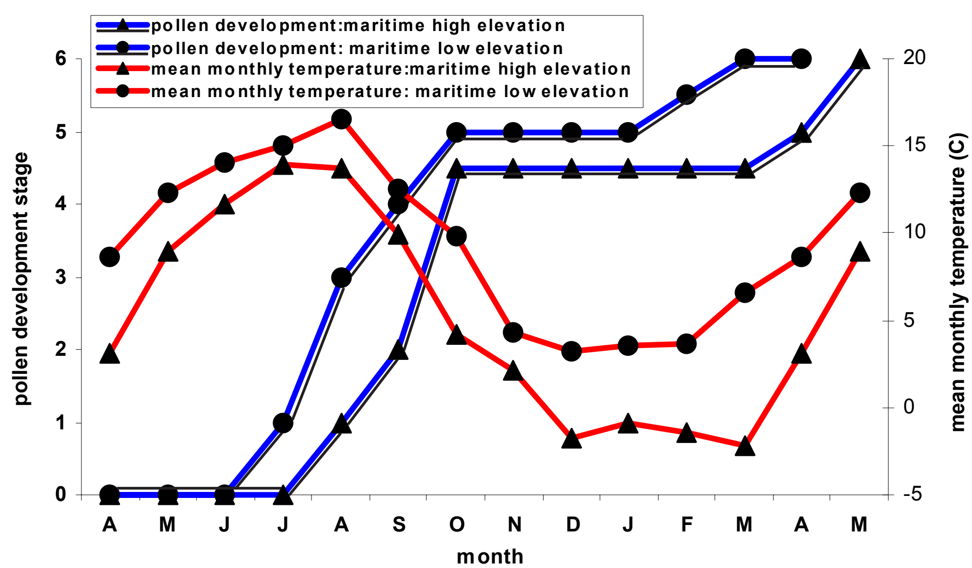
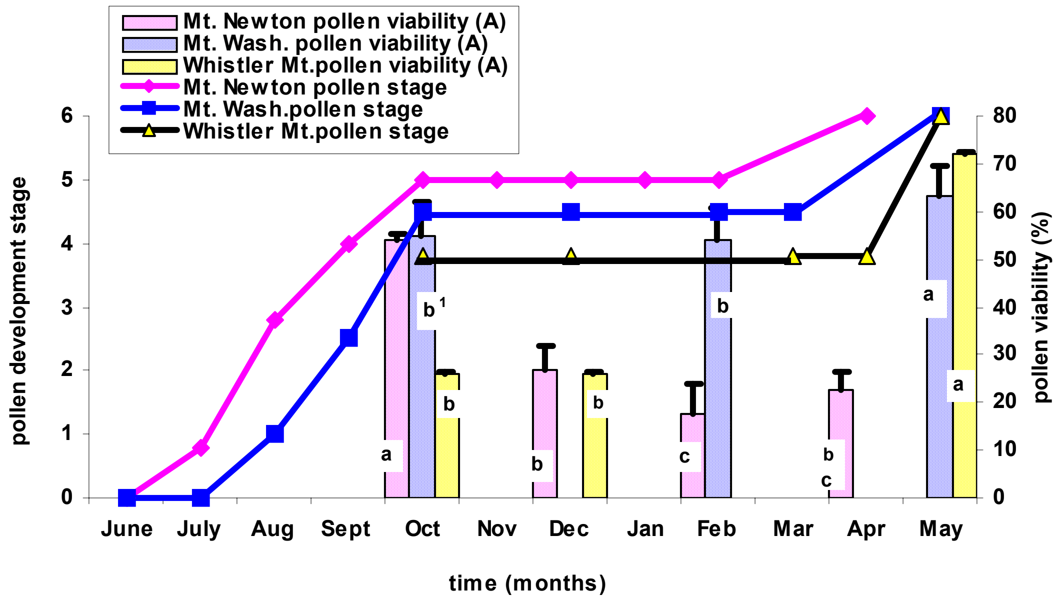


Figure 39. Relationship between yellow-cedar pollen development and mean monthly temperature at two contrasting sites, from spring 2001 to spring 2002.



(1) different letters denote significant differences (p<0.05) between times, within populations according to Fisher's LSD mean separation test

Figure 40. Yellow-cedar pollen development and viability (+/- s.e.) by population over time (2001 to 2002).

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

Oldrich Hak

The purpose of this study was to improve the genetic quality of seed through the reduction of self-pollination and at the same time to increase the operational efficiency of female cone production in seed orchards. Increasing the proportion of female cones to male cones in the crown, by focusing induction treatments to specific areas in the crown and calibrating the treatments to an optimum time period, was the first objective of the study. The second objective was to determine when in the growth season the effectiveness of cone induction treatments ceases. The third objective was to establish the most effective treatment period to maximize seed production. To meet the above objectives, all cone induction treatments were done on vigorous shoots where the presence of female cone production sites was the highest and of male sites the lowest.

Female to male cone ratio

Late summer cone induction treatments (August) and a combination of late spring and late summer treatments (May & August) produced significantly higher (p = 0.05) number of female cones on vigorous branches than control and spring treatments (May) alone. Male production was not significantly different between May and August treatment periods but the number of males was significantly lower in the May & August treatment period. Similarly, an August and a May & August cone induction treatment periods had significantly higher (p = 0.05) female to male cone production ratio in both, the proximal section of the vigorous shoot (Zone 1) and the distal section (Zone 2), than control and May treatments alone (Figure 41). The most dramatic increase in female to male cone production ratio was in Zone 1 in the May & August treatments.

Effectiveness of late summer cone induction treatments

Significant decreases in female cone production (p = 0.05) were observed during and after the 19-August treatment period (Figure 42). Figure two also illustrates the relationship between treatment periods, level of female cone production, and shoot increments. It shows a considerable and permanent decrease in shoot increments starting in the 12-August treatment period, which was followed by a significant reduction of female cone production in the 19-August treatment period. Observations during the pollination season revealed abnormalities in male and female flower development in the 19-August and later treatment periods. The occurrence of abnormalities in the 19-August treatment period varied between clones and ranged from zero to moderate while in the later treatment periods they became progressively augmented. The size of male and female cones was smaller than usual and the cones were still in their developing stage at the time of pollen shed and female receptivity in the rest of the orchard. Furthermore, the color of the abnormal male and female cones changed from the usual black and dark gray respectively to light brown, and the cones did not complete their development.

Timing of cone induction to maximize seed production

July and August treatment periods produced comparable number of female cones, but the production was significantly higher than in May or June periods (Figure 43). Figure 43 also illustrates the relationship between treatment periods, level of female cone production, and shoot increments. It shows that the highest cone production coincides with the peak levels of shoot increments in July and August.

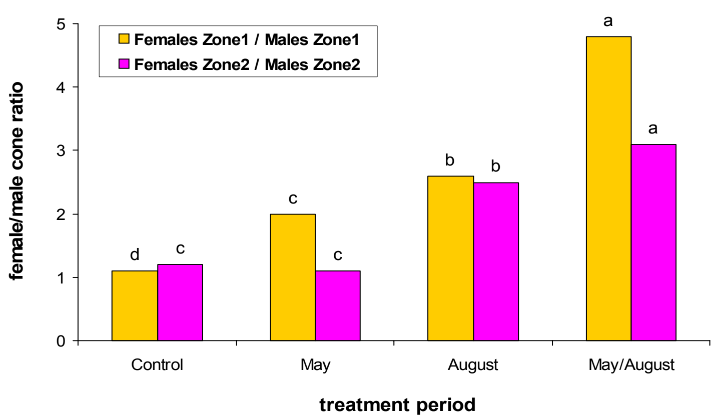


Figure 41. Effect of cone induction timing on female to male cone production ratio

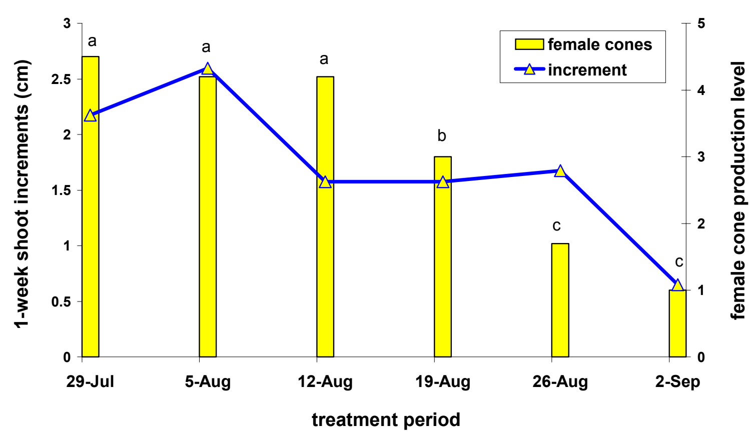


Figure 42. Relationship between late summer cone induction treatments, level of female cone production, and weekly terminal shoot increments.

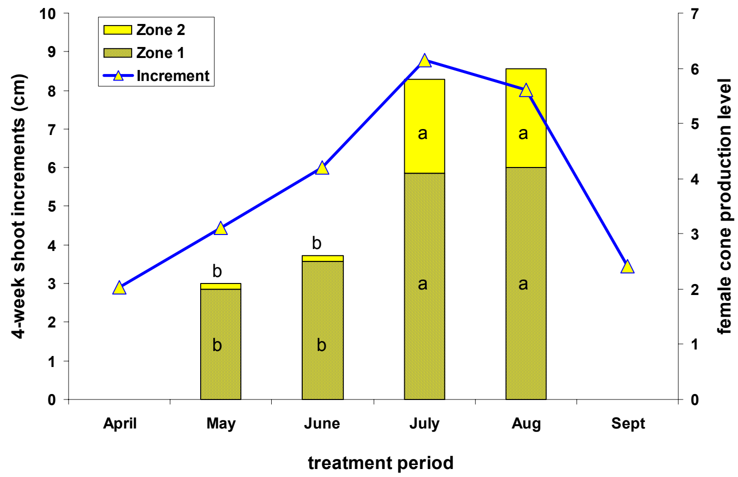


Figure 43. Relationship between the timing of cone induction treatments, level of female cone production and monthly terminal shoot increments.

4.9 Controlling Selfing Rates in Natural and Seed Orchard Populations of Western Red Cedar

Kermit Ritland

Annette van Neijenhuis

Previous studies based upon the analysis of genetic markers have demonstrated considerable selfing in Cwr seed orchards, but levels vary tremendously (10-60% selfing) among these studies. To document possible factors responsible for selfing, so that their levels can be better controlled, in the current year we evaluated the efficacy of SMP in Lost Lake Orchard 128, using material supplied by Annette Van Niejenhuis (Western Forest Products, Saanichton). In 2001, progenies of ten clones subjected to SMP, and another 10 clones not subject to SMP but mostly female, were genotyped (crops were also collected separately from the upper crown and the lower crown). Multilocus outcrossing rates are listed in Figure 44, (SE's in parentheses).

	SMP	Females	Mean
Top	0.798 (0.059)	0.889 (0.046)	0.844 (0.037)
Bottom	0.867 (0.050)	1.027 (0.051)	0.947 (0.036)
Mean	0.833 (0.039)	0.958 (0.034)	

Figure 44. Cw Multilocus outcrossing rate findings

The higher outcrossing rates at the bottom, compared to the top, is opposite the trend found in two previous studies. Also, it appears that SMP was not that effective in preventing selfing in this study, whereas SMP was highly effective in a previous study. The 2001 pollen season was extraordinary — the crew could just see the pollen wafting about like a fog, so we conclude that excess pollen cloud results in (a) higher outcrossing in the lower parts of the tree, and (2) less effectiveness of SMP.

We are also evaluating how selfing rates can be evaluated on a routine and economical basis, and perhaps be used to estimate seedlot quality. Seed was sampled at random from a seedlot, without knowledge of parentage, genotyped and estimated the inbreeding coefficient *F*. If parents are outbred, the outcrossing rate is 1-2*F*. Also, at the genotyping stage, we also evaluated the feasibility and efficiency of "pooling" seeds in groups of two and three seeds (plus individual seed genotyping). The estimation procedure and properties for *F* for pooled samples is described in Ritland (in prep.). Using the same sample of trees for the SMP treatment above, we found:

Pool size	1	2	3
Top	0.23	0.73	0.74
Bottom	0.17	0.69	0.8

Figure 45. SMP treatment results

While the same trend of higher outcrossing in the bottom is evident, these estimates are biased towards detecting too much selfing, particularly when samples are pooled. With no pooling (size=1), the excess selfing is likely due to "null" microsatellite alleles, which cause heterozygous individuals to appear homozygous and hence selfed. The large bias observed in the pool sizes of 2 and 3 is due to not detecting all bands (e.g., there might be 4 bands but only 3 were recorded). These microsatellites exhibited large "stutter" bands and this makes the interpretation of more complex band patterns difficult. Also, with more bands, "template competition" can occur, causing the fading of some bands. Finally, simulated data indicate the statistical power of pooled samples is not much greater (10-30%) than the power of unpooled samples, further indicating that pooling is not effective. For the operational use of markers, we need loci with no null alleles, and if pooling is employed, markers should show little band stuttering (e.g., tri- or tetra-nucleotide repeats are needed) and no template competition. Further improvements of this methodology are planned for the current year. (SPU 0209)

4.10 Spruce Somatic Seedlings:

Development of Demonstration Sites in the Central Interior

Don Summers

In 2002/03, 12 clonal block demonstration sites (1998 planting) in the Prince George Region were measured for 5-year height growth. That data is being incorporated into a summary data set for all sites over the term of the project (1995 - 2003). Maintenance on stakes, labels and pins was carried out on most 1998 plots this year, as well as on 13 others in the project. A final report for the project is in preparation.

The Prince George clonal block project includes a total of 33 sites, each planted with several individual blocks of woods-run or select seedlings, rooted cuttings, or somatic seedlings (SE). These plantations are located in representative areas throughout the Prince George (PG Low), Prince George Nelson (PGN) and Bulkley Valley/ Prince George (BVP) interior spruce planning units. This project is meant to complement the more detailed SE Candidacy Trials established through the MOF Research Branch and FGC OTIP program.

The trials began in the early 1990's, with the start of commercial SE production (through BC Research, now CellFor, and various partners). The SE were largely untested under operational conditions, so experimental Candidacy Tests were established to assess the performance of individual SE clones. Clonal demonstration plots (this project) were planted to provide additional information, and to offer an opportunity to view pure blocks of individual clones under a variety of site conditions. Select seedlings, woods-run seedlings and for comparison, rooted cuttings were added to the mix .

Over the years, there have been a number of well-attended tours for local foresters to observe the performance of SE. A similar tour was held in the fall of 2002. Site maps and summary data for the project are being prepared and will be made available for co-operating licensees and Districts for future reference.(SPU 1406)

Figure46. Somatic embling at 5 years near Bear Lake, north of Prince George

Figure 47. Woods run seedling at 5 years near Bear Lake, north of Prince George

4.11 Seed Orchard After-Effects:

The Effect of Seed Orchard Environment on Progeny Performance for Interior Spruce .

Joe Webber

Introduction

The term used to describe the effect of seed orchard environment on progeny performance is seed orchard aftereffects. Aftereffects have been demonstrated in many species including Norway spruce, Scots pine and interior spruce. Progeny created from the same mothers and fathers differ significantly in adaptive traits (frost hardiness) and growth characteristics. Our initial trial in testing aftereffects in interior spruce lacked sufficient clonal entries and design (polycrosses instead of single parent crosses) to extend our conclusions of this work to the entire population of interior spruce selections.

In this new study, we expanded the number of clonal entries, created single parent crosses on 20 mothers using 20 unrelated fathers from two sources (i.e., north on north and south on north for PG and south on south and north on south for Vernon). The design was not a complete 20 x 20 factorial but rather an incomplete factorial with pollen parents nested within mothers, which were nested within sets. A set comprised of five groups of 4 pollen parents applied to each of 4 female parents. The design is more fully described in the 2001 summary report available from the OTIP Coordinator, Roger Painter.

The two orchard sites being compared are Vernon and Prince George. The Vernon (50º 14´N by 119º 16´W) crosses were completed in 1996 (Kalamalka arboreta) but the Prince George (53º 45´N´ by 122º 41´N) crosses (Red Rock arboreta) were not made until 1999. Since orchard site (KAL) was confounded with seed storage (three years), we also collected in 1999 open pollinated cones from each of the mother trees at Prince George and Vernon.

For each site, five sets of 16 crosses with each of 2 pollen sources (north and south) were made for a total of 160 family lots per site. The total for both sites is 80 specific female x male crosses each comprised of four north x south combinations (i.e., north x north, south x south, north x south and south x north) for a potential total of 320 families plus OPs. However, since only 18 of the original 20 clones used at KAL flowered at Prince George, only 144 crosses were made (72 north female x north pollen and 72 north female x south pollen) plus their corresponding OPs. The overall total number of families generated was 340. Since some of the crosses were lost (mostly at PG), we ended up having a total of 324 families for sowing. For details of the planting design, refer to the 2001 summary report on file with the OTIP Coordinator, Roger Painter.

We selected two northern sites (PGTIS and a recent cut block near Wansa Creek). Each site consisted of 5 blocks and 20 mainplots per block (comprised of one male and four females), four female/male sources (i.e., north, south combinations) per cross and 6 tree row plots for each female/male combination. The following is an example for one of the four males in Set 1 (Male 21):

M21															
F48				F123				F132				F142			
N/N	S/S	N/S	S/N	N/N	S/S	N/S	S/N	N/N	S/S	N/S	S/N	N/N	S/S	N/S	S/N
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

N/N (PG/PG) north mother x north father
N/S (PG/KAL) north mother x south father
S/S (KAL/KAL) south mother x south father
S/N (KAL/PG) south mother x north father

Figure 48. An example of Set 1

For each specific cross, we used a 6-seedling row plot. A mainplot (20 per site) consisted of 96 seedlings plus their corresponding OP crosses from each site (also 6 tree row plots x 5 row blocks). Thus, there are a total of 30 seedlings per cross to be planted in each of the two sites. Randomization within each planting site was first by mainplots, then by mothers within each mainplot and finally female/male source combinations within each female/male cross. OP families were also randomly assigned to each block.

At both sites planting was completed by the first week of June 2001. A total of 10,800 trees were planted at both sites (9600 from crosses and 1200 from OP). Spacing within each plantation was 1m within rows and 2m between rows. At the end of planting, the first year heights (2000 nursery heights) were recorded.

Activities Completed in 2002.

In the spring of 2002, 2001 height growth (before 2002 bud flush) was measured and a damage assessment made for each site. We also completed site maintenance for the PGTIS site (mowing) and a single fall (October) frost determination at the WANSA site.

First (nursery) and second year heights for both sites are shown in Figure 49.

		Female/Male Location			
SITE		HT (cm)			
		KAL/KAL	KAL/PG	PG/PG	PG/KAL
PGTIS	Ht1 - 2000	25.0 (0.13)	25.1 (0.13)	24.0 (0.12)	25.1 (0.13)
	Ht2 - 2001	38.0 (0.12)	38.0 (0.13)	37.8 (0.13)	38.3 (0.14)
WANSA	Ht1 - 2000	25.2 (0.11)	25.1 (0.13)	24.0 (0.12)	25.4 (0.13)
	Ht2 - 2001	39.4 (0.14)	39.4 (0.15)	38.7 (0.14)	39.5 (0.16)

Figure 49. Summary of first- and second-year heights (cm +/- standard errors) for two Prince George plantation sites.

First-year height grow for the northern source (PG/PG) was about 1 cm less compared to the other three sources but if southern pollen was used, then height growth was similar to the southern sources. This effect was also apparent in second-year growth but to a lesser extend (about 0.7 cm difference).

First-year winter damage was assessed when second-year heights were being recorded. Table 50 shows the categorical rating used to assess bud flush and winter damage.

Code	Category
0	terminal bud not flushing
1	bud flush late or slow
2	bud flush complete but shoot extension slow
3	bud flush complete with rapid shoot extension
4	terminal bud dead
5	terminal shoot dead
6	whole tree dead

Figure 50. Coding and categories used to assess first-year winter damage at the PGTIS plantation site.

Figure 51 shows the number of individuals in each of the six categories for the PGTIS plantation only. Less than 1% of the trees at the WANSA site showed any winter damage so we restricted our assessment to the PGTIS site only.

	Number of Seedlings and Percent Damage by Class and Parent Source					
	Damage	Number of	Female/Male Parent Source			
WANSA	Class	Seedlings	KAL/KAL	KAL/PG	PG/PG	PG/KAL
	none	8400	29.1	24.3	20.9	25.8
	<50%	1024	31.4	24.0	20.9	23.6
	>50%	180	36.1	24.4	22.8	16.7
	dead	232	30.6	19.4	21.1	28.9
PGTIS			KAL/KAL	KAL/PG	PG/PG	PG/KAL
	none	1086	29.1	24.5	21.2	25.2
	<50%	5906	28.9	24.0	20.4	26.7
	>50%	2803	31.0	24.2	22.0	22.9
	dead	43	25.6	20.9	18.6	34.8

Figure 51 Winter damage for each of the two plantation sites showing the number of seedlings and the percent damage by class for each of the four parent sources.

The effect of plantation site on damage is apparent. At the PGTIS, 89% of the seedlings showed some damage where only 16% were damaged at WANSA. For the PGTIS site, female source had a significant (Chi-Square statistics) effect on damage with the southern sources showing about 8-10% more damage than their northern counterparts. The effect of male source also seems important. Northern pollen sources applied to southern females (KAL/PG) showed less damage and southern pollen applied to northern females (PG/KAL) showed more damage when compared to their south/south and north/north counterpart.

Finally, we assessed both spring and fall frost using fluorescence technique. A sub-sample of trees from each of the south/south and north/north parent sources at the WANSA site only was considered in these tests. Sampling was done in May and September 2002. Neither the spring or fall test showed any differences due to parent source.

We do not feel that either the spring or fall sampling periods was optimum for distinguishing between parent sources. The May sampling may have been too early and the fall sampling period was likely to late. We will attempt to retest the fall frost earlier (late August or early September). We will also consider assessing bud flush for each of the four parent sources.(SPU1407)

4.12 Genetic Worth Evaluations of Interior Spruce Seedlots: (A)

Analysis of OP Seed From Four Different Years.

Craig Newton

BC RESEARCH Inc.

Background.

Seedlot quality and corresponding *genetic worth* is maximal when panmixis (random mating) is high and pollen contamination is low. In this way both the genetic gain (trait improvement) and genetic diversity of reforestation populations are maintained from the breeding program through operational delivery by seed orchards. The main variable that impacts the quality of OP seedlots is the windborne male pollen contribution. Until recently methods to monitor the male gamete have depended on indirect assays such as male strobili surveys to estimate panmixis and pollen traps to estimate pollen contamination. Both are open to high variation and do not reflect what actually is happened in fertilized seed. The development of chloroplast markers for conifers has provided an alternative approach that promises to increase the accuracy of seedlot genetic worth evaluations. Chloroplasts are paternally inherited in conifers and, providing sufficient genetic polymorphism (*haplotype* diversity) is available, offer a direct measure of which pollen fertilised a given seed. Highly informative markers of this type have been developed previously for Lodgepole pine and more recently for Spruce.

This study.

A set of five highly polymorphic spruce chloroplast markers (89F/62R2, 84.1F/R3, 8F3/R3, 7F3/R2, S2spF2/R3) are being used to evaluate a) spruce seed orchard parental chloroplast diversity (SPU 1415) and here, b) to evaluate parental contribution in 4 seedlots from different years from spruce Orchard 304 at the Kalamalka Station. The goal is to measure pollen contribution within a given seedlot year to assess differences in parental contribution (panmixis) and then to measure contribution over different seedlot years to evaluate whether any differences in pollen contribution are systemic and lead to long term deviations in the genetic output of seed orchards.

Progress.

Three bulked seedlots (#60277, 60432 and 60712) were obtained from the Surrey Seed Centre. The fourth seedlot, corresponding to the year 2002 cone collection, was provided (C. Walsh) as half sib cone collections so that maternal contribution (and selfing) could be estimated. Approximately 500 seed from each of the 3 bulked seedlots were hand dissected and the embryos excised for DNA purification. For the half sib collections, between 48 and 72 seeds were similarly prepared for each of the 40 clones in orchard 304. All embryo DNAs were then amplified with the spruce chloroplast 5 locus multiplex and analysed by polacrylamide gel electrophoresis. The figure below shows the chloroplast haplotypes obtained using this multiplex marker system. The seed data is currently being compiled. (SPU1414)

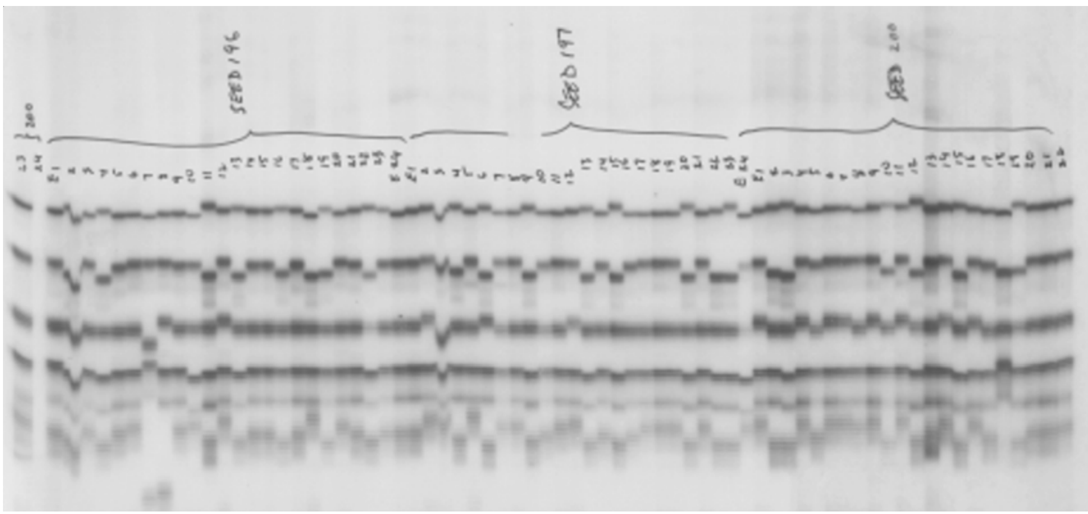


Figure 52. Interior spruce seedlots analysed with chloroplast multiplex markers.

4.13 Genetic Worth Evaluations of Interior Spruce Seedlots: (B)

Chloroplast DNA Haplotyping of Parental clones.

Craig Newton

BC RESEARCH Inc.

The ability to monitor gene flow in reforestation populations is necessary to ensure that the genetic gains from tree improvement programs are being delivered at the operational end through seed orchards. Moreover, it is important to verify that operational seedcrops maintain the genetic diversity of starting parental populations, to ensure that reforestation activities do not negatively impact the sustainability of long term managed forest populations. In conifer reforestation populations, gene flow is primarily determined by the paternal wind-borne pollen gamete, as pollen is the only variable that is not directly amenable to management and selection. To this end, considerable effort has been directed towards developing DNA marker assays, particularly chloroplast (cp) DNA assays that are specific for the paternally inherited male pollen gamete.

This study.

Preliminary studies (SPU1408) identified a set of chloroplast loci that exhibit high levels of polymorphism in spruce. Subsequently, these markers were combined into a 5 locus PCR multiplex where all five loci are scored simultaneously using one PCR reaction and a single lane on an analytical gel electrophoresis device. The goal of this study is to evaluate this marker system to determine the levels of chloroplast multilocus haplotype diversity in operational spruce seed orchards.

Progress.

Vegetative tissue was sampled from parental clones in 5 spruce orchards (#209, 304, 305, 306 and 620) located at the Kalamalaka station. A total of 248 tissues were obtained and total DNAs were isolated and banked. These parental DNAs have been analysed with the chloroplast multiplex and the haplotypes are currently being compiled. Figure 53 shows a sample of parental multiplex DNA profiles from orchard 304. A total of 28 unique multilocus haplotypes can be seen in the 30 lanes for which complete data is available. Only three clones share identical haplotypes (208, 226, 247). Similar results were obtained for the other orchards. At this level of chloroplast haplotype diversity it should be possible to analyse pollen contribution in spruce with a high degree of accuracy. (SPU1415)

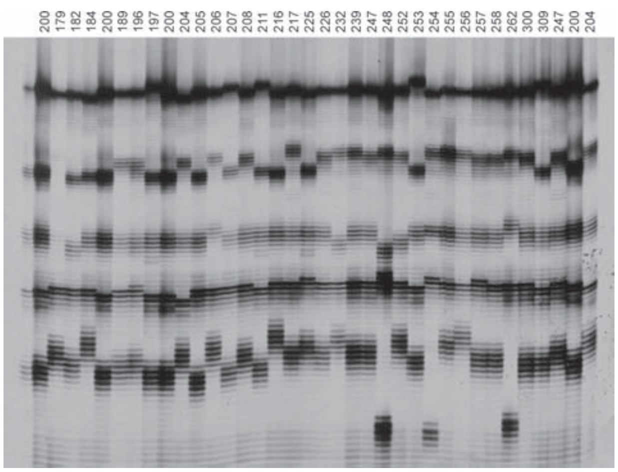


Figure 53. Chloroplast Multiplex analysis of Orchard 304 parent clones.

4.14 Genotyping of Sitka Spruce Parental Clones for Seedlot Evaluation and Clonal Identifcation.

Craig Newton

BC RESEARCH Inc.

Background.

Weevil resistance in spruce is one example of an improved trait that gives high genetic worth to seedlots. Therefore it is important that such high value traits be verified both at the clonal level (eg parent clones) and in seedlots derived from weevil resistant parents. Because there are no fast phenotypic assays, or specific DNA markers linked to weevil resistance *per se*, verification can only be confirmed by unambiguous identification of the selected parental clones and their progeny.

This study.

In this project we use 4 spruce specific nuclear microsatellites to identify weevil resistant clones by multilocus DNA 'fingerprinting' methods. DNA fingerprints will be used to confirm the clonal identity of parental clones in two weevil resistant orchards, #172 and #195. In addition spruce chloroplast DNA markers (see SPU1415) will be assessed for their diagnostic ability to monitor pollen flow in these seed orchards.

Progress.

Vegetative samples from the parent clones of Orchard 172 and #195 were collected and total DNAs prepared. Each genomic DNA was then analysed using the four spruce specific microsatellites (Ss25, Ss56, Ss2, Ss14) and the 5 locus spruce chloroplast multiplex. High levels of allele diversity were observed with the nuclear microsatellite markers and are sufficient to provide clone specific multilocus genotypes. These results are being compiled. The chloroplast markers, on the other hand, showed much reduced levels of chloroplast haplotype diversity compared to interior spruce populations. This difference appears to be Sitka specific as other populations from the same and different location show similar reduced levels of chloroplast haplotype diversity. For pollen monitoring purposes, this will require the additional use of nuclear markers to differentiate the possible pollen sources in seed derived from orchard 172 and 195. Together, these DNA marker sets should prove useful in ensuring that the gains from weevil resistant breeding trials are delivered to the field.(SPU 0607)

4.15 Estimation of Selfing Rates in Western Larch Using DNA Markers

Craig Newton
BC RESEARCH Inc.

Background

In western larch (*Larix occidentalis* Nutt.) and other conifer species, self fertilisation is one genetic parameter that has been shown to reduce seedlot quality and the field performance of reforestation seedlings. The ability to measure 'selfing' is therefore an important tool for detecting whether factors such as orchard design or certain management practices e.g. crown topping, are leading to increased levels of selfing and therefore negatively impacting seedlot genetic worth.

This study.

The best way to accurately measure selfing is to use molecular DNA markers to distinguish 'self' from outcross pollen sources in fertilized seed. In this way selfed seeds can be recognised by having a DNA marker that could only have arisen from its maternal parent. To achieve such discrimination requires DNA markers that are able to distinguish a large proportion (or all) of potential pollen sources within an orchard. The object of this project was to survey available larch specific markers, both nuclear and chloroplast in origin, to assess this diagnostic capability.

Two model Larch orchards located at the Kalamalka station were chosen for study. Orchards 332 and 333 contain appromately 100 unique clones each and are intended for the WK/SA and EK seed planning zones, respectively. Vegetative samples were collected from one ramet in each orchard and total DNAs were prepared and banked.

Larch DNA markers.

Two classes of larch genetic markers are available for this study. One consists of a set of 10 (LL2, LL3, LL4, LL6, LL7, LL8, LL10a, LL10b, LL13, LL14) nuclear microsatellite markers isolated previously for alpine larch (*Larix lyallii* Parl.). The questions for this study were whether the alpine larch markers would work in western larch and the number of unique alleles that are present for identifying selfing events in OP seedlots. The second set of markers consist of 4-5 chloroplast loci markers (89F/62R, G2.1/R1, 10F/RR, 59aF/R). These chloroplast markers have the advantage over nuclear microsatellites in that they are inherited in pollen and thus are ideally suited for identifying maternal pollination events. The main question here was whether the combined chloroplast variation of the 4-5 sites produce clone specific chloroplast DNA mutlilocus haplotypes that can be used to monitor selfing.

Progress.

Figure 54 shows results for one microsatellite marker (LL10a) in western larch clones from orchard 333.

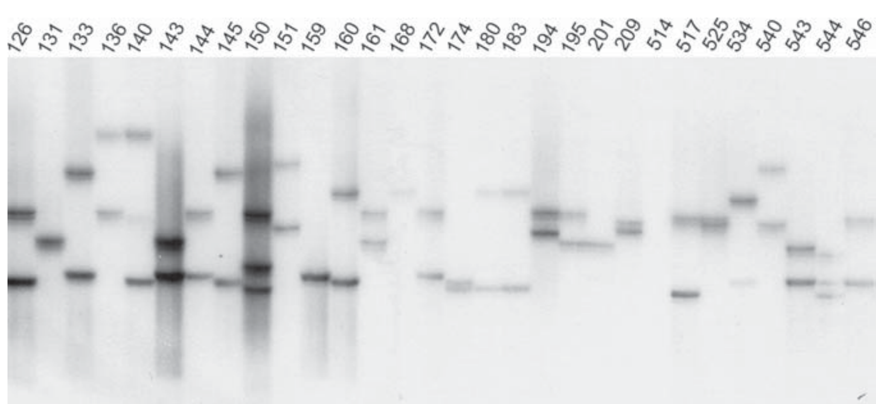


Figure 54. Selected larch clones from orchard 333 analysed with microsatellite marker LL10a.

At least 10 distinct alleles are evident in the clones shown. Similar tests are being compiled for the remaining larch nuclear microsatellites and the chloroplast markers. Final results will include all ten microsatellite markers and the 4-5 chloroplast specific markers. Unique nuclear alleles and chloroplast multilocus haplotypes will be compiled for both orchards in order to assess their ability to detect selfing in these populations. These result will then be used to analyse seeds from parental clones where respective nuclear alleles and/or chloroplast haplotype are clone specific and thus a measure of self fertilisation events. (SPU1303).

4.16 Enhancing Seed Production in North Okanagan Lodgepole Pine Seed Orchards.

Joe Webber

Evidence from previous pollination experiments and data from our cultural experiments (irrigation, misting) applied to two north Okanagan lodgepole pine seed orchards clearly shows that operational seed yields (15 filled seed per cone) can be obtained. The chronic low seed set in north Okanagan lodgepole pine seed orchards was not related to pollen supply (quantity, quality, uptake or selfing) but rather was primarily related to *Leptoglossus* damage. To a certain extent, better cultural technique (irrigation) has also improved seed yields but the effect was less pronounced because spring temperatures during the last three years has been cool.

Figure 55 shows data obtained from Stoehr and Hollefreund (1999) presented in the summary report of the Interior Lodgepole Pine Seed Set Task Group.

Figure 55 shows seed yields from open pollinated cones that were bagged and unbagged. An average of 9, 10 and 8 filled seed per cone were lost due to insect damage in the years 96, 97 and 98. Only the yields in 1998 did not meet operational targets (for insect protected cones). The year became extremely hot and dry after April. The drip irrigation in use at this time was not sufficient to keep soil moisture at a level required to maintain good cone development. It is our hypothesis that if the seed orchard soil moisture is fully charged in early April and maintained somewhat near field capacity during May (pollination) and June (fertilzation), then operational targets for seed set can be achieved. However, insect damage (*Leptoglossus*) must be controlled.

We now believe that the drip irrigation system used by

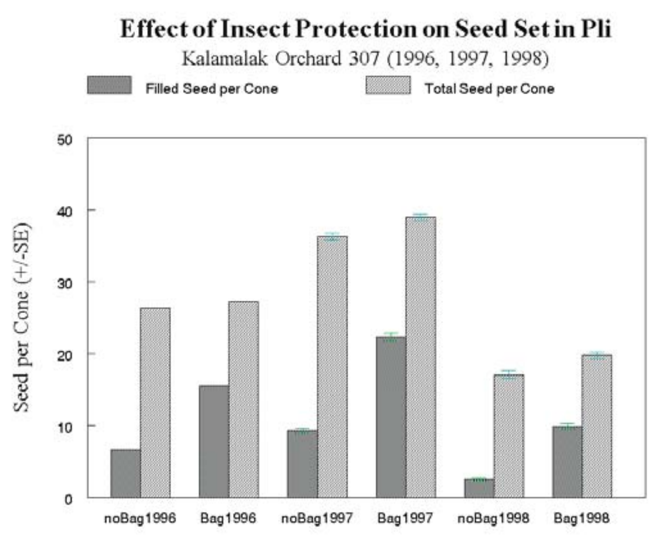


Figure 55. The effect of insect damage on seed yields for lodgepole pine in orchard 307 for the pollination years of 1995, 1996 and 1997 and the cone collection years of 1996, 1997 and 1998.

many of the north Okanagan lodgepole pine seed orchards was limiting the volume of root development, which in turn was not sufficient to support the development of large crown masses. During hot dry weather, either the volume of roots available or the amount of water supplied (or both) did not meet the tree's demand when temperatures were very hot (>30°C) over an extended period.

The details for the cultural treatments applied to both lodgepole pine orchard 307 (KAL) and 308 (PRT) are available in the last two issues of the FGC Tree Improvement Program Annual Reports (2000/2001 and 2001/2002).

Our cultural systems (mist and irrigation) did improve seed yields at KAL in all three years (Figure 56) but not at PRT (Figure 57). However, the most significant effect on seed yields was protecting the cones from insect damage. It is also important to note that weather conditions prior to and during pollination seasons (April/May) were cool for all three years. Weather conditions during the fertilization and embryo development periods (June/July) were normal (hot and dry) for the years 2000 and 2002 but much cooler than normal for 2001. Seed yields from both orchards in 2001 were among the highest recorded (average of 19 filled seed per cone for open pollinated, unbagged cones) for any north Okanagan lodgepole pine seed orchard. This also coincides with aggressive insect control measures.

We also observed increases of first- and second-year cone mass due to better irrigation and misting at KAL but the results for PRT were mixed. Figures 58 and 59 show the first- and second-year cone dry weights by year for KAL and PRT, respectively. Overhead cooling (mist) had the biggest effect on first-year cone mass and irrigation effects were more noticeable on second-year cone development (KAL only). The results for PRT are less clear. The response for mist and irrigation effects at PRT is not consistent. It cannot be explained hy first-year cone masses are lower than that of the control blocks. Considerable differences between soil types in the control and irrigation/mist block occur and this may explain the apparent anomalies. Because we can not explain the results for treatments at PRT, we have decided to drop PRT from future studies.

Seed weight data for KAL and PRT are shown in Figure 60 and 61, respectively. Irrigation (but not mist) did improve seed weight at KAL only.

	Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags				
2000	9.7 (1.6)	13.0 (1.5)	11.9 (1.4)	15.9 (1.9)
2001	18.8 (na)	19.5 (na)	18.5 (na)	21.9 (na)
2002	16.7 (1.9)	22.5 (1.6)	17.6 (1.6)	20.6 (1.6)
Means	**15.1**	**18.3**	**16.0**	**19.5**
Open Pollinated - Insect Bagged				
2000	na	na	na	na
2001	25.5 (2.9)	26.8 (2.8)	23.7 (3.5)	26.9 (3.0)
2002	24.3 (2.5)	25.8 (1.6)	28.0 (2.6)	24.9 (1.9)
Means	**24.9**	**26.3**	**25.8**	**25.9**

Figure 56. Mean seed yields (+/- standard errors) for open pollinated cones at KAL (orchard 307) for cones bagged and unbagged in each of the four treatment blocks for each of three years.

	Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags				
2000	8.1 (1.1)	5.2 (0.7)	6.4 (1.1)	7.5 (1.1)
2001	9.0 (na)	11.5 (na)	6.2 (na)	15.0 (na)
2002	14.7 (1.8)	14.3 (1.5)	8.9 (1.6)	15.2 (1.7)
Means	**11.60**	**10.30**	**7.20**	**12.60**
Open Pollinated - Insect Bagged				
2000	na	na	na	na
2001	na	na	na	na
2002	24.2 (3.1)	18.6 (2.0)	15.6 (2.1)	21.6 (1.5)

Figure 57. Mean seed yields (+/- standard errors) for open pollinated cones at PRT (orchard 308) for cones bagged and unbagged in each of the four treatment blocks for each of three years.

2000/01/02 Dry Cone Weights for Kalamalka Seed Orchard 307 By Treatment Block				
	Control	Mist/Irrigation	Irrigation	Mist
Yr1 Seed Cones				
2000	0.229 (.015)	0.272 (.017)	0.223 (.013)	0.319 (.039)
2001	0.195 (.008)	0.276 (.021)	0.242 (.021)	0.245 (.023)
2002	0.182 (.011)	0.217 (.009)	0.192 (.007)	0.203 (.007)
Yr2 Seed Cones				
2000	6.54 (.445)	6.19 (.899)	5.46 (.624)	6.16 (.956)
2001	6.86 (.408)	6.95 (.658)	6.67 (.498)	6.64 (.308)
2002	6.19 (.278)	6.93 (.276)	6.83 (.303)	5.98 (.254)

Figure 58. Mean (+/- standard errors) dry weight for first- (mg) and second-year (gm) cones for KAL (307) by treatment blocks and year.

2000/01/02 Dry Cone Weights for PRT Seed Orchard 308 By Treatment Block				
	Control	Irrigation/Mist	Irrigation	Mist
Yr1 Seed Cones				
2000	0.232 (.018)	0.205 (.010)	0.193 (.013)	0.252 (.036)
2001	0.192 (.007)	0.178 (.008)	0.168 (.010)	0.242 (.027)
2002	0.161 (.009)	0.156 (.010)	0.148 (.009)	0.199 (.016)
Yr2 Seed Cones				
2000	4.92 (.327)	5.43 (.307)	3.50 (.222)	5.03 (.433)
2001	5.42 (.442)	5.02 (.376)	4.04 (.278)	6.30 (.493)
2002	4.51 (.346)	4.62 (.301)	3.92 (.185)	5.33 (.548)

Figure 59. Mean (+/- standard errors) dry weight for first- (mg) and second-year (gm) cones for PRT (308) by treatment blocks and year.

	Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags				
2000	4.1 (0.14)	4.2 (0.16)	4.6 (0.24)	4.4 (0.10)
2001	na	na	na	na
2002	4.1 (0.13)	4.8 (0.13)	4.8 (0.13)	4.1 (0.11)
Open Pollinated - Insect Bagged				
2000	na	na	na	na
2001	3.2 (0.18)	3.9 (0.25)	3.6 (0.27)	3.5 (0.21)
2002	4.2 (0.16)	5.0 (0.16)	5.1 (0.16)	4.3 (0.13)

Figure 60. Mean (+/- standard errors) seed weight (mg) for KAL (307) by treatment blocks and year.

	Control	Mist/Irrigation	Irrigation	Mist
Open Pollinated - No Insect Bags				
2000	3.9 (0.19)	3.9 (0.14)	3.6 (0.17)	4.0 (0.18)
2001	na	na	na	na
2002	4.0 (0.17)	4.0 (0.16)	3.6 (0.14)	4.3 (0.18)
Open Pollinated - Insect Bagged				
2000	na	na	na	na
2001	na	na	na	na
2002	4.5 (0.23)	4.2 (0.18)	4.1 (0.18)	4.6 (0.23)

Figure 61. Mean (+/- standard errors) seed weight (mg) for PRT (308) by treatment blocks and year.

First and second-year cone numbers were recorded for each block in each year. Figures 62 and 63 show the counts for first- and second-year cones for KAL and PRT, respectively. We did not see any effect on treatments on either first year cone numbers. This is important because we were concerned that irrigation and or misting could have a detrimental effect on cone differentiation leading to fewer cones the following year. Apparently, when treatments were concluded (August), the drying of soil moisture was sufficient to naturally induce the crop for the next year.

	Control	Mist/Irrigation	Irrigation	Mist
Pollen Bud Clusters				
2000	37.6 (2.0)	34.1 (2.1)	35.6 (1.7)	30.7 (1.9)
2001	46.7 (2.9)	34.7 (3.0)	36.0 (4.4)	32.8 (2.5)
2002	61.1 (3.8)	30.4 (2.7)	38.8 (3.1)	43.8 (3.2)
First-Year Cones				
2000	16.8 (1.2)	13.4 (2.1)	12.8 (1.7)	13.7 (1.9)
2001	16.7 (1.7)	17.2 (1.8)	15.2 (1.5)	13.1 (1.3)
2002	12.7 (1.7)	14.3 (1.9)	15.1 (2.0)	12.2 (1.4)
Second-Year Cones				
2000	7.9 (0.9)	8.3 (0.9)	7.1 (0.7)	5.2 (0.4)
2001	15.4 (1.1)	12.2 (1.0)	11.5 (0.9)	12.2 (0.9)
2002	13.4 (1.5)	15.2 (1.7)	13.5 (1.4)	11.6 (1.3)

Figure 62. Mean (+/- standard error) cone bud surveys for KAL (307) by treatment blocks and year.

	Control	Mist/Irrigation	Irrigation	Mist
Pollen Bud Clusters				
2000	22.9 (1.0)	21.0 (1.2)	31.0 (1.5)	25.1 (1.4)
2001	32.2 (2.4)	30.7 (2.6)	36.5 (2.7)	32.9 (2.2)
2002	40.0 (2.5)	38.0 (4.0)	38.9 (3.1)	37.3 (3.0)
First-Year Cones				
2000	4.8 (0.5)	7.7 (0.6)	7.3 (0.5)	6.0 (0.5)
2001	8.1 (1.2)	11.8 (1.3)	12.4 (1.4)	8.4 (1.0)
2002	7.2 (1.2)	12.7 (1.7)	11.2 (1.6)	9.7 (1.2)
Second-Year Cones				
2000	7.1 (0.9)	6.1 (0.5)	7.2 (0.5)	6.3 (0.6)
2001	3.9 (0.3)	7.1 (0.6)	6.0 (0.5)	5.1 (0.4)
2002	6.9 (1.1)	9.1 (1.1)	9.7 (1.2)	6.3 (0.8)

Figure 63. Mean (+/- standard error) cone bud surveys for PRT (308) by treatment blocks and year.

Orchard pollen supply (pollen cloud density), seed cone receptivity, and pollen shed (synchrony) were also monitored. In all three years, pollen cloud density were among the highest recorded for any conifer orchard and exceeded the pollen load to naturally pollinate the orchard by several hundred fold. Irrigation and misting treatment had no effect on pollen cloud densities recorded for each of the four treatment blocks, nor did treatments affect time of seed cone receptivity or pollen shed. Synchrony between seed cone receptivity and pollen shed was also good.

Conclusions

Our conclusions for last year remain the same. Controlling *Leptoglossus* may be the single most important management activity for lodgepole pine seed orchards in the north Okanagan. We still want to test the effects of improved irrigation and misting during a very hot pollination spring, in particular, their effects on pollen uptake. We do feel that over-head misting (crown cooling) is beneficial for fertilization and early embryo development. But again we have yet to test these effects during very hot, dry pollination and early fertilization periods.(SPU 0711)

4.17 Technical Support for Ministry of Forests Research Branch

Enhancing Seed Production in North Okanagan Pli Orchard Projects

Gary Giampa

Background:

Funded as OTIP SPU 0705, this project allowed Kalamalka staff to continue assisting Joe Webber's Research Branch team with their "Enhancing seed production in North Okanagan Pli seed orchards" project. Dr. Webber's team used Kalamalka orchard 307 and PRT orchard 308 for their studies. Staff at Kalamalka provided labour and assisted with technical tasks as required. It was not possible for Dr. Webber's team to be on site at all times during the field season as they are based out of Victoria. For this reason it was important that a technically proficient group of local workers were available to monitor the project and take care of routine maintenance as well as unexpected incidents.

Activities

During the 2002 field season Kalamalka staff were active at both Kalamalka and Grandview sites. We assisted the Research Branch team with a variety of duties including:

- Setting up, maintaining and repairing the irrigation system.
- Selection and flagging of branches on individual trial trees.
- Observing pollen flight and flower receptivity, recording data.
- Collecting and applying pollen.
- Installing and removing isolation bags. Installing insect bags.
- Monitoring and controlling pitch moth on trial trees.
- Executing various phenological surveys.
- Collecting samples.

Kalamalka staff members are prepared to continue assisting with this project during the 2003 field season.

4.18 Estimating Selfing Rate in a Lodgepole Pine Seed Orchard

After Mixing of Orchard Pollen Cloud by Low-Flying Helicopter

Michael Stoehr and Helga Mehl

Background

Seed set in lodgepole pine (Pli) seed orchards in the Okanagan Valley has been very low, resulting in a shortage of genetically improved seed for reforestation. As lodgepole pine is one of the most widely planted species in BC, this shortage has serious effects on present and future reforestation needs. Several studies and operational trials are underway to either find the problems associated with this low seed set or to find solutions to remedy the problem. One of the identified problems was the low number of pollen grains in the micropyle of receptive ovules. However, after the pollen cloud in the orchard was stirred up by low-flying helicopters, the number of pollen grains in the micropyle had increased. As yet, it is not known if seed set was increased after this treatment and if self-fetilization was higher than expected. An increase in selfing could be due to the mixing movement of pollen caused by the action of the helicopter rotors. In normal wind-pollinated situations, pollen movement is lateral reducing the exposure of cones to self pollen and increasing the chance of cross pollinations.

We have molecular markers that enable us to determine if a seed has been selfed or cross-pollinated. These markers are based on chloroplast DNA (cpDNA), which is inherited in conifers via the male parent. In this study, we are using easily and unambiguously identifiable clones to determine the rate of selfing after pollen mixing, using helicopters in an operational Pli seed orchard near Vernon, BC.

Activities

All 61 cone-bearing lodgepole pine clones in Vernon Seed Orchard Company (VSOC) Orchard 219 were genotyped and the easiest-to-identify 7 clones were chosen for further analysis. Genotyping was done with the use of chloroplast DNA markers using up to 5 different primer pairs. In the seven selected clones, open-pollinated seeds from 10 cones per clone were analysed in the fall following the previous year's application of helicopters to disturb and mix-up the pollen cloud in the orchard. The overall selfing rate was low with an average of 4%, and individual selfing rates ranged from 0 to 17% (Figure 64). These observed selfing rates are very similar to those observed in other conifer species. Therefore, the use of helicopters to disturb the pollen cloud in lodgepole pine orchards can be recommended if seed set is increased by this treatment.

Clone #	Total Seed Assessed	# of Seed Selfed	Outcrossed Seed	% Selfing Rate
445	113	2	111	2%
478	240	0	240	0%
483	46	0	46	0%
1616	126	9	117	8%
1739	53	9	44	17%
1745	33	0	33	0%
1795	36	0	36	0%
			Average:	4%

Figure 64. Clones used and samples processed to determine selfing rates in lodgepole pine seed orchard at Vernon Seed Orchard Company.

4.19 A Management System for Pine Shoot Moth

in British Columbia Lodgepole Pine Seed Orchards

René Alfaro
Tia Heeley

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts

The European pine shoot moth, *Rhyacionia buoliana* (Denis and Schiffermueller) (Figure 65), is an important shoot-boring insect of pines in Canada. It was first discovered in North America in 1914 on Long Island, New York, on imported ornamental pines from Europe. This moth was first recorded in British Columbia, in Victoria, on imported nursery stock in 1925.

Figure 65. Pine shoot moth adult.

The first outbreak on the mainland of BC occurred in 1938 when native lodgepole pine, *Pinus contorta*, planted as ornamentals in Vancouver were attacked. The moth then spread to the interior of BC by 1961. Presently the host range in western North America extends from north of Kamloops, BC (50° 41' 40 N, 120° 27'W) south to Oregon (45° 31'N, 122° 41'W). *Rhyacionia buoliana* has one generation per year in BC. Adult moths have light reddish orange and silver forewings, gray hind wings, and a wing span of approximately 19 mm. Within 24 hours from emergence, during June and July, adults mate and begin to lay eggs. Yellowish disk-shaped eggs are laid on shoots, on or near the buds of the lower whorls of host trees. Eggs hatch approximately two weeks later and the young larvae construct a tunnel-like web, coated with resin and debris, between the needle base and the candle of the current year's growth. Initial feeding occurs on the needles within this tunnel. The first- and second-instar larvae are yellowish with black heads and thoracic shields. Dark brown third-instar larvae exit the tunnels and migrate to new buds, where a large, resin-lined web is constructed. Larvae bore into the bud to feed before overwintering within the dead bud. The following spring, larvae migrate to the upper whorls of the tree and bore into an elongating shoot where they complete their development before pupating. This boring deforms or kills the shoot. The pupal stage lasts for about two weeks.

As with other shoot borers, such as Pissodes strobi, the tree is seldom killed. Shoot moth damage results in deformity and growth loss, causing economic loss to plantations in southern United States and South America. Deformities such as crooks, bushy growth, spiked tops and forked stems result in lower timber quality of commercially harvested species. The shoot moth has been considered an unimportant forest pest in Canada, as it prefers non-native ornamental pines. Incidence on lodgepole pine in forestry settings is minimal, though it has attacked seedlings in forest nurseries. However, in recent years damage has become widespread in lodgepole pine seed orchards in central BC. In 1999, larvae of *R. buoliana* were detected in 25% of lodgepole pines at a seed orchard near Vernon, BC (50°23'N, 119°33'W). In 2000, the infestation increased to approximately 80% of the lodgepole pine trees, causing a significant reduction in seed production by damaging pollen and cone-bearing shoots (Figure 66).

Figure 66. Cone-bearing shoot of lodgepole pine damaged by pine shoot moth

In response, orchard managers instituted a program of chemical and mechanical control in 2000 and 2001, and chemical control alone in 2002. Mechanical control consisted of clipping and removing infested shoots by hand, before shoot moth adults had emerged.

The objectives of this study were to establish the biology and distribution of *R. buoliana* in the southern interior of BC using pheromone traps, to determine peak flight in relation to degree-day accumulation, and to determine the parasitoid complex and level of parasitism at the Vernon Seed Orchard Company.

Results.

Of the larvae and pupae recovered from infested pine shoots, twenty-three percent in 2000 and sixteen percent in 2001 contained *R. buoliana* parasitoids. The dominant parasitoid was *Orgilus obscurator*, an introduced species, which was obtained from 5.6% of the shoots. These parasitism levels are considered very low. Due to the intensive mechanical and chemical control program, infestation at the Vernon Seed Orchard Company has decreased in 2001 and 2002 compared to 2000. However, populations are likely to rebound if control efforts are reduced because of the low incidence of parasitism and the ability of the moth to establish quickly. In order to enhance natural controls, efforts should be directed to enhance the level of *O. obscurator* parasitism as this insect has the potential to reduce moth populations. Work in Ontario, suggested that increasing orchard ground herbaceous diversity may provide the parasitoid adults with a food source (nectar and pollen). This in turn increases the longevity and fecundity of *O. obscurator*.

Pheromone trap catches and weather observations over three years indicated that peak *R. buoliana* flight occurred when about 800 degree days had accumulated from January to August (using a threshold of 5°C) (Figure 67).

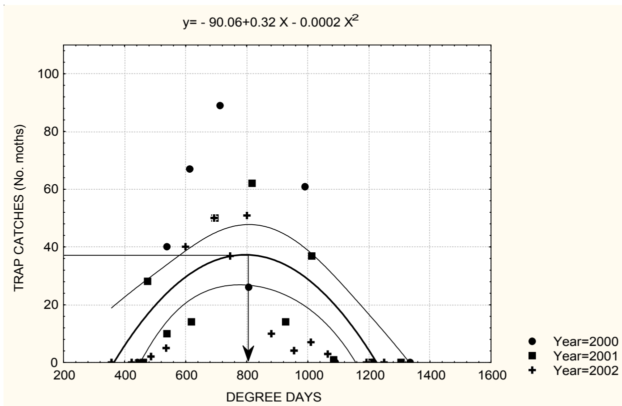


Figure 67. Degree-day accumulation at the VSOC for adult *Rhyacionia buoliana* catches in pheromone traps.

Figure 67 shows the degree-day accumulation at the Vernon Seed Orchard Company for adult Rhyacionia buoliana catches in pheromone traps for three years (2000 – 2002). For degree-day accumulation a threshold of 5°C and a starting date of 01 January was used. The solid curve represents fitted quadratic formula; dotted lines are the 95% confidence limits for the curve. The arrow indicates degree-days to peak emergence.

The information collected in this project on lifecycle, periods of larval activity, and degree-day accumulation can be incorporated into a management plan for effective control of shoot moth populations. First flight occurs before 157 degree-days; therefore, pheromone traps should be in place by this date. Chemical control using a systemic insecticide, if needed, targeting the sixth instar should commence when 130 degree-days are accumulated or about two weeks after peak flight to target first-instar feeding. Since the larvae migrate to new buds and spin a fresh web prior to moulting to the second and third instars they are vulnerable to chemical control at these times. In summary, we proposed a management system where natural controls are enhanced by increasing orchard biodiversity, and close population monitoring. If needed, the application of systemic insecticides could be accurately timed using the degree-day emergence curve reported here, thereby reducing costs and increasing effectiveness.(SPU1006)

4.20 Cone and Seed Production in Lodgepole Pine

Research and Methods for Increasing Seed Production.

John N. Owens

This is the final year of a three-year study undertaken at Kalamalka (KSO) and PRT seed orchards in the warm and dry Okanagan Valley, and at the cooler and wetter Prince George Tree Improvement Station (PGTIS). In the 1990's seed set per cone at KSO was unacceptably low (less than 10), whereas at PGTIS the seed set was at least twice that amount. The overall purpose was to compare the reproductive biology of lodgepole pine at these three sites to determine the causes of low seed production at the two Okanagan Valley orchards (KSO and PRT) and find ways of increasing seed production to the level obtained at Prince George. In the third year of the study (2002-2003), the purpose was to make cone counts and do cone and seed analyses and data analysis and complete anatomical studies for various control and operational pollination trials done in the spring of 2000 and 2001.

The first cone analyses were done in 1997 at KSO and again at KSO, PGTIS and Skimikin in 1999. Similar seed analyses were then done in 2001 at KSO, PRT and PGTIS and at KSO and PGTIS in 2002 for cones pollinated using several pollination times (Stages) and treatments (misting, blowing and cone position) at pollination. During this 6-year period, the seeds per cone remained the same at PGTIS and those at KSO steadily increased, regardless of treatment, from 11, to 12, to 15 in 1997, 1999 and 2000, respectively. Empty seeds have decreased from about 22 per cone in 1997 to about eight per cone in 2002. In the last two years, based on detailed analyses of 885 cones from 10 clones, the seeds per cone increased to 22 and 23, respectively, for all treatments. For open pollinated (control) trees with no insect bags in 2001 and 2002, seeds per cone were 21 and 22, respectfully. At the same time empty seeds decreased from 23 per cone in 1997 to about 8 per cone in 2002. Cone survival in 2000-2002 was 75-85% but survival for earlier years is not known. The main difference in the trees during this time is that they were severely top-pruned in the mid-1990's. Since then, they have grown from the low shrub form in which pollen and seed cones intermingle to an arborescent form in which there is separation of seed cones in the upper crown but still a mix of seed cones and pollen cones in the lower crown. During the last 3 years seed cones in the lower crown have produced significantly fewer filled seeds and more empty seeds than cones from the upper crown. In the lower crown one would expect a higher level of self- pollination.

Two types of studies support the hypothesis that most empty seeds resulted from self-pollination: 1. Developmental studies of open-, cross- and self-pollinated cones; and, 2. Field trials in which pollen was mechanically blown around in the orchard. In the self-pollination study, it was shown that most self-pollinated ovules developed normally for the first year then aborted soon after fertilization then most selfed embryos aborted. Following embryo abortion, the megagametophyte tissue degenerated leaving an "empty seed", one with a collapsed megagametophyte. Because the seed coat is well developed by the time of fertilization, seeds aborting after fertilization are full-sized and look the same externally as empty seeds that result from self-pollination. In self-pollinated cones from KSO, 8 to 25% of normal appearing seeds were filled and 75 to 98% were empty, whereas at PGTIS, 8% were filled and 92% were empty. In cross-pollinated cones, where there was no selfing, 89 to 98% of the normal appearing seeds were filled and 2 to 11% were empty in cones from the two clones studied at KSO. In open (wind) pollinated cones from the same two clones at KSO and PGTIS, about 65% of normal appearing seeds were filled and 35% were empty. All cones had insect bags so the differences were not due to insect damage. Other seeds aborted soon after pollination because they were not pollinated or before fertilization perhaps due to pre-fertilization incompatibility. This ranged from 17 to 42% at KSO and 18 to 52% at PGTIS. Conifers and hardwood trees are known to have late-acting self-incompatibility resulting in early embryo abortion. This is true for lodgepole pine but some embryos and seeds resulting from self-pollination develop. This varied from 8-25% at KSO and about 11% at PGTIS. This rather high percentage of self-embryos may result from the complete lack of competing embryos in selfed seeds. One aspect of the effects of selfing that was not studied adequately is early pre-fertilization incompatibility reactions that may prevent fertilization. These may prevent pollen-tube growth or cause branching as was observed in lodgepole pine and interior spruce. This needs further investigation in lodgepole pine since a high proportion of ovules abort early due to no pollination or other unknown causes before fertilization.

In 2001 at KSO and PGTIS pollen was blown around sections of the two orchards using existing equipment for the purpose of increasing the numbers of ovules pollinated per cone and increasing the cross-pollination of cones. Earlier studies showed that this increased pollination success. Results from cone and seed analysis indicated that blowing increased seed per cone by about 8 seeds in cones from the top half of the crown but only about 2 seeds per cone in the lower crown. This was also shown in seed efficiency in which a higher percentage of fertile ovules developed into filled seed either as a result of increased pollination success or less self-pollination. Simply blowing pollen around daily either by tractor drawn blowers or by helicopter will increase seed per cone by about 10%. Blowing did not increase cone survival at KSO where pollination success is high. At PGTIS where pollen is less abundant, blowing pollen increased seed per cone by about five and seed efficiency by about 15% in the upper crown but increases in the lower crown were slight. At PGTIS blowing pollen increased cone survival by 10% in the upper crown and 5% in the lower crown. These results indicate that blowing pollen in the orchard may increase total seed production by up to 20% over existing amounts.

Misting trials during pollination were done in 2000 and 2001 at KSO to increase the humidity to a level similar to that at PGTIS. This was done to increase the abundance and size of pollination drops to facilitate pollen uptake into the ovules. Misting for four hours, 0700-1100, increased the humidity to a level slightly less than at PGTIS but higher than in non-misted areas at KSO during the four hours of misting and until about 1500. Misting also increased the number of visible pollination drops per cone following misting and there was a carry-over effect to the next day. Pollination drops appear in the early morning at Stages 4-6 and remain visible until mid-morning then they recede into the ovule carrying pollen inside. At PGTIS about 60% of ovules have visible pollination drops during this time whereas at KSO, cones from non-misted trees less than 5% of ovules have pollination drops at Stage 4 and up to 20% at Stages 5 and 6. Soon after misting for 4 hours at KSO 35-75% of ovules had pollination drops and cones from misted trees had a slight (10%) carry-over effect until the next day. Ground irrigation had no effect so it was not a result of water stress within the tree. However misting did not affect pollen uptake or final seed set in these relatively wet cool years but this may be a useful technique in hot dry years. The misting method used was satisfactory but required cleaning of some misting heads. Sprinklers placed above the crowns in every second row would work just as well. These same sprinklers could be used to reduce protandry in dry hot years.

The anatomical studies were done on open- and control-pollinated seed cones at KSO and PGTIS. Observations show that ovule, embryo, seed and cone development are the same at both orchards but phenology differs. In general, the same stages occur 2-4 weeks later at PGTIS than at KSO. Cones are receptive for about one week and ovules may receive over 20 pollen grains during this time. Pollen lands on all surfaces of the cone but enters and funnels down around the cone axis where the inverted ovules are located. Each ovule has two long integument arms that secrete sticky lipid microdrops soon after the cones emerge and become receptive (Stage 3). Pollen adheres to these microdrops but not to other cone surfaces. The cuticle on the different cone surfaces varies in the amount and form of epicuticular wax present. Abundant and long epicuticular wax causes water to bead and move over these surfaces and down toward the ovules. They pick up pollen from cone surfaces and carry it closer to the ovule tips. Thus water as from sprinkling, rain or dew may facilitate movement of pollen to the ovules. Sprinkling late in the day or at night or early morning may increase pollination success in dry springs. After several days (Stages 4-6), a pollination drop is exuded from the ovule and floods the space between the micropylar arms and pollen adhering to the arms is released and floats up into the micropyle and into the micropylar canal of the ovule.

The pollination mechanism of lodgepole pine is similar to other pines that have been reported with one important difference. The micropyle and the micropylar canal are very small, about the same diameter as the pollen, and will only take in up to four pollen grains lined-up in single file. This means that lodgepole pine does not require large numbers of pollen grains on the arms for successful pollination and high numbers of filled seed and seed efficiency (SEF). This is shown by the cone and seed analysis from the 2000 pollinations at different stages (3-5, multiple and open). Surprisingly, pollinations done at Stage 3 had the highest number of filled seed and SEF of all treatments. Also, our studies done in 1982 using pollen stained several colors and later molecular studies by ministry staff showed that the first pollen to be applied was preferentially taken in over later arriving pollen. Why should this occur? Originally we thought that it was that the first pollen to arrive occupied sites on the arms closer to the micropyle but our multiple pollinations showed that this was not necessarily true. The first pollination at Stage 3 commonly results in five or less pollen per pair of micropylar arms, the second pollination at Stage 4, 10 and the third pollination at Stage 5, 15 or more grains per pair of arms. But, as shown using colored pollen, the first pollen applied was not necessarily closer to the micropyle. Our recent studies with the Cupressaceae gave some insight into the mechanism of pollen uptake into the ovule. There, pollen hydrates and sheds the hard rigid outer covering (exine) leaving a soft pliable pollen grain due to the cellulose nature of the inner wall (intine). Hard non-pliable grains clog the micropyle, like grains of sand, whereas soft pliable grains float in an amoeboid fashion around the hard grains and into the micropyle. In the Pinaceae, as shown in larch, it takes about 24 hours for pollen to hydrate, soften or shed the hard exine. The pollination drop is not secreted until Stages 4-6, several days after Stage 3, so pollen applied at Stage 3 would be more fully hydrated, soft and pliable than pollen arriving later, when the pollination drop is secreted. This soft and pliable pollen may then move around and between the pollen more recently applied and allowing it to enter the micropylar canal. Thus, early arriving pollen would have an advantage, not just by position on the arms, but also by the hydrated more pliable nature of the pollen.

These observations, along with the seed set and cone survival data from pollinations done in 2000, shows that just adding more pollen by SMP, especially at late receptive stages, may have little benefit in increasing seed per cone compared to SMP at early Stages 3 and 4.

But, there might be a benefit from increasing the number of pollinated ovules thus increasing cone survival. Cone survival is usually over 90% and not a problem at KSO where there is abundant pollen but it is a problem (~70%) at PGTIS where pollen is less abundant. SMP at early stages of receptivity may also be beneficial at PGTIS by increasing the proportion of orchard pollen compared to pollen from outside the orchard thus increasing the genetic quality of seeds produced, at least for trees along the borders of the orchard. To determine this, six pollen monitors were placed outside the orchard, two on each of the long east and west sides and one at each of the narrow north and south sides. These were weather-vane type monitors that measured total pollen per day plus fixed slides facing north, south, east and west measuring pollen per day from each direction. These data showed trees along the edge of the orchard received an average of 52% of their pollen from outside the orchard, with over 60% on east and south sides. The proportion of outside pollen would decrease in the central portion of the orchard but this could not be measured.

Summary

The results from this study show that seed production per cone at KSO has rapidly increased from 1997 to 2002, now averaging 23 seeds per cone and a SEF of 33%, which is about the same as at PGTIS. The number of cones per tree is very high at KSO, commonly about 200 and often over 400 per tree giving about 4500 to 9000 seeds per tree. The biological limit of filled seeds per cone for lodgepole pine is about 50 seed per cone. There is no way of increasing the proportion of fertile scales thus seed potential. Evidence from our studies indicate that the earlier low seed set was due to high levels of self-pollination in the top-pruned trees and increased seed production has resulted from trees growing taller and separating pollen cones from seed cones in the upper crown. Seed production per cone could still be increased by 10-20% by blowing pollen within the orchard by helicopter or existing tractor-pulled blowers and giving SMP at an early stage of receptivity to early flowering trees. In very hot dry springs, sprinklers will be necessary to prevent extreme protandry and protogyny and to increase humidity thus the number and size of pollination drops. The number of seeds per cone at PGTIS is now about the same as at KSO but cone survival is much lower at PGTIS. This could be improved by increasing the number of ovules pollinated per cone and accomplished by blowing pollen around within the orchard. Seed quality could be increased by SMP at early stages of pollination of trees around the borders of the orchard in order reduce the effects of pollen contamination from outside the orchard. Some new insights into cone structure and the pollination mechanism of lodgepole pine help explain the causes for low seed potential and low seed set in the species compared to many other pines. (SPU1003)

4.21 Damage Potential of Field Densities of *Leptoglossus occidentalis*

Ward Strong

The Western Conifer Seedbug, *Leptoglossus occidentalis*, is the most serious pests of conifer seed orchards in the Interior of BC. Tests over the past 6 years have shown that it is capable of reducing seedset by up to 80%, and routinely reduces seedset by 10 to 30%. The problem of low seedset in lodgepole pine orchards in the southern Interior has largely been attributed to *Leptoglossus*. It also feeds on white pine, douglas-fir, spruce, and larch, though the problem is characterized less in these tree species.

Management of the seedbug is dependant upon the use of broad-spectrum insecticides. Despite years of study, no other control methods have come to light, such as biological controls, trapping methods, or cultural techniques. Since insecticides are expensive and pose worker and environmental hazards, they should be used only when and where needed. Appropriate use requires two techniques: a method of estimating field densities of *Leptoglossus* (monitoring technique), and a method of relating these densities to damage potential (density-damage relationship). Development of a monitoring technique is the subject of another OTIP project, 0717. This project is designed to develop a density-damage relationship, so that the damage potential of monitored densities of *Leptoglossus* can be estimated.

Methods

Leptoglossus densities were monitored weekly throughout the summer of 2002 at each pine orchard in the southern Interior of BC. Large pine orchards were divided in half, each half monitored separately. In total there were 19 orchards and half-orchards ("replicates"). Monitoring consisted of half-hour transects through the orchard on foot, visually examining cones and counting *Leptoglossus*. This monitoring method has been in use for several years. Although the effects of factors like weather, time of day, and season are unknown, the method seems to give repeatable results between field scouts.

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

In each replicate, feeding damage was assessed by two methods.

a) Insect exclusion bags were placed over cones to protect them from *Leptoglossus* feeding. At harvest, bagged cones and exposed cones (available for *Leptoglossus* feeding) were collected. Seeds were extracted, and for each sample, filled seeds per cone, total seeds per cone, and percent filled seeds were computed. The difference between exposed and bagged cones was a measure of feeding damage.

b) Exposed cones were collected from each replicate. Seeds were extracted, and empty seeds were analysed by the antibody method developed at Simon Fraser University to determine whether they had been fed upon by *Leptoglossus*. This method detects the residues of salivary enzymes left inside seeds after they have been fed upon by *Leptoglossus*. The antibody analysis was conducted at the laboratory of Dr. Michael Stoehr with the BC Ministry of Forests. The percent of empty seeds which had been fed upon was a measure of feeding damage.

Results

The antibody analyses have not yet been completed; results to date have been less successful than anticipated. Very few analyzed seeds (16 out of 965) turned out positive for *Leptoglossus* feeding. This may be because very few seeds were fed upon, or more likely because the salivary enzyme residues, used to detect whether feeding had occurred, degrade over time under field conditions. Because of this possibility, the antibody method results were not used in this analysis.

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

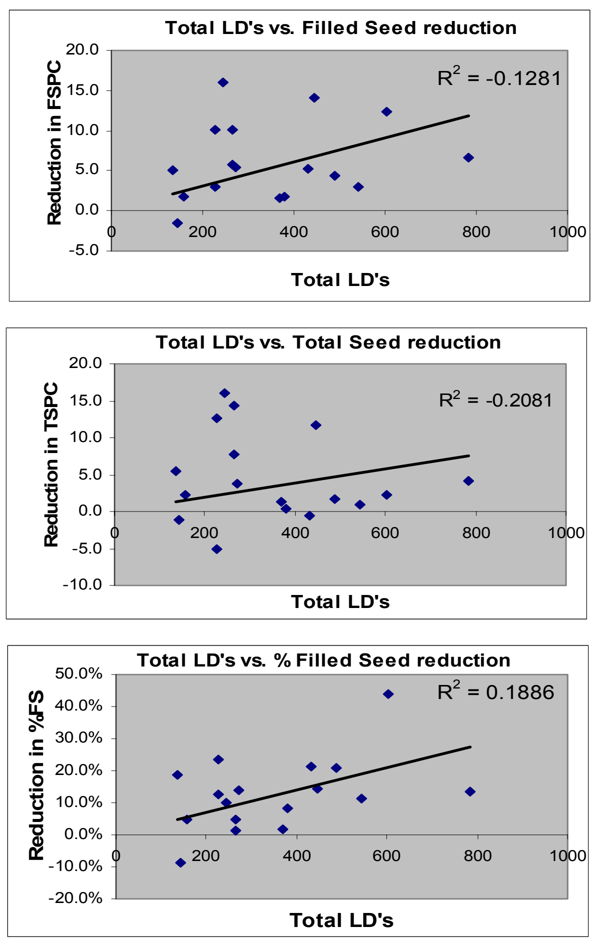


Figure 68. Exclusion bag treatment regressions

The exclusion bag treatments have been harvested, the seed extracted, X-rayed and filled and empties counted, and analysis has started. Some regressions are shown on the opposite page. Each point on the graph represents one orchard replicate. Although a nice regression line is shown, the r^2 value is exceedingly low, indicating no relationship between LD's and subsequent damage. A poor relationship was expected, due to variability in the monitoring method; differences in cultural techniques, orchard age, microclimate, and other site-specific factors; and experimental error in sample collection.

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

Once an accurate density-damage relationship has been described, we will be able to make well-informed decisions for managing *Leptoglossus*. Pesticide spray thresholds will be the main decision-making tool. We might be able to say, for example, that "*x* number of *Leptoglossus* found in our half-hour search indicates a potential seed loss of *y*%, and therefore a spray is not warranted". In this way, pesticide applications will be minimized, used only when and where necessary. (SPU 0716)

4.22 Monitoring *Leptoglossus* with Traps and Attractants

Ward Strong

Sarah Bates

A simple, quantitative method of monitoring seed orchards for *Leptoglossus* densities is desired. Currently, visual surveys are used, conducted by walking transects through an orchard for one-half hour, examining cones and conelets, and counting all stages of *Leptoglossus*. Although this method seems repeatable between surveyers, the effects of temperature, rainfall, height, side of tree, time of day, and time of year are unknown. A method of trapping *Leptoglossus* might provide a better means of monitoring. Unbaited traps were tested in 2000 and 2001; the use of baits was tested in 2002.

Two trap types were tested:

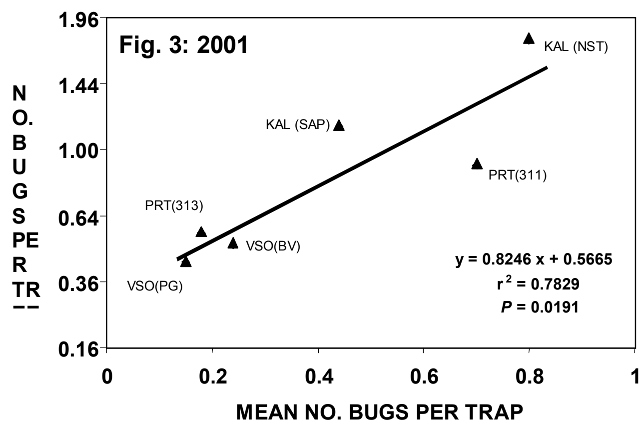
Figure 69. Yellow panel trap (height 1 m)

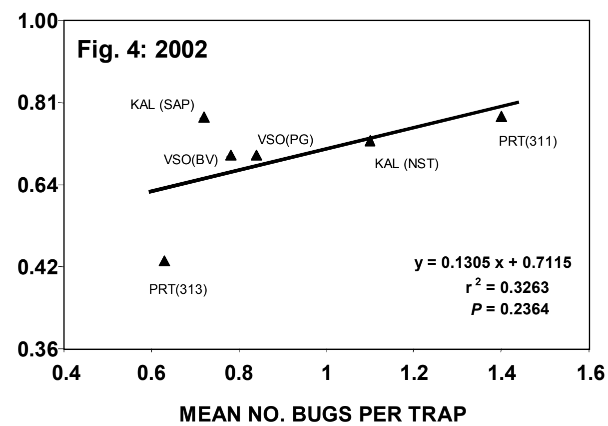
1. Yellow panel traps, used in 2000 and 2001 (Figure 69). These corroplast structures intercept *Leptoglossus* in flight, and the yellow colour may be attractive also. One hundred fifty yellow panel traps were distributed throughout six mature lodgpole pine seed orchards in the Vernon area in April 2002. Half the traps were baited with a *Dioryctria* pheromone component, (Z)-9-tetradecenol acetate, which is known to attract *Leptoglossus.* Captured insects were counted weekly and traps removed at the end of May. Also during May, whole-tree counts of *Leptoglossus* were made in each orchard to relate trap numbers to counted field densities.

Figure 70. Japanese beetle trap (height 30 cm)

2. Japanese beetle traps (Figure 70). These are also yellow interception traps, smaller than the panel traps, with a holder for release of pheromones or other volatiles. These traps were used to test the attractiveness of other baits than the one used in panel traps. Baits used were 10 pheromone components of cone-feeding moths, and one of the Douglas-fir Cone Gall Midge. Ten replicates of each bait were placed around a young (10-yr-old) white pine orchard at Skimikin. Traps were installed at the end of April 2002; catches were counted and traps removed at the end of May.

Panel trap catches were 0.63 – 1.40 bugs per trap, which was higher than in 2001, though the field density of seeds bugs was substantially lower than in 2001. High catches may have been due to the addition of a lure to the traps. Plotting seed bug density against trap catches in 2001 resulted in a significant regression (Figure 71), whereas there was no relationship in 2002 (Figure 72). The relationship in 2001 could have been spurious, or there may have been a great deal of variability in the field counts in 2002 due to low densities and poor weather.





Figures 71 and 72. Regression of trap counts to field counts was significant in 2001 but not in 2002.

No seed bugs were captured in any of the Japanese beetle traps, including the unbaited controls. The lack of seed bugs observed in traps may have been due in part to poor weather the spring of 2002. Since field monitoring of the white pine orchard was not conducted, field densities were unkown.

For the future, there are two promising routes to look into. The first is refinement of visual monitoring. The effects of weather, time of day and year, and other aspects can be quantified. This will take much of the variability out of monitoring and make the counts highly repeatable. This system can then be used to develop a density/damage relationship, leading to a decision-making framework. I will be setting up experiments to help refine visual monitoring in 2003. The second route is determination of the male-released sex pheromone. This pheromone was discovered at SFU in 2001. Once characterized and synthesized in the laboratory, the pheromone can be used not only to monitor *Leptoglossus*, but also to control them. Traps baited with female-released sex pheromones catch only males, which has almost no impact on the number of mated females, and the subsequent number of eggs laid, in an orchard. Traps baited with male-released sex pheromones, on the other hand, catch females; every female caught reduces the number of eggs laid in the orchard. Characterization of the male-released sex pheromone will be a subject of study at SFU in 2003.

5.0 Extension and Communications

5.1 Pli Booklet Revision

The Reproductive Biology of Lodgepole Pine

John N. Owens

UVic

ES0045

From 1984-1986 five booklets were written about the reproductive cycles of nine of our commercially important conifers, including lodgepole pine. These were based mostly on studies done in natural stands. Since that time more has been learned about many aspects of the reproductive biology of these species especially regarding cone induction, pollination, pollen management, embryology, seedling production, and factors affecting seed and cone production. A lot of this newer work has been done in seed orchards that often bring new types of problems. The early booklets are now out of date and most are out of print. In 2002-2003 the booklet on lodgepole pine was revised and new information added to cover more broadly the reproductive biology of the species in both natural stands and seed orchards. Over the next three years, the other booklets will be revised and new booklets added on western white pine, Douglas-fir and larch.

The format of the revised booklet is like that of the 1984 booklet. It consists of 47 double column pages and includes 101 color and black and white photographs, diagrams and graphs covering all aspects of reproduction from cone initiation, through pollination to seedling development. Cone induction and enhancement are related to the development and phenology of long-shoot-bud development and specific field methods for cone enhancement are given in an appendix. Pollen-cone and seed-cone development and phenology are illustrated with color photographs of all stages and the details of the pollination mechanism and explained using color and scanning electron microscope photographs. Details of fertilization, not before known, are shown through light and electron micrographs and this information is used to explain the method of cytoplasmic inheritance in pines. Embryo and seed development are shown and related to polyembryony and times and causes of cone, seed and embryo abortion. Cone and seed production in natural stands and seed orchards are contrasted and methods are given that may enhance both in seed orchards. Seedling development is briefly described.

A reference list of 42 of the more accessible articles is give as well as a complete glossary of terms used in the text. Four short appendices are provided covering methods for determining reproductive success and pollination success in pine, monitoring pollen development in conifers, and pollen germination in pine. The booklet is intended for seed orchard personnel, geneticists and tree breeders, and biologists working on aspects of ecology, physiology and molecular biology of conifer reproduction and regeneration. It will also be useful to the forester and forestry and biology students who want a quick general summary of conifer reproduction or specific coverage of lodgepole pine reproductive biology.

5.2 Development Of ETAC Extension Notes,

From A Series Of OTIP Technical Reports

Roger Painter,
Tree Improvement Coordinator

Since the inception of the Operational Tree Improvement Program (OTIP) a number of projects have been undertaken to solve technical problems related to orchard management. As our overall program increased its efforts and moved into new species and developed newer generations of orchards there came a need to find better management techniques and improve our knowledge of the biology. Over the years these projects have added substantially to the working knowledge of our orchardists and to our ability to manage conifer crops.

The OTIP program has been funding technical support projects since 1997. Final reports have been required as part of project management and have been maintained on file. The distribution of the project reports has been somewhat ad hoc. A few have been used in various newsletters (e.g. TICtalk, Seed and Seedling Extension Notes), and the authors have selectively distributed some, but others have not been widely distributed.

This project involved reviewing all past OTIP reports on file and selecting upwards of 10 of those that could be developed into the ETAC Extension Note series in 2002-3. The project would rely on the original project leaders to rewrite their reports into publishable format and then have them submitted to a review team for editing and printing. The project was also provided with funding to cover the cost of printing.

The project resulted in the preparation of six reports that are currently in the process of being edited. A team of four reviewers for each report was selected with associated knowledge to review submissions. The overall tree improvement program is an intensive activity and with a limited number of specialists. It was difficult to get all project leaders to commit to the time necessary to produce their contribution and for those that did, there were some problems in preparing them in time to meet fiscal year-end. Although accepted by the project leaders as an excellent extension opportunity, not all of them were able to complete their contributions in time to meet this year's deadline. It is the intention of the author and the Extension Technical Advisory Committee to continue with this project in the next year and produce as many of these Extension notes as possible. (ES0048)

Appendix 1

FGC Seed Planning Units

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

Appendix 2

Tree Species

Conifers

Conifers	Latin Name	Abbreviation
western redcedar	*Thuja* plicata	Cw
yellow-cedar	*Chamaecyparis nootkatensis*	Yc
Douglas-fir	*Pseudotsuga* menziesii	Fdc
Interior Douglas-fir	*Pseudotsuga* menziesii var. glauca	Fdi
amabilis fir	*Abies* amabilis	Ba
grand fir	*Abies* grandis	Bg
noble fir	*Abies* procera	Bp
subalpine fir	*Abies* lasiocarpa	Bl
mountain hemlock	*Tsuga* mertensiana	Hm
western hemlock	*Tsuga* heterophylla	Hw
Rocky Mtn. juniper	*Juniperus* scopulorum	Jr
alpine *(subalpine)* larch	*Larix* lyallii	La
western larch	*Larix* occidentalis	Lw
limber pine	*Pinus* flexilis	Pf
lodgepole pine	*Pinus* contorta	P1
lodgepole pine	*Pinus* contorta var. latifolia	Pli
ponderosa pine	*Pinus* ponderosa	Py
shore pine	*Pinus* contorta var. contorta	Plc
western white pine	*Pinus* monticola	Pw
whitebark pine	*Pinus* albicaulis	Pa
Engelmann spruce	*Picea* engelmannii	Se
Sitka spruce	*Picea* sitchensis	Ss
white spruce	*Picea* glauca	Sw
spruce hybrid (*Interior spruce/s*)	*Picea* cross (*Se and Sw mixtures*)	Sx
Sitka x unknown hybrid	*Picea* sitchensis x?	Sxs
western *(Pacific)* yew	*Taxus* brevifolia	Tw

Hardwoods

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

Discussions by Tree Species

Conifers	Abbreviation	Page Location(s)
western redcedar	Cw	9, 10,27, 29, 37, 39, 41
yellow-cedar	Yc	10, 26, 27, 37, 38, 39
Douglas-fir	Fdc	7,28, 29, 30
Interior Douglas-fir	Fdi	12, 20, 24
amabilis fir	Ba	6, 26, 35, 36,
grand fir	Bg	35, 36
western hemlock	Hw	10, 11, 34
western larch	Lw	16, 48
lodgepole pine	Pli	15, 16, 20, 22, 24, 49, 53, 54, 63,
western white pine	Pw	14,30
Sitka spruce	Ss	11, 12, 14, 47
spruce hybrid (*Interior spruce/s*)	Sx	11, 12, 16, 19, 21- 25, 42, 45-48

Hardwoods		
hybrid poplars	.Ax	17
paper birch	Ep	18

Appendix 4

Authors and Species Topic

FGC

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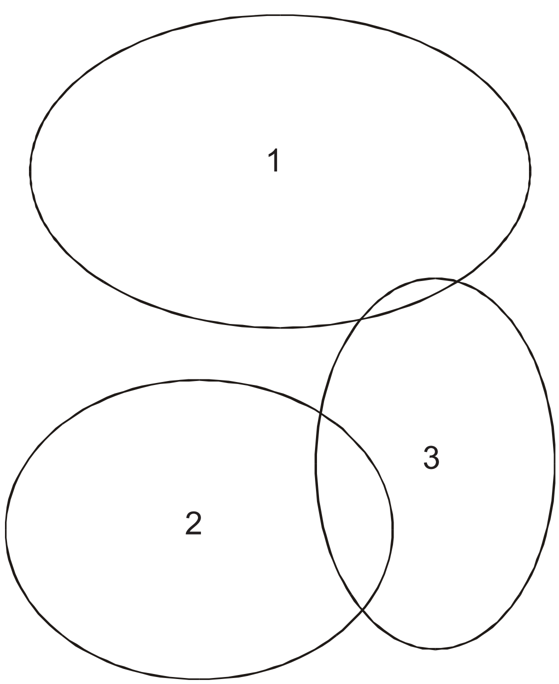

Back Cover Interpretations - White Pine Research

In British Columbia (BC) we have been involved with white pine and blister rust since the rust's discovery on imported infected pines through the port of Vancouver in 1910. An initial patchy effort was intensified in 1987 with the establishment of an MoU between the BC Forest Service and the CFS and the start of parent tree selection and seedling inoculation of open-pollinated families. From this and other material (USDA Forest Service: Idaho and Dorena and the Texada population) we have the basis of a breeding and seed orchard program based primarily on partial resistance mechanisms. An F1 generation is being produced for future research.
Additionally we are considering single gene resistant traits, such as MGR-HR (or the Cr2 gene), which can be pyramided onto the partial resistance of our breeding population. Efforts, particularly for conservation interests, are also being started for whitebark pine.

Plate 1

Alvin Yanchuk in front of marked resistance shown in full-sib blocks. This is not the Major Gene Resistance for Hypersensitive Response (MGR-HR) as in the Champion mine area near Dorena, Oregon where virulence to the Cr2 gene has overcome the HR resistance. Whatever this is (some type of ”tolerance” reaction?) it is also quite dramatic.

Plate 2

Don Pigott collecting parent tree scions from some of the best families of the CFS screening program.

Plate 3.

Whitebark pine. Although our program for white pine has now collected some valuable resistance whitebark pine is still very much at risk and a small conservation effort is being established for this species.

BRITISH COLUMBIA