TIC*talk*

FGC Forest Genetics Council of British Columbia

Information for and from the tree improvement community of British Columbia

Volume 3, Number 1, Spring 2000

Third Edition

Welcome to the third edition of TIC*talk,* the periodic newsletter of British Columbia's Forest Genetics Council (FGC).

Much has happened in British Columbia's tree improvement community since our spring 1999 issue. Some highlights:

- GenSeed Ltd. became a reality after four years of deliberation and planning by the transitional Tree Improvement Council and its successor, the current Forest Genetics Council.
- Forest Renewal BC worked closely with Council in developing its 10-year Tree Improvement Program. Ten million dollars has been committed for fiscal year 2000/2001.
- Council's business planning process matured with the development of species plans for each of the province's seed planning units.
- Council created two new technical advisory committees for gene conservation and extension.
- Council established the Forest Genetics Council Achievement Award.
- Ministry of Forests made significant strides in quantifying and incorporating genetic gain in its reporting systems, and in growth and yield and timber supply analysis models.
- Vandals caused serious damage at various research facilities and seed orchards.

Articles in this issue address these topics and more...

The spring 1996 and 1999 issues of TICtalk, and backgrounders on Council, can be downloaded from the FGC Web site: ***www.fgcouncil.bc.ca***.

FGC Establishes Achievement Award

In spring 1999, Council established an FGC Achievement Award to recognize outstanding contributions to forest gene resource management in British Columbia.

The award's first recipient is Dr. Gene Namkoong, one of the world's leading forest geneticists. Recently retired from his position at the University of British Columbia, Dr. Namkoong led development of the Coastal and Interior Tree Improvement Councils' first Strategic Plan.

FGC co-chair Dale Draper presented the award to Dr. Namkoong at a symposium held in his honour at UBC from July 23–25, 1999.

FGC Forest Genetics Council of British Columbia

Achievement Award

To Dr. Gene Namkoong,
with thanks and appreciation for your contributions
to forest genetics in British Columbia—in particular,
for contributing to a provincial forest gene resource
management strategy and initiating the NSERC
Industrial Research Chairs in Population Genetics.

July 1999

Larry Pedersen, Chief Forester
Province of British Columbia

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

INSIDE

FGC Technical Advisory Committees

The Forest Genetics Council (FGC) operates at several levels. Council members, representing the Ministry of Forests, Forest Renewal BC, forest companies, and universities, provide strategic direction to the provincial forest gene resource management program. Technical Advisory Committees (TACs) provide technical and policy information and advice to the Council. TACs also contribute to the development of FGC plans and associated budgets (e.g., species, extension, and forest gene conservation plans).

In 1999, Council created two new TACs for gene conservation and extension

Coastal and Interior TACs

The Council first established Coastal and Interior TACs to:

- advise Council on technical and policy issues, program priorities, and budgets
- strike subcommittees including *species committees* and others to deal with specific technical issues such as clonal forestry
- evaluate and rank projects for funding based on the FGC Business Plan
- assist with monitoring progress towards FGC Business Plan objectives
- communicate with and receive input from seed users
- provide technical advice to stakeholders
- provide a forum for stakeholder input.

In 1999, Council created two additional TACs for gene conservation and extension.

Gene Conservation TAC

Gene conservation is a fundamental element of Council's strategic plan. The GCTAC will address issues related to gene conservation and genetic diversity. The Committee's main focus is to ensure that enough resources are allocated to gene conservation, and that needed activities are identified and implemented. Its first act has been to recommend that Council approve a proposal to establish a Gene Conservation Centre at the University of British Columbia.

Extension TAC

The ETAC is responsible for developing an extension strategy for Council, and plans for program-level extension activities. The extension strategy will guide Council's extension, communications, and education activities. Council's communications, which are carried out by the FGC Secretariat, also fit into this broad strategy.

Council approved an extension activity plan for 2000/2001 at its March 10, 2000 meeting. The activity plan includes development of publications, workshops, Web-based information, and personal contacts.

Contact the TAC Chairs with your questions, concerns, or ideas.

Forest Genetics Council Technical Advisory Committee Chairs

TAC	Chair	Affiliation	E-mail address
Coastal (CTAC)	Sally Aitken	University of BC	aitken@interchange.ubc.ca
Interior (ITAC)	Michael Carlson	MOF Kalamalka Forestry Centre	mike.carlson@gems3.gov.bc.ca
Gene Conservation (GCTAC)	Diane Medves	Weyerhaeuser Canada	dr.medves@mbltd.com
Extension (ETAC)	Chris Hawkins	University of Northern BC	hawkins@unbc.ca

Seed Planning, Policy, and Programs Workshop

submitted by Diane Gertzen

Currently, about 37% of provincial sowing uses Select (Class A) seed, and this percentage is expected to increase annually. To support the information needs of seed production decision-makers and users, the 1999/2000 Operational Tree Improvement Program (OTIP) funded the development and delivery of a workshop on seed planning, policy, and programs in British Columbia.

The purpose of the workshop was to highlight issues of gene conservation, diversity, and genetic worth, and to promote a better understanding of the impacts of using improved seed on forest productivity and timber supply.

On March 15, 2000, 54 people—including Ministry of Forests (MOF) regional and district staff, licensees, and consultants—attended the pilot workshop in Nelson, B.C. The one-day session included the following presentations:

- gene conservation/diversity, genetic worth, and an overview of seed transfer guidelines (Alvin Yanchuk, MOF)
- interior spruce, western larch, and interior Douglas-fir programs (Barry Jaquish, MOF)
- lodgepole pine program (Michael Carlson, MOF)
- Nelson Forest Region seed supply (Mike Madill, MOF)
- Vernon Seed Orchard Company seed orchard development and seed production (Tim Lee, VSOC)
- Tree Improvement Branch programs and policies on seed availability, forecasting, mapping, and the Species Plan Information Reporting (SPIR) system (Leslie McAuley, Ron Planden, Jack Woods, Dave Reid, MOF).

There are plans to deliver similar sessions in British Columbia's five other forest regions in 2000/2001. A field component may also be offered.

Jordan River Field Trip

On June 4, 1999, the Ministry's Tree Improvement Branch hosted a one-day field trip for Timber Supply Branch staff to the Jordan River tree improvement field trials on the west coast of Vancouver Island. Tree breeders, geneticists, and researchers from MOF Research Branch and the Canadian Forest Service attended as resource people.

The purpose of the trip was to introduce timber supply analysts to current tree improvement research, show them how genetic gain is expressed in the field, and to promote contacts between analysts and resource people.

The exchange was useful to hosts, participants, and resource people alike.

- Analysts learned where the genetic worth values they are using come from: "Good practice to 'see' the results, not just ponder the numbers."
- Hosts got pointers on how to improve the extension experience: "Dialogue at each of the stops may have helped me to see more of the particular family/feature differences."
- Resource people learned what additional information analysts need: "The risks of loss of genetic diversity associated with the program."

The field trip was an example of extension at its best—a learning experience for all.

Under the guidance of Council's new Extension TAC, activities that link researchers with users of improved reforestation materials will increase

Vandals Hit B.C. Research and Saanich Seed Orchards

In October 1999, vandals destroyed important trees at a biotechnology institute on Vancouver's University of British Columbia (UBC) campus and a Vancouver Island seed orchard. The group claiming responsibility for these acts apparently thought that these trees were genetically modified.

All material damaged in the attacks originated from wild forest stands and traditional tree breeding programs

Several hundred research trees in an open compound at B.C. Research Institute on the UBC campus were damaged or destroyed on October 27, 1999, causing major setbacks in several research projects. Some of the trees were part of a Ministry of Forests (MOF) study comparing the growth and survival of Douglas-fir and western hemlock seed from different geographic sources around the province.

Western Forest Products' Saanich Forestry Centre was attacked on October 31, 1999, resulting in an estimated $250,000 of damage to gene archives and seed orchards of Sitka spruce, western hemlock, and yellow-cedar. This vandalism may delay Western's reforestation efforts in hemlock by as much as seven years.

More recently, on March 27, 2000, vandals damaged or destroyed an estimated 1600 young trees at the MOF Saanich Seed Orchard. The casualties included Douglas-fir, white pine, naturally occurring weevil-resistant spruce, and demonstration hardwood and softwood plantings. This attack has set back seed production at the Saanich Seed Orchard by five years. The damage represents an investment loss of some $100,000, not including the future value of the seed.

No genetically modified materials are used to reforest British Columbia's Crown lands

None of the material vandalized in these attacks was genetically modified, genetically engineered, gene-spliced, or bio-engineered. All material damaged in the attacks originated from wild forest stands and traditional tree breeding programs.

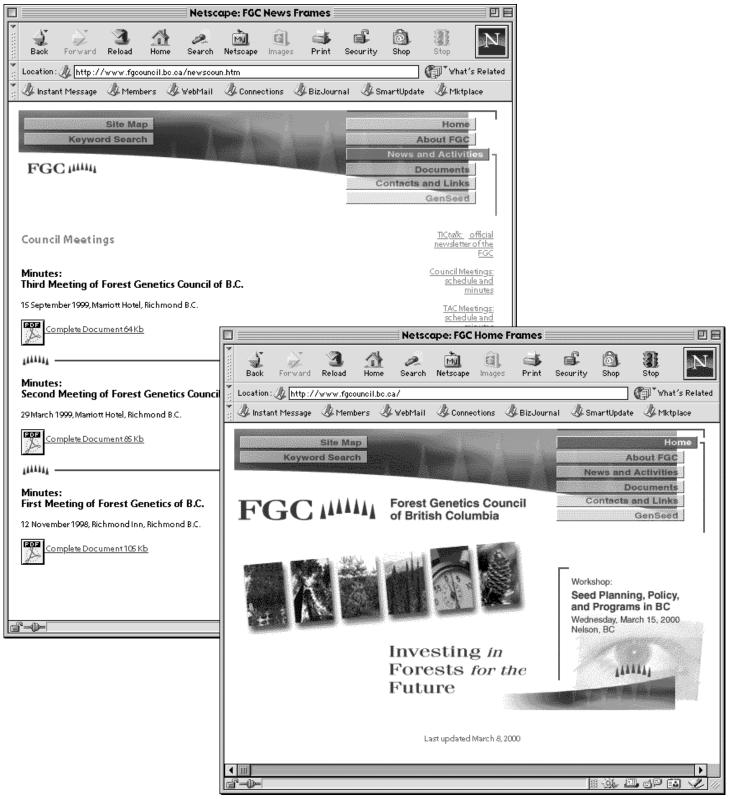
The Facts

- Products of genetic engineering, often described collectively as genetically modified organisms (GMOs), are defined by the introduction of foreign DNA into the genetic material of the product.
- Over 200 million trees are planted in British Columbia each year. None of these is "genetically modified."
- Tree breeding is not genetic modification. Breeding identifies and selects naturally occurring characteristics from the genetic variation in natural forests. It does not introduce new genes or modify existing genes.
- The tree breeding programs of the MOF use trees selected from wild stands to identify nature's best growing, strongest, or most pest-resistant trees. Seed or cuttings are collected from these trees, then grown and tested for desirable characteristics. The best trees are used in seed orchards, where they are carefully tended so that they produce large volumes of high quality seed. Using many parent trees from many stands maintains genetic diversity.
- Regulations established by the provincial government and enforced by the MOF (orchard licensing, seed registration, seed transfer guidelines) ensure that seedlings are planted only on appropriate sites.
- Somatic embryogenesis (SE) is a high-tech means of reproducing plant material. It does not recombine or add genetic material.
- The Forest Genetics Council does not support research on genetic engineering, and no genetically modified materials are used in Crown land reforestation in British Columbia.

www.fgcouncil.bc.ca

New Look

The Forest Genetics Council Web site (***www.fgcouncil.bc.ca***) received a facelift in 1999. Cortex Consultants Inc. redesigned the site interface to make it easier for visitors to locate articles, track current events, and maintain their bearings while casually surfing.



Location: http://www.fgcouncil.bc.ca/newscoun.htm

Council Meetings

Minutes:
Third Meeting of Forest Genetics Council of B.C.
15 September 1999, Marriott Hotel, Richmond B.C.
Complete Document 64 Kb

Minutes:
Second Meeting of Forest Genetics Counci
29 March 1999, Marriott Hotel, Richmond B.C.
Complete Document 85 Kb

Minutes:
First Meeting of Forest Genetics of B.C.
12 November 1998, Richmond Inn, Richmond B.C.
Complete Document 105 Kb

Location: http://www.fgcouncil.bc.ca/

Workshop:
Seed Planning, Policy, and Programs in BC
Wednesday, March 15, 2000
Nelson, BC

Last updated March 8, 2000

Articles and bulletins available through the site are now classified under five major headings:

- *About FGC*
- *News and Activities*
- *Documents*
- *Contacts and Links*
- *GenSeed.*

Highlight areas include background information about FGC membership and operating structure, minutes from past Council meetings, news of upcoming meetings/events, and key documents related to forest gene resource management. Current and past versions of TIC*talk* are also available as downloadable PDFs.

Security Issues

Web site security became a concern in the aftermath of seed orchard vandalism in southwest British Columbia in October 1999. [*Editor's note: see article on Vandalism.*]

Subsequently, we removed information from the site that could identify individuals or facilities that might be targeted by vandals (e.g., the names and addresses of Councillors and seed orchard operators).

The physical Web site itself continues to operate in a secure, well-guarded environment, and is updated frequently.

Send information about upcoming meetings, courses, position openings, and other items of interest for posting on the FGC Web site to ***fgc@cortex.org***

Forest Renewal BC's Tree Improvement Program

submitted by Janet Gagne

Through its Tree Improvement Program (TIP), Forest Renewal BC has made a significant long-term commitment to support the management of the forest gene resource in British Columbia. This article describes Forest Renewal BC's new strategic investment focus, and the role of its TIP in achieving the Corporation's strategic objectives.

Through strategic investments, Forest Renewal BC seeks to increase the volume, value, and health of British Columbia's second-growth forests

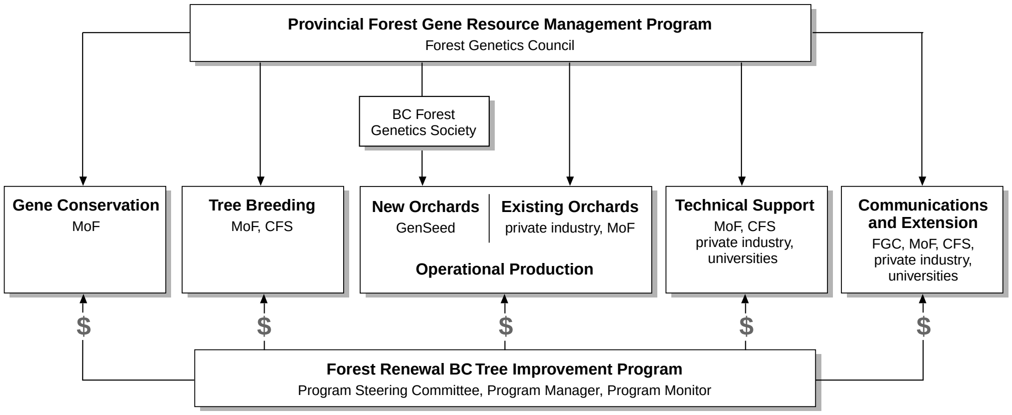
Forest Renewal BC has a clear mandate to develop and act on a long-term commitment to renew British Columbia's forests and forest industry. Working with a significantly reduced budget in its second five-year term (1999–2003), the Corporation restructured from a program-delivery agency to a smaller, performance-based, and strategically focused investment agency. In doing so, it has established clearly defined, measurable performance goals and evaluation mechanisms that will improve its decision-making and accountability.

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

One of Forest Renewal BC's aims is to contribute to stabilizing the medium- and long-term sustainable harvest levels in British Columbia. Through strategic investments, it seeks to increase the volume, value, and health of second-growth forests. The Corporation is targeting a significant portion of its land-based funding to this end; its Tree Improvement Program (TIP) is one of these initiatives.

The goals of Forest Renewal's TIP 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. This program is consistent with the provincial strategy for forest gene resource management developed by the Forest Genetics Council (FGC) (see figure). Working with the Council, Forest Renewal BC invested $7 million in 1999/2000 through its TIP. In 2000/2001, the Corporation will increase this investment to establish new seed orchards through GenSeed Ltd. [*Editor's note: see GenSeed Ltd. article for more information.*]

Provincial strategy for forest gene resource management



To focus on performance, the TIP includes a program monitor to ensure the development of a results-based management system. Jim Burbee, the program monitor, worked closely with the FGC to develop the key performance measures and indicators of the results-based management system. The TIP emphasizes a planned approach based on the FGC Strategic Plan. The Forest Renewal TIP is incremental to existing government and industry tree improvement programs, and Forest Renewal BC funds are tracked through the Corporation's Investment Management System.

The Forest Renewal BC Program Steering Committee meets annually to review the TIP budget and overall program progress. The Committee includes the program manager (Janet Gagne), program monitor (Jim Burbee), FGC co-chairs (Dale Draper, Shane Browne-Clayton), and a member of each of Forest Renewal BC's Environment Committee (Rod Willis) and Forest Resources Committee (Rod Beaumont). These committees advise the Forest Renewal BC Board of Directors about priorities for investment in all Forest and Environment programs relating to Forest Renewal BC's annual Business Plan.

Operational Tree Improvement Program 2000/2001

submitted by Roger Painter

The Forest Genetics Council's Operational Tree Improvement Program (OTIP) is funded through Forest Renewal BC's Tree Improvement Program (TIP) and administered by the Ministry of Forests. OTIP is a strategic program to address needs identified in the FGC species plans *(see side bar)*.

The Forest Renewal TIP funds activities through five subprograms. [*Editor's note: see Forest Renewal BC article.*] In 2000/2001, OTIP will fund projects related to operational production in existing orchards and technical support. Core breeding, communications and extension, and gene conservation activities will be funded under their respective subprograms. The development of new orchard production capacity, including establishment of new orchards and expansion of existing orchards, will be planned and implemented through GenSeed Ltd. [*Editor's note: see GenSeed article.*]

The 2000/2001 OTIP Call for Proposals was issued in November 1999. Council received 116 proposals requesting over $2.5 million. Review subcommittees of the FGC Coastal and Interior TACs evaluated proposals against criteria from the strategic objectives of the FGC provincial forest gene resource management program and the Forest Renewal TIP. Council accepted the recommendations of the review subcommittees at its meeting of March 10, 2000, and has submitted them to Forest Renewal BC for funding. The following table summarizes the OTIP recommendations for 2000/20001.

A species plan describes the tree breeding and seed production activities to achieve projected seedling needs and genetic gain for each of the 42 seed planning units in the provincial forest gene resource management program.

Seed planning units are the combination of species, geographic area (seed zone), and elevation band upon which tree breeding and orchard seed production are based, and for which a species plan is prepared.

OTIP 2000/2001 funding ($ '000)

Subprogram		Coast	Interior	Total
Operational Production	$	292.2	262.7	554.9
	# projects	*24*	*37*	*61*
Technical Support	$	390.8	646.1	1036.9
	# projects	*19*	*18*	*37*
Total	$	683.0	908.8	1591.8
	# projects	*43*	*55*	*98*

Reviewing OTIP proposals is a significant effort by dedicated volunteers in the Coastal and Interior TACs. On behalf of Forest Renewal BC and those who submitted proposals, Council thanks the reviewers for their dedication and hard work.

GenSeed Ltd. – A Milestone for Tree Improvement in British Columbia

submitted by Jack Woods

GenSeed Ltd. will accelerate investment in expanding seed orchard capacity by negotiating seed contracts with suppliers

The Forest Genetics Council of British Columbia (FGC) is the stakeholder body guiding the provincial forest gene resource management program. The Council seeks to expand the production and use of improved seed[1] on Crown land in British Columbia. The goal is to use improved seed for 75% of all sowing by the year 2007. Achieving this goal will almost double the current level. In keeping with its objective of supporting the development of a private-sector seed orchard industry, Council also wants the private sector to undertake most of this expansion of production capacity.

However, private sector investment in seed orchards is limited by:

- lack of incentives
- reduced budgets
- the current tenure system
- the requirement for long-term investments in seed orchards.

In its 1998 strategic plan for forest gene resource management in British Columbia, Council proposed the development of a "seed company" to accelerate investment in expanding orchard capacity. The seed company would invest in production facilities (mostly seed orchards) by negotiating seed supply contracts with suppliers. In September 1999, with the incorporation of GenSeed Ltd., the seed company became a reality.

By 2012, orchard expansion and development are expected to supply enough revenues from seed sales for GenSeed to be self-sufficient

Mandate

GenSeed's primary mandate is to expand seed orchard production capacity to meet FGC Business Plan objectives. In addition, GenSeed will provide program management services to Council. GenSeed will work with forest and nursery companies to expand the use of vegetative propagules where Council's technical advisory committees (TACs) consider it appropriate and worthwhile (e.g., for weevil-resistant Sitka spruce).

Legal Structure and Ownership

The challenge in creating GenSeed was to ensure that it could operate independently in a sound business-like manner, and still take its direction and mandate from FGC business plans. Because Council is not a legal entity that could own GenSeed, the Councillors created the B.C. Forest Genetics Society under the *Society Act.* This non-profit organization could own a company to expand orchard production. The Society will also conduct other business on behalf of Council.

GenSeed Ltd. is a registered company under the *Company Act*, and is wholly owned by the B.C. Forest Genetics Society (see figure). GenSeed's Board of Directors currently includes Chairman John Cuthbert, RPF (formerly Chief Forester of British Columbia); Reid Carter, RPF (National Bank Financial); Glen Dunsworth, RPF (Weyerhaeuser Canada); Shane Browne-Clayton, RPF (Riverside Forest Products); and Dale Draper, PhD (B.C. Ministry of Forests).

Capitalization

The Forest Renewal BC Tree Improvement Program is providing start-up funding for GenSeed. By the year 2012, orchard expansion and development are expected to supply enough revenues from seed sales for GenSeed to be self-sufficient. All revenues will be invested in further orchard adjustments and enhancements.

Planning and Objectives

GenSeed's business plan and investments will be based on the long-term and annual business plans prepared by the Council's TACs. For example, GenSeed might invest in lodgepole pine to meet the following FGC Business Plan objective:

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[1] "Improved" refers to the fact that the seed comes from tree 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 improved reforestation materials including vegetative propagules.

to expand seed production capacity for lodgepole pine, for areas below 1100 m elevation in the Bulkley Valley Seed Planning Zone, to 17.6 million seedlings annually with an average genetic worth of 14.

Acquisition Procedures

GenSeed will expand orchard production and build an inventory of improved reforestation materials with seed and propagules obtained through supply contracts. Seed supply contracts will usually be awarded through the following request for proposal procedures:

- advertise appropriately for the project
- screen proposals based on technical, financial, and managerial criteria
- negotiate specific terms with the leading proponent(s)
- develop and sign a contract for services.

Direct awards may occasionally be used where only one proponent is suitable for the work, such as for grafting rootstock that is only available at a single site. After an initial transition period, contracts for grafting and orchards will rarely be direct awarded.

A percentage of seed produced through the expanded capacity supported by GenSeed contracts will flow to GenSeed's seed inventory. The rest may be used internally by the orchard owner (see figure). Sales from GenSeed 's inventory will generate income that will, in turn, support the company's operations and FGC objectives.

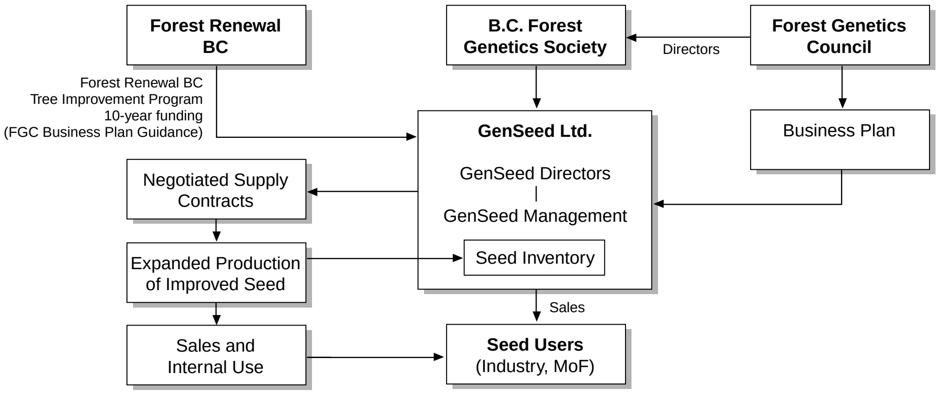
Next Steps

GenSeed is currently completing its first contracts for grafting to expand seed orchards. Later in the spring (2000), GenSeed will seek proposals for 2001 orchard grafting, and organize rootstock with suppliers. Orchard expansion contracts will begin with the low elevation Douglas-fir orchard in the Nelson Seed Planning Zone. GenSeed will seek proposals for other orchard expansions as planning is completed.

Orchard expansion will begin with the low elevation Douglas-fir orchard in the Nelson SPZ

GenSeed will seek proposals for other orchard expansions as planning is completed

Organizational relationships among GenSeed, Forest Renewal BC, the B.C. Forest Genetics Society, and the Forest Genetics Council



Focal Point Seed Zones Tested in British Columbia

submitted by Bill Parker

Bill Parker, a scientist from Lakehead University in Thunder Bay, Ontario, has developed a new approach to defining seed planning zones. His "focal point seed zones" are currently being used to guide seed transfers for black spruce and jack pine in northern Ontario.[2] *In 1999, Parker joined the Ministry of Forests (MOF) Research Branch for three months to test this approach in British Columbia. With his MOF colleague Cheng Ying, Parker identified focal point seed zones for lodgepole pine in the Kootenay region.*

Conventional seed zones are fixed geographic areas within which seed may be moved from a source to a reforestation site

Parker's approach uses GIS technology to delineate a unique seed zone for any reforestation site (the focal point)

Conventional seed zones are fixed geographic areas within which seed may be moved from a source to a reforestation site. In British Columbia, seed planning zones were originally identified to ensure that reforestation stock was planted in the same general area in which seed was collected. Recently, the boundaries of seed planning zones in British Columbia's interior were modified to incorporate new biological information gathered from seed source testing, to be consistent with the biogeoclimatic ecological classification (BEC) system, and to increase administrative efficiencies.[3]

The approach pioneered by Dr. Bill Parker uses geographic information systems (GIS) technology to delineate a unique seed zone for any site (the focal point) requiring seed for artificial regeneration. The focal point method finds the best matches between potential seed sources and a specific reforestation site. The matches are based upon similarities in *adaptive variation*—the patterns of genetic variation present in the natural forest that have evolved due to climate differences associated with changes of latitude, longitude, elevation, and other factors such as proximity to large bodies of water.

The establishment of fixed boundaries in conventional seed zones may not give the best adaptive match, particularly when a reforestation site is near a boundary. In contrast, the focal point seed zone method converts our knowledge of a species' adaptive variation into *spatial data*. With GIS technology, these spatial data are used to make an uncompromising match of seed to planting site.

Methodology of Focal Point Seed Zone

Producing focal point seed zones requires several steps. Most of the work is completed "up front" to develop mathematical models of adaptive variation for each species of interest. These models are then used with GIS technology to identify the zone of seed sources that best match a particular focal point reforestation site. Broadly stated, these steps are:

- Provenance testing: Seed is collected from natural stands throughout the management area. Common-garden provenance tests are established, maintained, and measured to compare the growth of the seedlings from the sampled stands. Appropriate descriptors of tree growth are selected (e.g., measures such as height and diameter growth, and if available, other attributes such as frost hardiness and date of bud flush). These activities may occur over many decades.
- Growth analysis: Measurements of the selected growth descriptors are analyzed to show differences among seed sources, to identify the principal components of variation, and to correlate these with climate variables. The objective is to establish the relationship between genetic variation in the species and climate differences.

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[2] FPSeedZ, an ArcView 3.1 stand-alone program to generate focal point seed zones for black spruce and jack pine in northwestern Ontario, is available on request. Contact bill.parker@lakeheadu.ca for more information.

[3] For more information about B.C.'s Class A and B seed planning zones refer to TIC*talk*, Vol. 2, No. 1, Spring 1999, p. 20, or visit *www.for.gov.bc.ca/tip*

- Mapping: Once established, mathematical models are used to convert the observed adaptive variation into a spatial database of high-resolution geographic grids. GIS technology is then used to map the adaptive variation. For any point on the map (the focal point), a geographic area (the seed zone) that meets acceptable limits of similarity can be defined.

Testing the Approach in British Columbia

British Columbia's comprehensive provenance testing program for lodgepole pine[4] provided an ideal test for the focal point seed zone approach. This initial attempt used 3- to 20-year height and diameter measurements from five test sites representing the Kootenay region. Because these growth variables are highly correlated, the results could be summarized into three composite measures of growth.

Ideally, these new descriptors would then have been modeled by regressing them against climate variables. However, because British Columbia does not yet have a completed digital climate model, the geographic variables of latitude, longitude, and elevation were used as surrogates of climate variables.

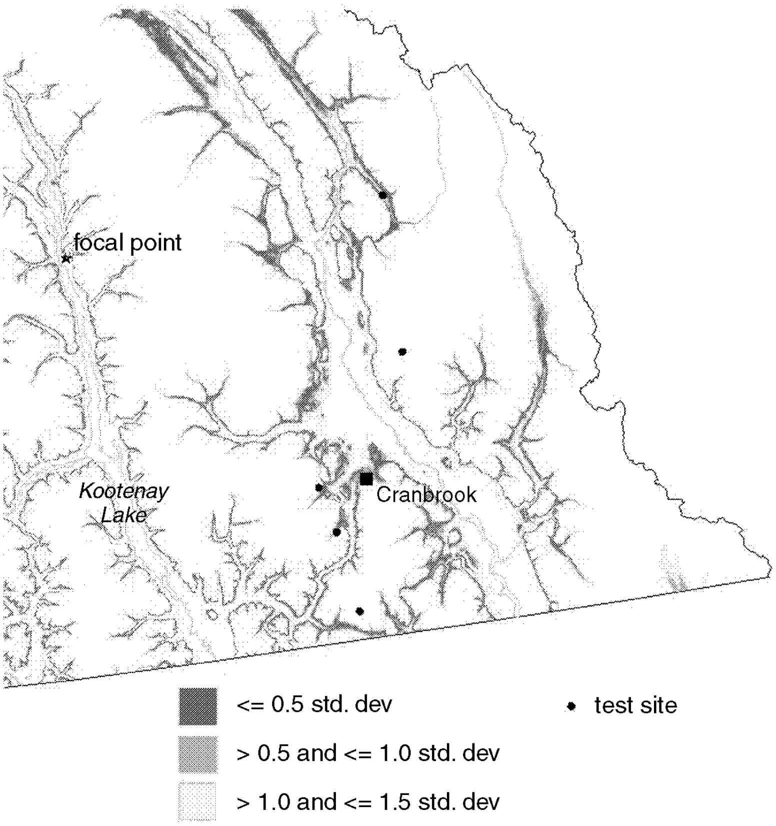
The following map shows an example of a focal point seed zone for lodgepole pine in the Kootenay region. The five test sites are indicated as solid circles. The focal point, representing a potential reforestation site, is shown as a star; it was located arbitrarily at 50°02' north latitude and 116°93' west longitude at an elevation of 1143 m. The denser the shading on the map, the better the match in adaptive traits to the designated focal point.

The map illustrates that the shaded zones represent narrow elevation bands. However, what cannot be seen is that the exact elevation limits vary with changes in latitude and longitude. The test application showed the congruence of the results with the well-known BEC zones of British Columbia.

Future Application

In addition to providing the best possible match of seed to planting site, the focal point approach has another important advantage over traditional seed zones. When a digital climate model becomes available for British Columbia, it will be possible to specify a modified target climate and generate appropriately modified seed-suitability areas. In this way forest managers will be able to predict where improved seed from today's orchards will perform best under tomorrow's predicted climates.

Focal point seed zone for lodgepole pine in the Kootenay region



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[4] The lodgepole pine provenance testing program, established by Keith Illingworth in 1974, includes 140 sources of lodgepole pine grown at 60 locations in 12 regions of the province.

Genes, Climate, and Wood Production

This article is an overview of a lecture by Dr. Gerald E. Rehfeldt, presented at the University of British Columbia on February 2, 2000.[5] *The full paper is available from the UBC Faculty of Forestry Web site: www.forestry.ubc.ca/schaffer/rehfeldt/*

Lodgepole pine, like most forest tree species, is composed of populations that are physiologically attuned to a finite range of climates

Because trees cannot migrate, a changing climate will affect wood production

Introduction

Most forest tree species are composed of populations with different climatic optima that have arisen through environmental selection. Lodgepole pine, for instance, is subdivided into geographically distinct subspecies within which populations are arranged along clines[6] that parallel climatic gradients.

Dr. Rehfeldt assessed the effects of a fluctuating climate on the growth, survival, and productivity of populations of lodgepole pine by analyzing data from the Illingworth provenance tests established in British Columbia in the mid 1970s. His approach involved:

- developing a regional climate model using polynomial regressions driven by geographic variables
- predicting the climate at each planting site
- developing regressions using a simple quadratic model that predicts height, diameter, and survival for each provenance from climate variables.

Human intervention will be required to maintain wood production near optimum as climates change

This will involve conservation, propagation, and planting of genotypes most appropriate to the new climates

Genecology

Rehfeldt's analyses indicated that natural populations of lodgepole pine occupy suboptimal environments—i.e., that they were growing in conditions that were not ideally suited to highest growth rates. He also found that optimal growth occurs when populations are grown in the same climates as those where they occur naturally. He explains these apparently anomalous results by the fact that genotypes are in competition, and that most populations are competitively excluded from their ecologic optimum. The realized niche, therefore, tends to be suboptimal.

Response to Changing Climates

Climate change has short-term and long-term impacts. The short-term, direct impacts will depend on the physiologic plasticity, or ability of trees' physiologic systems to adjust to fluctuations in climate. The long-term impacts will depend on the evolutionary process through which populations adapt to climate changes over subsequent generations.

Rehfeldt explored 16 climate-change scenarios with temperature changes between -3°C and +5°C and precipitation levels of -100, 0, and +100 mm.

For southern British Columbia in general, he suggests that any change in temperature or in the balance between temperature and precipitation would decrease the productivity of lodgepole pine.

In northern British Columbia, he suggests that a decrease in temperature would result in either annihilation or decimation of lodgepole pine. Warming temperatures, particularly if accompanied by increases in precipitation, would increase survival, growth, and productivity.

Adjusting to the climate changes predicted by current models of global change will take natural processes a long time—300 to 1500 years. Following the long-term evolutionary adjustments to climate change, Rehfeldt suggests that future productivity of lodgepole pine in British Columbia should increase substantially.

Forest Management

While noting that views on climate change are intuitive, Rehfeldt believes that climate change has begun and that forest managers should start to address this change in their reforestation activities.

He emphasizes the need to conserve and propagate genotypes of future importance,

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[5] The lecture was based on Rehfeldt, G.E., Ying, C.C., Spittlehouse, D.L., and D.A. Hamilton. 1999. Genetic responses to climate in *Pinus contorta*: niche breadth, climate change, and reforestation. Ecological Monog. 69, 375-407.

[6] A gradient in gene, genotype, or phenotype frequency.

such as lodgepole pine on southeastern Vancouver Island. He expresses urgency in these measures in light of recent rates of human encroachment into the island's natural ecosystem.

He notes that to maintain wood production near the optimum will require human intervention in the evolutionary process. He suggests shortcutting the evolutionary lag with planting programs that transfer appropriate genotypes between seed zones, and recommends starting to transfer genotypes from warmer provenances to cooler ones.

Western White Pine Seed Set and Cone Drop

submitted by John Owens

A recently completed Operational Tree Improvement Program (OTIP) project on seed production in western white pine determined the pollination biology, cone and seed potential, and final cone and seed production in two orchards—an older half-sib coastal orchard[7] in Saanich (Vancouver Island) and a young clonal orchard[8] near Kalamalka (B.C. Interior).

Cone and Seed Potential

Western white pine features a large seed potential per cone (150 for coastal and 175 for interior). The amount of seed produced, as measured by the seed efficiency factor[9] (SEF), varied dramatically between the two orchards without the use of supplemental mass pollination[10] (SMP). SMP showed greater benefit in the younger Kalamalka orchard than in the older Saanich orchard with abundant pollen cones.

Seed production (SEF%) by number of SMP applications, for two seed orchards

Orchard	No SMP	≥ 1 SMP
Kalamalka	<5%	20–30%
Saanich	<30%	30–40%

Cone Survival

Cone survival, an often-ignored aspect of reproduction, is very important in pines. Cone drop commonly occurs about two months after pollination and may be largely due to inadequate pollination success. Pollination success, as measured by pollen on the ovules or in the ovules, or fertilization success measured one year later, greatly increased SEF and cone survival. Without SMP, cone survival was dramatically greater at the older Saanich orchard where pollen was abundant.

Cone survival (%) by number of SMP applications, for two seed orchards

Orchard	No SMP	1 SMP	> 1 SMP
Kalamalka	5%	15%	30%
Saanich	40%	50%	50%

Conclusions

With the high potential for seed production per cone in western white pine, a small increase in cone retention can greatly increase seed production. SMP can improve both seed production and cone retention, but the effect on cone retention is often not monitored. The relationship between cone retention and clone should also be monitored as coastal and interior clonal orchards mature.

Supplemental mass pollination can improve both seed production and cone retention in western white pine

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[7] Offspring resulting from a cross of one parent to many other parents unrelated to each other or the common parent.

[8] Trees grown from scions grafted onto rootstock.

[9] The number of filled seed as a percentage of seed potential.

[10] A broadcast application of pollen to female reproductive structures that are not isolated from airborne pollen.

Western Redcedar: Managing the Contradiction

submitted by John Russell

Pacific Northwest conifers are among the most genetically variable organisms on earth. This quality enables them to survive and adapt to environmental change. Atypical in possessing abundant adaptive genetic variation is western redcedar. This article discusses the characteristics of western redcedar that allow it to successfully occupy a wide variety of ecosystems over an extensive geographical area. It also explains what this means to managing the gene resource of the species.

Western redcedar may not need the adaptive genetic variation levels that have enabled other Pacific Northwest conifers to survive and adapt

Western redcedar (*Thuja plicata*) occurs along the Pacific coast from northern California to southern Alaska at elevations from sea level to over 1000 m. In the interior it grows from southern Idaho to central British Columbia at elevations of 300–2000 m. It thrives in many variants—predominantly in Coastal Douglas-fir, Coastal Western Hemlock, and Interior Cedar–Hemlock biogeoclimatic zones. Also, it occurs over a range of site conditions, from nutrient-poor moderately dry sites to nutrient-rich wet and/or stagnant sites. Much of western redcedar's range appears to be limited by the ability to withstand cold when precipitation is not limiting.

Unlike other Pacific Northwest conifers, western redcedar displays minimal genetic variation in studies using biochemical markers, and moderate quantitative genetic variation. Adaptive genetic variation is minimal, and western redcedar can be considered a generalist in how it perceives its environment—i.e., populations do not differ dramatically in their responses to environmental stresses. How can western redcedar be so successful with minimal adaptive genetic variation?

Characteristics Underlying Species Success

Western redcedar features several biological attributes that allow it to survive environmental changes and stresses with minimal adaptive genetic variation. These attributes include phenotypic plasticity, self-pollination, and vegetative propagation.

Like other Cupressaceae species, western redcedar exhibits substantial phenotypic plasticity—variation in characteristics without genetic alteration—that enables it to respond quickly to environmental change. For example, shoot growth can start and stop in response to temperature late into the fall. In contrast, most Pinaceae have a predetermined amount of growth that is in tune with seasonal photoperiodic changes.

Also atypical of other Pacific Northwest conifers, western redcedar readily self-pollinates and produces viable seed. While nursery-grown seedlings of selfed progeny are difficult to distinguish from outcrossed seedlings, there is evidence of delayed inbreeding depression[11]—selfed trees grow around 10% less than outcrossed trees after outplanting. In comparison, Pinaceae exhibit dramatic losses from selfing—in some cases, with reductions in survival and growth of over 60%.

Without seed production, or if a particular tree is successful, cloning can be an alternative survival tool. In contrast, recombining genes sexually produces individuals that are similar but not replicates of the parent. Western redcedar readily propagates by branch layering, ensuring the future survival of an established tree or population of trees.

With the previous biological attributes to ensure survival and colonization in the face of environmental change, western redcedar may not need the adaptive genetic variation levels that have enabled other Pacific Northwest conifers to survive and adapt.

What do these unique combinations of evolutionary tools mean for managing the western redcedar gene resource?

Gene Resource Management

Managing the gene resource of western redcedar involves developing strategies for gene conservation, seed procurement and

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[11] Inbreeding, or the mating of related individuals, usually causes loss of vigour known as inbreeding depression.

transfer, and tree breeding in the context of minimal adaptive variation, plasticity, selfing, and vegetative propagation.

Gene conservation: we're in good shape

As noted earlier, western redcedar is a generalist in how it perceives its environment. For example, coastal populations are less cold hardy than coast:interior transition and interior populations. However, cold hardiness differs little between populations widely separated in elevation within a seed planning zone. This means that gene conservation can be concentrated on a relatively few, large populations because most of the genetic variation lies within populations.

A recent survey[12] of substantial stands of western redcedar protected in legislated parks and reserves indicates that the species is adequately represented in all relevant biogeoclimatic zones. Also, over 700 clones collected from range-wide populations are protected in gene archives.

Seed transfer: broader horizons

Seed transfer can be broader with generalist species than with specialists. There is every indication that seed transfer within and between seed planning zones will become less restricted for western redcedar in the future. Nevertheless, caution is warranted. Recent analyses of *Keithia* disease in a provenance field trial showed that resistance to disease was more specific to seed origin. Coastal low-elevation populations, which have a higher level of natural *Keithia*, showed the most resistance and coastal high-elevation and interior populations, the least.

Tree breeding: developing elite populations

Western redcedar seed orchards were established in the early 1990s for a guaranteed supply of seed, rather than for breeding. At the time, redcedar was thought to have little genetic variation. However, recent research has shown that there is sufficient genetic variation in western redcedar to economically justify a tree improvement program.

Recent research has shown that there is sufficient genetic variation in western redcedar to economically justify a tree improvement program

Most future seedling demands, and the western redcedar breeding effort, will focus on the Maritime Seed Planning Zone below 600 m. Over 700 wild-stand phenotypic selections from coastal British Columbia, Washington, and Oregon will be mated with a common 20-clone polymix. The resultant progeny will be field-tested to obtain breeding values. Currently, three annual series of 150 families per year have been established on three to four sites below 600 m in the Maritime Seed Planning Zone. In addition, two to three smaller tests consisting of a subset of families have been established each year on higher elevation sites in the Maritime and Submaritime Seed Planning Zones. These tests will collect information for refining seed transfer guidelines and support the deployment of orchard seed beyond current limits. Breeding and test establishment of these first generation selections will be completed by 2003.

Future seed orchards: designs to maximize gain

At selection age in the progeny test (7–12 years), the existing orchards can be rogued. After all 700 families reach selection age, high-gain orchards can be established. To realize the full gain potential, current and future western redcedar orchards should be managed and/or designed to minimize selfing. This objective can be accomplished either through full-sib crossing with vegetative amplification, pollen management, or by production of male and female clones through crown production and hormone applications.

To realize the full gain potential, current and future western redcedar orchards should be managed or designed to minimize selfing

Wood durability: the future for western redcedar

Second-growth western redcedar may not be as rot-resistant as old growth. However, current research indicates the potential of genetic selection for wood durability without compromising improved growth, either by sampling parent trees, or progeny as early as 10 years of age. Selecting trees that have higher extractives content consistently throughout the heartwood will improve future second-growth wood durability. Selections for durability are anticipated for the next round of western redcedar seed orchards.

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[12] Lester, D.T. and A.D. Yanchuk. 1996. A survey of the protected status of conifers in British Columbia: *In situ* gene conservation. B.C. Min. of For. Research Report No. 4. 34 p.

Genetics, Silviculture, and Disease in Bulkley Valley Lodgepole Pine

submitted by Sally John

Background

Silviculture variables such as density can affect the relative ranking of genotypes through genetic differences in competitive ability

In 1997, Forest Renewal BC awarded Babine Forest Products one of British Columbia's three Enhanced Forest Management Pilot Projects (EFMPPs). One goal of this EFMPP is to double current mean annual increment and thus increase timber supply. Since tree improvement is widely viewed as a cost-effective method of increasing forest productivity, genetics seemed an obvious area to explore. Isabella Point Forestry Ltd., contracted to implement this component of the EFMPP, has developed two projects to investigate the potential effect of stand density on genetic ranking, and whether susceptibility to comandra rust is under genetic control.

Harvest index is a measure of the proportion of tree biomass allocated to the bole or harvested portion of the tree.

The Ministry of Forests (MOF) breeding program for lodgepole pine, led by Michael Carlson, is well established provincially and in the Bulkley Valley, which includes the Babine area. Progeny tests were planted in 1985 and 1986, and seed orchards have been set up at the Prince George Tree Improvement Centre and at the Vernon Seed Orchard Company site. Predicted gains in individual tree growth rates are substantial and verifiable.

Does Stand Density Affect Genetic Ranking?

After determining that there is genetic variation in the way biomass is allocated to stem and branches, we are planning a trial to test the effects of spacing on genotype performance

Progeny tests are used to help distinguish between genetic effects and those resulting from variation in site conditions. They are usually planted at a uniform spacing to avoid density effects. However, studies elsewhere have shown that silviculture variables such as density can affect the ranking of genotypes through genetic differences in competitive ability. Discussions with MOF staff Michael Carlson and Gerry Pinkerton and Babine forestry staff Bill Chapman and Sherry Maine suggested that a study investigating this possible interaction might be useful.

It is possible to closely examine available evidence from existing genetic tests and design small experiments using remnant seed from original progeny tests to look at height growth, crown attributes, and volume productivity as a function of available growing space. Several intermediate stages are necessary. First, we must ascertain that in lodgepole pine there is genetic variation in how biomass is allocated to stem and branches. Then, trials can be established to determine whether the patterns of biomass allocation are influenced by spacing.

We analyzed existing MOF harvest index data for 60 lodgepole pine families with parental elevations ranging from 600 to 1650 m in a farm-field test at Skimikin, near Salmon Arm. We found significant differences among families in harvest index, even when corrections were made for tree size and elevation. In other words, there is real variation in biomass allocation patterns among families from similar elevations.

We are now planning a trial to test the effect of spacing on genotype performance. In July 1999, we assessed crown-form traits on 134 families at age 14 on two test sites in the Bulkley Valley. We identified three contrasting crown types:

Crown-form traits of three contrasting crown types for 134 families of lodgepole pine

Crown-form traits	Type 1	Type 2	Type 3
Harvest index	high	intermediate	low
Branch length and distribution	short branches in both upper and lower crown	long branches in upper crown, shorter branches in lower crown	long branches in both upper and lower crown
Distribution of biomass	most biomass clearly allocated to bole		large proportion of biomass allocated to branches

Type 1 families are apparently genetically programmed to have short branches, with few live branches in the lower crown, and with these branches extending barely 0.5 m towards their neighbours. Type 3 families are apparently genetically programmed to have long branches. Almost all individuals of Type 3 families had extremely long live lower branches extending past neighbouring trees (1.5 m away), despite fairly dense shade.

Type 2 trees would be desirable for many deployment situations, because the genetic tendency to long branches would facilitate capturing the site's growing space, while low shade tolerance would accelerate dieback of lower branches and self-pruning.

We hypothesize that Type 2 crowns grow vigorously in open conditions but respond to competition by restricting growth of competing branches. We will test this by establishing family plots with varying amounts of growing space per tree, from tight to wide spacing, and examining patterns of biomass allocation under this range of spacing. Remnant seed of selected families was sent from the MOF Kalamalka Forestry Centre to PRT's Telkwa nursery for stratification in March and sowing in mid-April. Seedlings will be established in field trials in 2001.

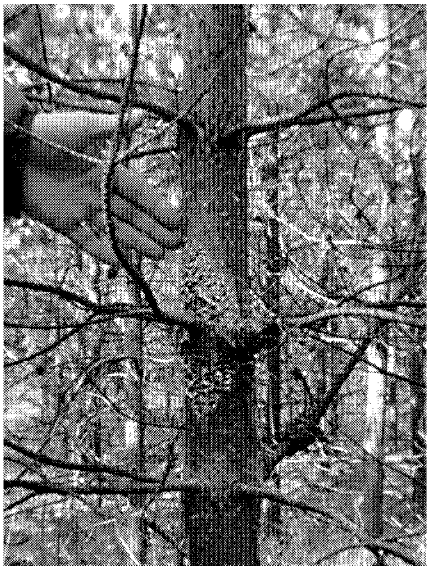
Is Susceptibility to Comandra Rust under Genetic Control?

Lodgepole pine hosts the largest array of fungal pathogens of any timber species in British Columbia. It suffers large timber losses to disease, particularly comandra rust (*Cronartium comandrae*), but also to western gall rust (*Endocronartium harknessii)* and stalactiform rust (*Cronartium coleosporioides*). Survival and growth of young lodgepole pine are severely reduced by rusts, particularly comandra. In one study, trees with bole infections of comandra suffered 87.2% mortality, while stalactiform blister rust killed 66.2% of trees with bole infections. The Lakes TSA is one of the most heavily affected areas of the province, and losses are considerable in the Babine area.

Although several studies of infection rates, and growth and survival of infected trees, have been reported for all three of these diseases, studies of host susceptibility and host–pathogen interactions have been largely limited to western gall rust. Discussions with Michael Carlson, MOF pathologist Alex Woods, and local forestry staff suggested that investigating the genetics of disease resistance in the Bulkley Valley would be worthwhile.

Established progeny tests in the Bulkley Valley provide an excellent opportunity to explore the genetic resistance of lodgepole pine to comandra rust

Diamond-shaped stem canker of comandra rust on a young lodgepole pine in the Bulkley Valley *(photo: S. John)*



The degree of genetic control of disease resistance can only be estimated in stands with a known genetic structure, such as progeny tests. Assessments can reveal whether certain families are more resistant to a given disease than others. Established progeny tests in the Bulkley Valley provide an excellent opportunity for obtaining these estimates.

If resistant families can be identified in the MOF breeding program, improved stock could be deployed in disease-prone areas

Assessments on the Chowsunket Lake progeny test site will be carried out in spring 2000, and analyses completed later this year. Through these assessments, resistant and susceptible families in the MOF breeding program may be identified. This result could help in developing deployment strategies for improved stock in disease-prone areas, and may affect selection and breeding in the next generation.

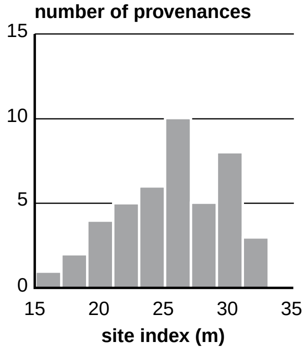
More information on this project is available on the Babine EFMPP Web site at: *www.babineefmpp.com/index.html*

Site Index at the Trinity Valley Douglas-fir Provenance Trial: Some Implications

submitted by Pat Martin and Barry Jaquish

A range-wide interior Douglas-fir provenance trial at Trinity Valley east of Enderby, B.C., provides an excellent opportunity to consider some issues of site index and tree genetics. In the late 1960s, Douglas-fir seed was collected at 64 locations ranging from the coast to the interior, and from British Columbia to Mexico. In the fall of 1975, seedlings from each seed source (provenance) were planted at Trinity Valley in 5 x 5 tree plots with three replications. The height, diameter, and other attributes of these trees have been measured periodically since establishment.

Distribution of provenances by site index



Due to mortality and damage, mostly to the southern U.S. Rocky Mountain sources, only 44 of the 64 provenances contained two acceptable site trees in each replicate at each measurement period. Using the interior Douglas-fir growth intercept model,[13] we estimated site index for each of the 44 provenances from the height and age of the six site trees at the 20-year measurement. The figure shows the site index predicted for these 44 provenances planted at the Trinity Valley site.

Douglas-fir can achieve a wide range of dominant heights at age 50 depending on its genetic composition

This suggests that the definition of site index should specify a particular genetic base

Site index—the height of suitable dominant trees of a species at age 50—is intended to describe the growth potential of a species on a particular site. The Trinity Valley data highlight a problem with this definition. As shown in the figure, Douglas-fir can achieve a wide range of dominant heights at age 50 depending on its genetic composition. Should the site index for Douglas-fir at Trinity Valley be 16 m, 31 m, or something in between? The Trinity Valley data suggest that the definition of site index should specify a particular genetic base—for example, the local unimproved seed source.

Seed from local Trinity Valley sources is in the upper third of the distribution of site indices, but not the highest. The best growers are trees from the coast:interior transition areas of British Columbia and Washington. On a limited and special approval, material from these locations is being out-planted on appropriate interior sites to see if this provenance can perform well elsewhere.

Geneticists have repeatedly demonstrated that every species varies widely in growth rate among and within seed sources. Some variation lies in the rate of dominant height growth, which translates into variation in site index. Other "gains" from the tree-breeding program may be expressed as increased disease resistance, improved form, or enhanced radial growth. To properly mimic genetic effects, stand growth models will need to modify both height growth (site index) and other tree characteristics.

In British Columbia, three methods are commonly used to predict site index: growth intercept, site index curves, and site index/biogeoclimatic ecological classification (SIBEC). The growth intercept and site index curve methods predict site index from tree growth measured on site. In contrast, the SIBEC method predicts site index from the site's ecological characteristics. Both the growth intercept and SIBEC methods produce reasonable results. However, if genetically superior seed is used or if stock is planted off site, site index is best predicted by expressed growth rather than site characteristics.

The wide range of site index predicted at Trinity Valley poses challenges for:

1. estimating site productivity
2. separating genetics from site effects
3. incorporating genetics into stand growth models
4. using the SIBEC method to estimate site index.

Please contact the authors with questions or comments on these issues.

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[13] Nigh, G.D. 1997. Interior Douglas-fir growth intercept models. B.C. Min. of For., Research Branch, Victoria, B.C. Extension Note No. 12.

Genetic Worth — Rating Genetic Quality

submitted by Leslie McAuley, Michael Stoehr, and Jack Woods

What Is Genetic Worth?

The genetic worth (GW) of a seed or vegetative lot is an estimate of the percentage increase in performance of an improved seedlot over that expected from wild-stand material.

GW is estimated for individual traits of commercial interest for orchard tree species. A seed or vegetative lot may have multiple GW values, one for each trait. These values usually include estimates for stem volume (GW-G), and may include estimates for relative wood density (GW-D) or pest resistance (GW-R).

Gains are estimated for a specific reference rotation age and for an average site index for the seed planning unit (species, seed planning zone, elevation band). Actual gains may be higher or lower depending upon actual rotation age, site index, and silviculture treatment.

How Is GW Calculated?

GW for each orchard seedlot is calculated based on the genetic quality of the parent trees in the seed orchard. This genetic quality is called a breeding value (BV).

The average orchard BV is weighted by the parental contribution to a seedlot, with adjustments for contamination by non-orchard pollen. Therefore, seed orchards with higher BV parents produce seedlots with higher GWs.

To calculate GW, a seedlot rating protocol that has been standardized for all orchard species across the province is used. Individual seedlots from an orchard may differ from year to year based on the proportional contribution of parents in the orchard or from contaminant pollen. Gains are in percentages with the higher numbers indicating better performance potential.

Where Can I Find GW Information?

GW values can be viewed on the provincial Seed Planning and Registry (SPAR) system used to order seed for reforestation on Crown land. GW is stored in the Genetic Class & Worth field displayed along with seed and vegetative lots. Currently, SPAR sorts seedlots by germination percentage, making it necessary to scan seedlots in the GW field to find the seedlot with the highest GW. Multiple GWs may be displayed with an asterisk (GW*) if space is limited.

How Is GW Related to Genetic Diversity?

For Class A certification, each seedlot requires an estimate of effective population size to meet genetic diversity registration standards. Effective population size is related to the number of different parent trees in the orchard and the amount of seed each parent tree is contributing to the seedlot.

A high GW value does not imply that a seedlot has low genetic diversity. GW is related to the genetic superiority of the parents, not to the number of parent trees in the orchard. In other words, a seedlot can have both high GW and high genetic diversity. The breeder and orchard manager control a seedlot's genetic diversity, which must meet a minimum standard for registration for use on Crown land.

Can GW Be Tracked in Operational Plantations?

Estimates of the amount and level of genetic gain going out to the field can be extracted from the SPAR database by tracking seedling request orders. Weighted GW estimates are based on the GW and quantity of the seedlots selected for any given management unit (e.g., TFL). Percent Class A seed use summaries are also available from SPAR extracts. Historical genetic gain data are available from ISIS/MLSIS records if seedlot or Request ID information has been entered.

How Does GW Affect Mean Annual Increment?

GW values for stem volume (GW-G) represent a percentage increase in mean annual increment (MAI). This value can be captured as an increase in volume per

Genetic worth is an estimate of the increased performance of improved reforestation material over that of wild-stand material

A seedlot can have both high genetic worth and high genetic diversity

Each seedlot must meet a minimum standard for genetic diversity to be registered for use on Crown land

A higher genetic worth value for stem volume is comparable to a higher site index

hectare at rotation, or as a shorter rotation age. Seedlots with high GW-G values achieve faster juvenile height growth than wild-stand seedlots. Thus, a higher GW-G value is comparable to a higher site index. [*Editor's note: see article on site index at the Trinity Valley provenance trial*.]

The percentage gain in juvenile height is approximately equivalent to the percentage gain estimate for MAI. As a result, the GW-G value can also be used to estimate gains in early height growth and time to green-up as shown in the following table.

Expected gains in early height growth and rotation-age volume for coastal Douglas-fir at various genetic worth levels (site index 30)

Genetic worth	Height at age 7 (m)	Years to free growing (3 m)	Volume at age 65 (m^3/ha)
G+00	3.3	6.5	600
G+10	3.9	5.9	660
G+20	4.3	5.5	720

Modeling Genetic Gain in TIPSY

A test version of TIPSY makes it possible to adjust yield projections for genetic worth

Genetic gain is modeled as an increase in top height, which accelerates stand development

New methods and tools have become available recently that make it possible to explicitly recognize genetic gain in timber supply analysis, and to quantify the timber supply benefits attributable to genetic gain. This article describes one of a number of tools needed to do this—the modification of yield projection models to incorporate genetic worth.

In general, two types of information are needed to incorporate gains from tree improvement in timber supply analysis:

- the amount of improved seed used
- the change in stand yield expected from using that improved seed.

Determining how much improved seed is being used and where it is being deployed is complex. The Ministry of Forests (MOF) is modifying tools such as SPAR, SPIR, and ISIS/MLSIS to help track this information.

Staff in Research, Tree Improvement, and Timber Supply Branches worked together on changes to TIPSY, the Ministry's yield projection model, that make it possible to adjust yield projections for genetic worth.

Genetic gain is modeled in TIPSY as an increase in top height, which accelerates stand development. TIPSY retrieves supporting information (e.g., volume, diameter) from its internal yield tables, which are based on height. By design, the application of genetic gain increases yield by the target amount at an index age (approximating rotation age), and declines thereafter—the result of a diminishing percentage gain applied to an increasing volume.

To specify genetic gain in TIPSY, you must know the genetic worth of the seedlot, which can be obtained from the SPAR database at *www.for.gov.bc.ca/tip/spar/index.htm*

More information about how genetic gain is modeled in TIPSY is available from the Forest Productivity Section at MOF Research Branch. A test version of TIPSY (version 2.5 Alpha R), which can incorporate seedlot GW value in yield projections, is available as an executable file (wtip25r.exe) from the Ministry's FTP site: *www.for.gov.bc.ca/ftp/Branches/Research/external/outgoing/TIPSY/*

A new list server will be available soon for registration and downloading within the TIPSY Web site: *www.for.gov.bc.ca/research/gymodels/TIPSY/*

Incorporating Genetic Gain into Timber Supply Analysis

submitted by John Pollack and Ivan Listar

Nelson Forest Region is in the final stage of a three-stage pilot project to incorporate gains from using improved seed into Ministry of Forests (MOF) timber supply analyses. The purpose of the pilot is to determine how genetic gain affects wood flow in the Arrow, Golden, and Cranbrook timber supply areas (TSAs).

The unique species compositions, age-class structures, and constraint types associated with each TSA make it difficult to predict how wood flow will change with the inclusion of genetic gain. To date, TSAs have relied on rough estimates and sensitivity analyses to explore the potential effect of genetic gain on timber supply. Only recently have the tools to incorporate genetic gain into timber supply analysis more explicitly become available.

The project is funded by Forest Renewal BC through the Operational Tree Improvement Program (OTIP) and the Arrow Innovative Forestry Practices Agreement (IFPA). A committee with staff from Nelson Forest Region and districts, Timber Supply Branch, Research Branch, and Tree Improvement Branch provides a sounding board for technical decisions and expedites data requests. Timberline Forest Inventory Consultants Ltd. is carrying out the timber supply analysis.

The project involves:

- creating new analysis units and yield curves
- adjusting two model parameters (green-up age and minimum harvestable age) for managed stand species that are grown from improved seed
- incorporating this information into the data used in FSSIM[14], the MOF's timber supply model.

Stage 1: Incorporating Genetic Gain Information into FSSIM

The first stage of the project, started in summer 1999, involved developing a technical approach to bring genetic gain information into the timber supply analysis data for the Arrow TSA, as follows:

- Local field foresters estimated the species composition of regenerated stands for the different elevation bands included in the FSSIM data package for the TSA. This calculation made the regenerated stand types consistent with seed orchards and seed planning zones.
- Three changes representing stand-level effects were made to model the use of improved seed: adjusting volume tables to represent different levels of genetic gain, reducing the time to green-up, and reducing the age at which stands first become available for harvest.
- Genetic gain and seed production expectations from individual orchards were then compared with modeled planting requirements to determine if future orchard production was adequate for future planting demand.
- These stand-level and model adaptations were checked for consistency with the original IFPA base case.

Stage 2: Determining the Effect of Management Strategies on Timber Supply

Once the Steering Committee was satisfied with the results of Stage 1, a second stage was initiated. Stage 2 involved a series of sensitivity runs to determine the effects of various management strategies—for example, the development of a new orchard, or the deployment of scarce Class A seed into areas constrained by green-up, visual quality objectives, and other restrictions.

The pilot project will determine how genetic gain affects wood flow in three Nelson Region timber supply areas

This will improve the ministry's ability to determine the economic returns of tree improvement programs

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[14] FSSIM is the forest estate model used to evaluate TSA wood flow regimes. Its outputs help the chief forester set allowable annual cuts (AACs) for these management units.

Stage 3: Incorporating Genetic Gain into Golden and Cranbrook TSAs

The project will provide a method for evaluating how various tree improvement strategies influence timber supply

Stage 3, incorporating genetic gain into the timber supply analyses for Golden and Cranbrook TSAs, is still underway. The project team encountered some problems with data compatibility but expects the results of the Arrow and Golden TSAs to be ready for consideration by the project committee this summer (2000).

Application of Findings

By mid-summer 2000, this project will improve modeling of genetic gain in timber supply analysis and determining the economic returns of tree improvement programs.

It will make it possible to incorporate the MOF's tree improvement program activities in the Timber Supply Review (TSR), which culminates in the chief forester's determination of allowable annual cut (AAC) for a particular management unit.

Also, it will provide a method for evaluating how various tree improvement strategies, such as the selective deployment of improved seed or the establishment of new orchards, influence wood supply.

Species Plan Information Reporting System

submitted by Susan Zedel

Species plans contain breeding and seed production projections, plans for propagation and management, and analyses of current and proposed seed orchards

With funding from Forest Renewal BC, the Ministry of Forests Tree Improvement Branch is developing a Species Plan Information Reporting (SPIR) system. When complete, SPIR will be used to produce:

- seed inventory and seed use summary reports
- summary reports and charts to assist clients with seed planning (available vs. projected)
- seed needs analyses reports (supply vs. demand)
- species plan timeline reports
- Timber Supply Review reports based on selected seed planning units (SPUs).

Species plans are developed for the Seed Planning Units with the highest return

Tree Improvement Branch has developed a SPIR prototype with assistance from the Camosun College Computer Systems Technology Co-operative Education Program. A Web-based application of SPIR will be available in 2000/2001.

What Is a Seed Planning Unit?

Seed planning units (SPUs) are the new organizational units that form the basis for breeding and seed production planning. They are organized by species, seed planning zone, and elevation band. For example, the Pli BV Low is the SPU for interior lodgepole pine in the Bulkley Valley Seed Planning Zone at elevations below 1200 m. Based on Forest Genetics Council (FGC) strategic and business plans, SPUs are designed to facilitate program development and strategic planning for tree improvement.

What Is a Species Plan?

For each SPU, the potential economic return from a breeding and seed orchard program is determined. The SPUs are then ranked according to those indicating the highest return. FGC Species Committees develop species plans for those SPUs with the highest expected return. Species plans contain breeding and seed production projections, plans for propagation and management activities, and analyses of current and proposed seed orchards. Species plans also show the timeline for genetic improvement, including projected supply and demand for planting stock, and projected genetic gain.

For more information on SPIR, contact Ron Planden or Susan Zedel at MOF Tree Improvement Branch.

New Report Highlights Historical and Projected Seed Orchard Production

submitted by Jean Brouard

Background

In 1960, the first seed orchard in British Columbia was planted at Quinsam Heights, near Campbell River. Since then, more than 100 orchards of 14 tree species (or species complexes) have been established across the province. Advanced generation orchards have now replaced many first generation orchards. The Ministry of Forests (MOF) and forest companies share responsibility for orchards, with slightly fewer than half of current orchards being under MOF management.

Record keeping is complex, and each orchard has carefully tracked production data. In 1998, the Forest Genetics Council recognized the need for a comprehensive overview and production summary across all orchards. At the Council's request, and with funding from Forest Renewal BC, Isabella Point Forestry Ltd. and Yellow Point Propagation Ltd. were contracted to complete this review. The resulting report, *Seed Orchards in British Columbia: Historical and Projected Production*, assesses overall orchard capacity across the province.[15]

This report collates data from many different orchards established during different years on different sites. These orchards have also been managed at varying levels of intensity. While a production curve from one orchard is likely to be erratic and have limited predictive value, pooling the data from several orchards gives us a clearer picture of potential production rates.

Past and Predicted Production

The report summarizes information at several levels. Individual summary sheets for all active seed orchards in British Columbia include:

- establishment date
- predicted gain at establishment and on roguing
- number of parents represented
- number of trees in the orchard
- annual production over the past 10 years
- forecast production for the next 11 years.

Production figures give the number of plantable seedlings produced per orchard tree, grams of seed per tree, and total production (kg) for the orchard.

For each species, we grouped historical production from individual orchards to calculate mean production across all orchards as a function of tree age. These production figures were plotted to show the expected number of seedlings produced per orchard tree, as well as grams of seed and numbers of seed. Based on these historical production curves, we can predict future production per orchard tree at any given age. Thus, if we have an estimate of future seedling demand, we can calculate the number of orchard trees required to meet that projected demand.

The following figure shows the actual seedling production figures for three coastal Douglas-fir orchards (dashed lines), and predicted production for all currently active coastal Douglas-fir orchards (solid line). It demonstrates the difference between orchards, the large year-to-year variation within any one orchard, and the poor predictive value of any one orchard, as well as variation in age of first production (age 8 for orchard 116; age 7, orchard 120; and age 6, orchard 134).

The report provides a comprehensive overview and production summary of all ministry and industry seed orchards in British Columbia

Based on historical production curves for 14 commercial tree species, it is possible to calculate the number of orchard trees required to meet projected demand

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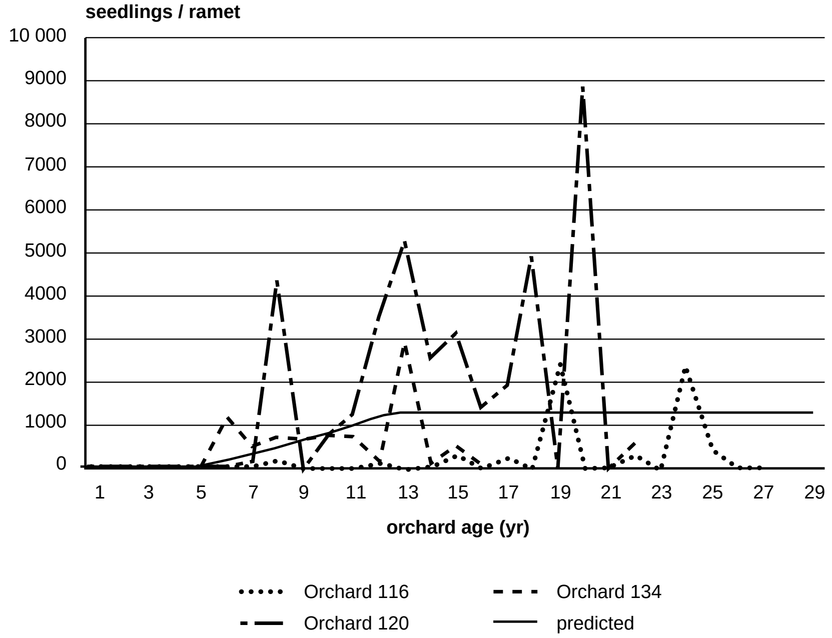
[15] Brouard, J., Pigott, D. and S. John. 2000. Seed orchards in British Columbia: historical and projected production. Produced for Forest Genetics Council of British Columbia, Victoria, B.C.

A sample orchard production curve for coastal Douglas-fir: actual production for three orchards and predicted production for all active orchards



For any one orchard, there is a large annual variation in production and poor predictive value

Age of first production varies greatly by orchard

Orchards Grouped by Seed Planning Unit

We grouped orchards by seed planning unit (SPU) within species. Each SPU is a unique combination of species, seed planning zone, and elevation. For example, Sx TO low is the SPU for interior spruce in the Thompson Okanagan Seed Planning Zone at elevations below 1300 m. Orchard grouping by SPU allows us to compare the projected demand with the combined projected supply from all active orchards producing seeds for that SPU. Each species section features a summary table that groups orchards by SPU and shows projected demand, predicted supply, and balance.

The report focuses on seed orchard production capacity

Annual production is driven by
- **age of orchard trees**
- **kilograms of seed collected**
- **number of potentially productive trees**

Trade-off between Production Capacity and Genetic Worth

The report focuses on production capacity—the number of seed or seedlings that can be expected in a given year. The genetic worth of the seedlots is detailed in the individual species breeding plans, and summarized in the genetic improvement strategy timelines of the provincial tree improvement plans.

As we acquire test information to provide breeding values for the better parents, existing orchards or trees within orchards will be progressively replaced by orchards or trees with higher breeding values. Part of the complexity in planning for tree improvement and tree seed supply stems from the time lags inherent in tree breeding, progeny testing, orchard establishment, and improved tree seed production.

How Is Orchard Productivity Measured?

The driving variables for productivity in a particular year are:

- age of orchard trees, or the number of years since ramets[16] were established in their final orchard positions
- number of kilograms of seed collected for the whole orchard
- number of potentially productive trees in that year.

From these data, we can calculate seed produced per orchard tree. Standard MOF conversions translate grams of seed to numbers of seed, and numbers of seed to numbers of potential seedlings.

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[16] Ramets are offspring produced by grafting a cutting (scion) onto rootstock.

Assumptions and Simplifications

Orchard age

We have made simplifying assumptions where necessary. For example, it often takes several years to establish an orchard, but the year of first planting is used as the establishment year. A more accurate (if more complicated) method is to use a date based on mean ramet age. Advancing front orchards or orchards where regrafting of high breeding value parents takes place further complicate the calculation. Also, the replacement of failed grafts affects the average orchard age. Because true orchard age is so complex, we have only used multiple establishment years where orchard establishment occurred in discrete phases.

Determination of seed mass

Seed mass is easily measured by weighing. In theory, the appropriate measure of orchard seed production should be the amount in kilograms registered on the Seed Planning and Registry (SPAR) system; in practice, there are complications. Managers sometimes estimate seed production indirectly, by measuring the volume of cones collected (in hectolitres) and by applying a constant seed recovery factor (kilograms of seed per hectolitre of cones). This formula could potentially include seed that is lost in extraction or spilled in transit. Also, because some forest companies plant on both private and Crown land, SPAR figures may distort the picture of orchard production, as seed produced for private land use may not be registered on SPAR.

Production figures were supplied by the orchard managers. These numbers ideally represent actual volumes of seed produced, aggregated for all targeted end uses.

Number of trees contributing to seedlots

Where possible, the actual number of trees available to contribute to a seedlot was used to calculate per-ramet productivity figures. Thus, if a specialty seedlot targeting high elevation planting sites was produced, only ramets of appropriate parents were counted.

Simplifying assumptions were made about orchard age, seed mass, and the number of trees contributing to seedlots

The report is available from MOF Tree Improvement Branch

New MOF Publications

Propagation of Rooted Cuttings[17]

This report completes a 3-year project on the use of rooted cuttings as a means of bulking-up selected families of Sitka Spruce, western hemlock, and Douglas-fir for reforestation. It describes cultural techniques for growing stock plants and rooted cuttings in containers consistent with most operational seedling production in British Columbia. It concludes that one-year container cutting is technically feasible for Sitka spruce and western hemlock, but that plagiotropism problems precluded the production of one-year cuttings of Douglas-fir.

The report is available from MOF Tree Improvement Branch (250.387.8939) or *www.for.gov.bc.ca/hfd/pubs/docs/Wp/Wp46.htm*

UV-B Risk to B.C. Trees[18]

Before a 1987 ban on the manufacture of chlorofluorocarbons (CFCs), thousands of tonnes of CFCs entered the atmosphere from air conditioners and refrigerators. Each chlorine atom in CFCs can destroy many thousand ozone molecules. Earth's natural ozone layer in the upper atmosphere absorbs UV-B wavelengths emitted by the sun. Since life as we know it has evolved under very small levels of UV-B, recent increases in UV-B levels may have many effects. This report discusses changes in seedlings due to increased levels of UV-B. It concludes that genecology and silviculture choices can help to minimize the risk of UV-B damage to forest productivity.

The report is available from MOF Research Branch (250.952.4136) or *www.for.gov.bc.ca/research*

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[17] Wigmore, B. and J. Woods. 2000. Cultural procedures for propagation of rooted cuttings of Sitka spruce, western hemlock, and Douglas-fir in British Columbia. B.C. Min. of For. Working Paper 46.

[18] Binder, W. and S. L'Hirondelle. 1999. Ultraviolet-B risks to British Columbia trees. B.C. Min. of For. Forestry Division Services Branch. Extension Note EN35.

1999 Seed Orchard Crop Information

submitted by David Reid and Susan Zedel

The following tables summarize the 1999 cone crop for British Columbia's interior and coastal seed orchards as of March 27, 2000. Some figures are unknown, pending completion of seedlot testing at the Tree Seed Centre. The Ministry of Forests will publish an extension note with a final summary for all orchards in June 2000.

1999 Interior Seed Orchard Crop Summary

Spec.	Orch. no.	Agency	Seed planning zones	Seedlot	Genetic worth	Cone yield (hL)	Seed yield (kg)	Potential no. of seedlings* ('000s)
LW	333	MOF	EK, NEK	60718	G+03	58.8	44.09	3,371.9
LW	332	MOF	NE, NEK	60717	G+02	56.0	45.07	2,626.4
LW	**Total**					**114.8**	**89.2**	**5,998.3**
PLI	219	VSOC	BV, BVC, BVP	60270	G+10	23.3	2.96	222.3
PLI	228	MOF	BV, BVC, BVP	61045	G+06	13.9	6.19	616.2
PLI	223	MOF	CP, CPP, BVC	61047	G+06	5.8	2.54	262.9
PLI	307	MOF	NE, PGN, TON	60716	G+06	25.5	4.86	486.5
PLI	230	MOF	NS	60715	G+02	46.0	13.09	1,549.4
PLI	222	VSOC	PG, PGN, BVP, CPP	60271	G+08	7.0	0.70	62.3
PLI	203	MOF	PG, PGN, BVP, CPP	61046	G+02	18.1	7.16	759.4
PLI	310	Riverside	TO, TON	60141	G+11	9.6	2.41	202.5
PLI	308	PRT	TO, TON	60405	G+06	58.2	14.11	1,483.7
PLI	**Total**					**207.4**	**54.0**	**5,645.2**
PW	335	MOF	KQ	60719	G+02	11.1	5.48	78.0
PW	609	MOF	KQ	60289	……	57.2	29.73	……………
PW	**Total**					**68.3**	**35.2**	**78.0**
SX	304	MOF	NE, EK, NEK	60712	G+23	107.9	120.99	13,879.0
SX	301	MOF	NE, NEK, PGN, TON	60291	G+05	14.2	16.91	2,193.2
SX	302	MOF	NE, NEK, PGN, TON	60292	G+05	15.8	16.97	2,415.9
SX	305	MOF	NE, NEK, PGN, TON	60713	G+05	23.6	20.63	2,795.6
SX	306	MOF	NE, NEK, PGN, TON	60714	G+03	22.2	21.03	2,347.9
SX	214	VSOC	PG, PGN, BVP	60272	G+21	11.4	1.47	187.6
SX	209	MOF	PG, PGN, BVP	60711	G+26	12.7	9.52	1,177.4
SX	206	MOF	PG, PGN, BVP	60290	……	13.8	17.60	3,046.4
SX	303	Riverside	TO, TON	60148	G+09	35.8	19.72	2,199.3
SX	303	Riverside	TO, TON	60149	G+08	24.6	14.81	2,162.5
SX	303	Riverside	TO, TON	60150	G+15	0.6	0.15	23.3
SX	**Total**					**282.60**	**259.8**	**32,428.1**

1999 Coastal Seed Orchard Crop Summary

Spec.	Orch. no.	Agency	Seed planning zones	Seedlot	Genetic worth	Cone yield (hL)	Seed yield (kg)	Potential no. of seedlings* ('000s)
BA	129	TFL	M	61118	G+02	2.0	……	……………
BA	**Total**					**2.0**	……	……………
CW	155	WFP	M	60699	G+02	3.1	2.06	480.9
CW	155	WFP	M	61025	G+02	3.6	1.71	374.2
CW	155	WFP	M	61026	G+02	9.8	6.50	1,653.8
CW	155	WFP	M	61027	G+02	31.7	21.36	5,056.2
CW	128	WFP	M	61028	G+02	10.6	5.67	1,479.4
CW	128	WFP	M	61029	G+02	33.9	20.67	4,877.4
CW	139	Canfor	M	60267	G+02	2.3	……	……………
CW	139	Canfor	M	60268	G+02	1.0	……	……………
CW	**Total**					**98.0**	**58.0**	**13,921.9**
FDC	149	MOF	M	60580	G+06	75.3	46.68	1,849.0
FDC	134	TFL	M	60641	G+04	94.2	46.82	1,653.4
FDC	134	TFL	M, GL	60642	G+10	80.0	……	……………
FDC	154	TFL	M	60643	G+06	50.0	……	……………
FDC	154	TFL	M	60644	G+09	107.0	……	……………
FDC	166	WFP	M	61023	G+10	41.8	23.63	716.3
FDC	169	WFP	M	61024	G+05	5.1	2.21	86.8
FDC	116	Canfor	M	61059	G+02	77.0	38.25	1,073.9
FDC	996	Weyer	M	60660	G+05	184.4	56.07	1,903.7
FDC	996	Weyer	M	60663	G+04	109.0	32.89	1,096.1
FDC	146	MOF	SM	60678	G+02	12.4	4.43	142.1
FDC	996	Weyer	M	60661	……	159.2	……	……………
FDC	**Total**					**836.2**	**251.0**	**8,521.3**
HW	143	MOF	M	60581	G+02	15.8	12.49	1,970.2
HW	133	Canfor	M	61007	G+16	3.9	2.66	……………
HW	127	WFP	M	61030	G+02	6.6	5.96	1,236.9
HW	126	WFP	M	61031	G+08	3.5	3.64	755.4
HW	126	WFP	M	61032	G+05	5.0	4.86	933.6
HW	**Total**					**34.8**	**29.6**	**4,896.1**
PW	175	MOF	GL, M, SM	60670	……	6.6	2.80	……………
PW	**Total**					**6.6**	**2.8**	……………
SX	131	MOF	SM	60677	G+02	56.0	24.79	2,681.1
SX	**Total**					**56.0**	**24.8**	**2,681.1**

* Potential no. of seedlings is calculated using the 1999 Ministry of Forests Sowing Guidelines.
Note: Species totals are incomplete where data for some seedlots is unavailable.

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