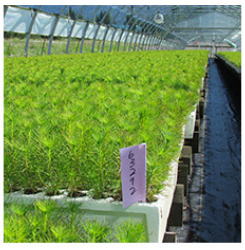
FGC Forest Genetics Council of British Columbia

Annual Report 2013/14



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Cover graphic: lodgepole pine pollen buds shedding

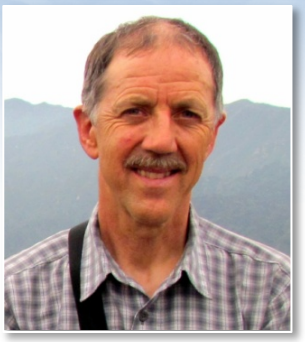
Pollen production and distribution is an important part of seed orchard management. Pollen represents the male component of the orchard, and the pollination of emerging female cones (megasporangiate strobili) is necessary for seed production. Orchard pollen is sometimes supplemented by spraying collected and dried pollen onto receptive female cones (supplemental mass pollination).

Orchard managers monitor pollen production and timing. Most orchards in BC are placed in geographic areas that are outside the natural species range, such as the north Okanagan valley, as this limits the risk of pollination from non-orchard sources. Such contaminant pollination has no genetic gain and may risk introducing genes from a different seed zone. Pollen contamination between adjacent orchards of the same species is also a concern to orchard managers. This is controlled by the careful placement of orchards so that orchards producing seed for different and incompatible seed zones are well separated.

(photos Tolko Ltd., D. Gaudet, J. Woods)

Overview and acknowledgements

JACK WOODS,
Program Manager,
Forest Genetics
Council of BC



This, the 13th consecutive FGC Annual Report, presents 2013/14 provincial-level performance indicators and financial summaries for the cooperative forest genetic resource management program. Further details are available in the FGC Business Plan for 2013/14, and the Tree Improvement Program Projects Report for 2013/14.

During the year Council-owned SelectSeed Ltd. reached a milestone by generating a profit on seed sales after orchard contract costs and after the costs of providing management services to Council. This met a business-plan objective, set in 2002, to generate net positive cash flow by 2013/14. More importantly, this success frees up funds for other FGC objectives. Staff in SelectSeed's partner companies are recognized and thanked for their work towards achieving this important milestone.

During the 2014 sowing year, a total of 265 million seedlings were sown. Seed for 165 million of these came from orchards. This is the largest annual amount of Class A seed sown in British Columbia. With this success, however, comes an additional challenge. Several moderate to poor seed production years in provincial orchards have resulted in a draw-down of Class A seed inventories. Also, better seed production from orchards, particularly lodgepole pine, is a familiar goal that all orchard managers are working to achieve.

Many people contribute to the success of this important provincial program, including, of course, orchard managers and tree breeding staff. Contributions also came from stakeholders working for companies and the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) who provide important support in many ways, including advice, encouragement, and advocacy. The unsung heroes of this success are the many people doing the routine work in seed orchards and the field work in progeny and genecology trials. Also making important contributions are university researchers and graduate students. I would like to thank and recognize all of these people for their work that has allowed us to reach the very significant milestones outlined in this report. In particular, I would like to thank Coastal Technical Advisory Committee (TAC) chair, Annette van Niejenhuis, Stephen Joyce for chairing both the Interior TAC and the Pest Management TAC, Genetic Conservation TAC chair Dave Kolotelo and his replacement Dr. Pia Smets, Extension TAC chair Diane Douglas, Seed Transfer TAC chair, Lee Charleson, and Decision Support TAC chair, Guy Burdikin. Also thanked for their ongoing support and guidance are Assistant Deputy Ministers Tom Ethier and Dave Peterson.

(photos B. Barber, R. Hansinger, D. Pigott, P. Smets, J. Woods)

Dave Peterson
Chief Forester
Assistant Deputy Minister
Tenures, Competitiveness
and Innovation

and

Tom Ethier
Assistant Deputy Minister
Resource Stewardship

BC Ministry of Forests
Lands and Natural
Resource Operations

Message from the Ministry of Forests Lands and Natural Resource Operations

We would like to congratulate the Forest Genetics Council of BC (FGC) for completing their 13th consecutive annual business plan and report. The investments the provincial government and forest sector direct to tree improvement continue to yield positive returns. The use of select seed accounts for over 50% of the ministry's annual service plan performance measure for timber-supply gains attributed to incremental silviculture investments. FGC's program is therefore considered one of the core elements of the Land Base Investment Strategy (LBIS).

We are also pleased to note that Council-owned SelectSeed Ltd. met its long-term objective of generating a profit by March 31st, 2014. This profit was realized after paying for FGC program management, communication, and organizational costs. Future SelectSeed income may serve as an alternate source to fund other cooperative activities. We are therefore supportive of FGC's current review examining potential future options for SelectSeed.

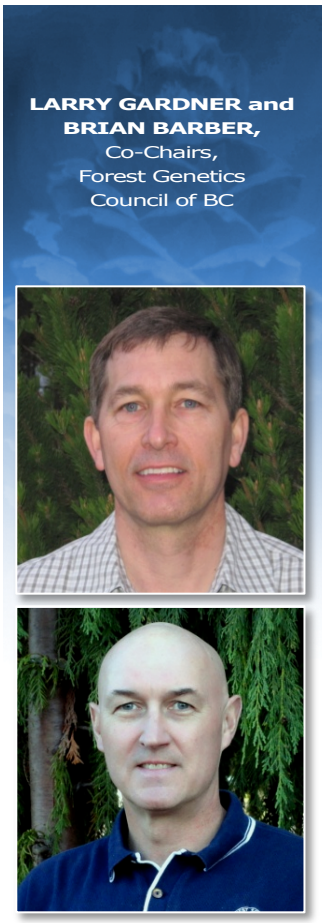
Credit to FGC and SelectSeed's success is attributed to the excellent collaboration between government and industry, and passion of staff. Both were clearly demonstrated during our recent (and separate) visits to the Okanagan Valley earlier this spring. We were impressed with the complexity of the tree breeding and seed orchard operations, level of cooperation, and the depth of knowledge of staff.

Council, its industry partners, and SelectSeed Ltd., made clear their concerns regarding succession issues within the ministry's professional and technical ranks to Minister Thomson and ourselves this past year. We acknowledge these staff are the custodians of decades of experience in tree improvement and forest genetics research. Council will need to develop solutions around retaining and replacing this invaluable knowledge, while balancing other priorities.

In addition to demonstrating exemplary leadership, FGC remains an effective forum for soliciting stakeholder input and developing government policies and priorities. We are therefore confident that the revised objectives and targets FGC develops for its next 5-year Strategic Plan will be measureable and realistic.

In closing, we would like to thank members of the FGC, it's affiliated technical committees, and Jack Woods, FGC Program Manager and CEO SelectSeed, for their contributions and enthusiasm.

Message from Forest Genetics Council Co-Chairs



In the FGC Strategic Plan for the period 2009 to 2014, a key measurable objective originally set in 2002 was to achieve 75% use of select seed provincially by 2014. Although we fell somewhat short of this aggressive objective, we are very pleased that select seed sowing this year rose to just over 70% after a steady climb for over a decade (see Figure 2). This is the highest level achieved to date, and it was done in a year when provincial sowing requests exceeded 250 million seedlings; the highest level in 7 years. As we complete a new 5-year strategic plan during the ensuing year, we will revisit these objectives in consideration of present and emerging challenges.

The most pressing technical challenges for this cooperative provincial program continue to be lodgepole pine seed production in orchards, adjustments to seed transfer standards under climate change, and reconciling seed orchard size and production capacities so that adequate high-gain seed continues to meet operational needs under new seed transfer standards. This latter challenge requires the synthesis of a great deal of information, including some "crystal ball" forecasting due to uncertainties regarding future harvest and seed demand as well as future seed zone ranges that are not clearly known at this time.

As we enter the post-MPB (mountain pine beetle) period, harvest levels are dropping in some central interior management units. In addition to the significant employment and economic issues, we are challenged to maintain a steady flow of select seed while at the same time supporting orchard size adjustments that will allow all operators fair market access and will avoid significant business disruption for suppliers. It is the role of Council to facilitate this discussion and to ensure that fair principles are applied as difficult decisions are made. Because of the long-term nature of the seed orchard business, it is in the interest of all players to work together for enduring solutions.

During the past year Council met quarterly, including a very enjoyable field trip to the Kettle River seed orchard site in the southern interior (photo page 15). This SelectSeed-contracted site has had good success with lodgepole pine seed production and is a good example of how SelectSeed has facilitated the participation of small, private operators in a low-cost and effective business model. Also in 2013, UBC, FLNRO, and SelectSeed Ltd. hosted a joint meeting of the Canadian Forest Genetics Association, Western Forest Genetics association, and IUFRO working groups. Delegates attended from 21 countries. We thank and congratulate the organizing committee for hosting this world-class event.

We would like to thank Dan Peterson for serving on FGC as FLNRO's Operations Representative for the past 3 years. We would also like to thank Dave Kolotelo and Jim Corrigan for their many contributions as chairs of the Genetic Conservation and Pest Management TACs, respectively. In closing we encourage readers of this annual report to also review the 2013/14 FGC Tree Improvement Program Project Report for more detail about FGC projects and people.

The FGC Annual Report presents provincial-level performance indicators for genetic resource management.

1.0 Introduction

This Annual Report presents provincial-level performance indicators outlined in the FGC Strategic Plan for 2009 to 2014. It also summarizes outcomes from projects funded through the Land Based Investment Strategy (LBIS) Tree Improvement Program. These projects are outlined in the Forest Genetics Council of BC (FGC) Business Plan for 2013/14. Performance indicators reported here represent results from both LBIS investments and the investment of cooperators.

1.1 Tree improvement and forest genetic resource management in British Columbia

Tree improvement and forest genetic resource management (GRM) includes increasing value through tree breeding and seed production, conservation of the genetic diversity of indigenous forest tree species, and enhancing forest resilience through scientifically-based seed transfer standards and the maintenance of genetic diversity. Support activities including research, extension, and records management also advance provincial GRM initiatives.

1.2 About the Forest Genetics Council of British Columbia

The FGC represents stakeholders in the management and conservation of the genetic resource of indigenous tree species.

The FGC is a multi-stakeholder group representing government agencies (Ministry of Forests Lands and Natural Resource Operations - FLNRO), the forest industry, universities, the Canadian Forest Service, and smaller forest-sector companies. The mandate of the FGC is to champion forest GRM, to oversee strategic and business planning for a cooperative provincial GRM program, and to advise the provincial Chief Forester and the Assistant Deputy Minister Resource Stewardship on GRM policies.

The FGC leads program development and business planning for provincial investments through the LBIS, and seeks efficiencies for all investments, including those by industry and university cooperators.

1.3 FGC vision and objectives

Council set the following vision statement and objectives in its five-year Strategic Plan (2009-2014), and annually develops a Business Plan outlining activities to meet these objectives.[1]

Vision

BC's forest genetic resources are diverse, resilient, and managed to provide multiple values for the benefit of present and future generations.

Objectives

- *Increase the average volume gain of select seed used for Crown land reforestation to 20% by the year 2020*
- *Increase select seed use to 75% of the provincial total sown by 2014*
- *Adequately conserve the genetic diversity of key populations of all forest tree species native to BC by 2015, through a combination of in situ, ex situ, and inter situ conservation*
- *By 2020, high-quality genecology research information will guide operationally efficient climate-based seed transfer policy and practice for all trees planted in BC*
- *Coordinate stakeholder activities and secure the resources needed to meet Business Plan priorities*
- *Monitor and report progress in genetic resource management activities*

Retirements

Tim Crowder

Seed orchard manager with the Ministry of Forests from 1979 to 1986 and with TimberWest Forests Ltd. from 1986 to 2014. Coastal Technical Advisory committee member from 1998 to 2014.

Giselle Phillips

Forest Genetics Technician with the FLNRO at the Kalamalka Forestry Center from 1978 to 2014.

Ev Taylor

Receptionist and clerk at the FLNRO Kalamalka Forestry Center from 1992 to 2014.

[1] For more information on the Forest Genetics Council, see *http://www.fgcouncil.ca.*

2.0 Budget and Expenditures

Land Based Investment Strategy Tree Improvement Program allocations and expenditures for the 2013/14 fiscal year are shown in Table 1. The table does not include in-kind costs, staff salaries, and other substantial inputs by industry, FLNRO, and university cooperators that contribute to the success of GRM activities in BC.

Table 1
Summary of Land Based Investment Strategy Tree Improvement Program budgets and expenditures for the period April 1, 2013 through March 31, 2014 ($ x 1000).

Subprogram	Budget ($)	Expenditures ($)
Genetic Conservation	252	260
Tree Breeding	1,265	1,064
Operational Tree Improvement Program (OTIP)	524	504
Extension and Communication	18	5
Cone and Seed Pest Management	125	121
Genecology and Seed Transfer	387	325
Genetic Resource Decision Support	65	65
Applied Tree Improvement and Biotechnology	182	182
Administration	40	22
Total	**2,858**	**2,548**
SelectSeed Ltd. orchards and FGC program management	0	0*

*SelectSeed provided program management services and expenses for communications (website, publications), meetings, research, and consulting on behalf of the FGC.

Overall spending was about 10% below budget due primarily to some projects not proceeding as planned or to projects being less expensive than expected. Non-allocated funds remained with FLNRO and were either re-allocated within the LBIS program or returned to provincial general revenue. Noteworthy is the absence of LBIS funds allocated to SelectSeed Ltd., the company wholly owned by the FGC. During the year, SelectSeed Ltd. provided management services, research, and consulting funds to the overall program totaling $188,240. These funds were derived from revenues on the sale of seed that exceeded SelectSeed Ltd. orchard contract costs, and are incremental to the LBIS funding listed here.

Under-spending in the Tree Breeding subprogram is largely due to lack of staff capacity to manage contracts for the large number of field sites. OTIP spending was close to planned, as most orchard projects were completed despite a low cone-crop year. No significant reallocations occurred between subprograms during the year.

3.0 Performance Indicators

Progress towards objectives set out in the FGC Strategic Plan for the period 2009-2014 (see section 1.3) are measured and reported annually. Two of these objectives are to increase the average genetic worth (GWg[2]) of Class A select seed to 20% and to increase select seed[3] use to 75%. Province-wide performance on these objectives has been measured and reported since 2000 and is shown below.

3.1 Increase seedlot genetic worth

Objective

Increase the average volume gain of select seed used for Crown land reforestation to 20% by the year 2020.

Performance

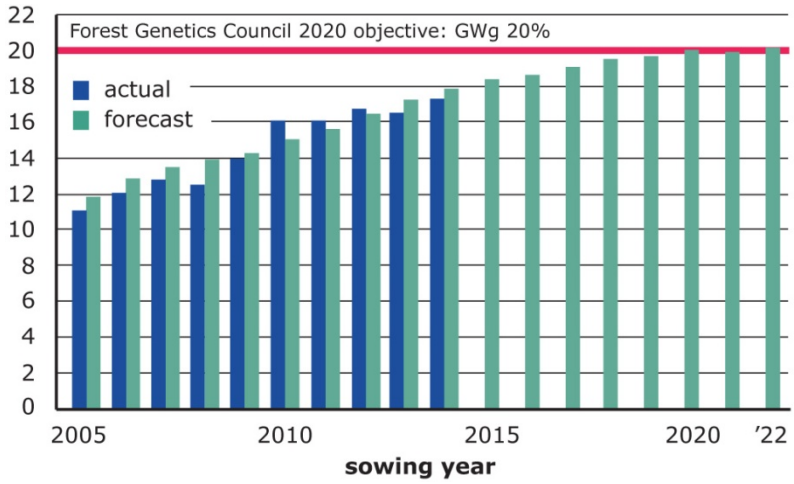


Figure 1
Actual and forecast annual average genetic worth for stem-volume growth (GWg) of select seed sown in BC.

The average GWg rose to 17.0% in the 2014 sowing year (16.5% in 2013), on a forecast of 17.8% (Figure 1). The rise from the previous year is primarily due to a larger proportion of higher-gain lodgepole pine being used and to more sowing of high-gain interior Douglas-fir and western larch. These gains were partially offset by a lower average GWg across all spruce seedlots sown (GWg of 19 in 2014 vs. 21 in 2013). This reduction for spruce reflects several years of poor seed production depleted high-gain seed inventories, resulting

[2] Genetic worth is a measure of rotation-age gain in a specific trait, relative to non-selected wild seed. Genetic worth for growth (GWg) is a measure of stand-based gains in wood volume expressed as a percentage.

[3] Select seed includes Class A seed from seed orchards and Class B+ seed from natural stands that have been identified, through field-based provenance trials, for superior growth performance.

in the use of lower-gain seedlots held in storage. Orchard upgrades, supported in part by the OTIP subprogram and using material identified in provincial breeding programs, continue to support genetic gain increases.

3.2 Increase select seed use

Objective

Increase select seed use to 75% of the provincial total sown by 2014.

Performance

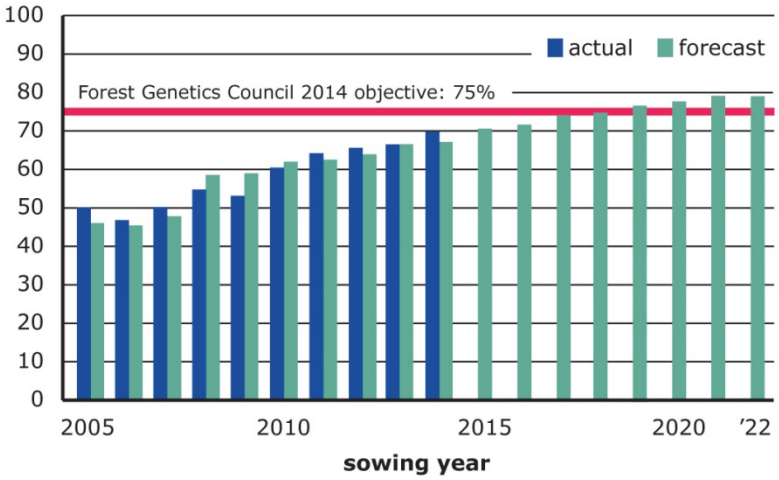


Figure 2
Actual and species-plan forecasts of select-seed use as a percentage of total provincial seed use, by year.

Select seed use as a percentage of total provincial sowing jumped to 70.2% in the 2014 sowing year from 66.4% the previous year (Figure 2). This increase is above the forecast level despite a rise in provincial seedling orders to 265 million from 242 million the previous year. Although this level of select-seed sowing represented a new high of 186 million, the FGC Strategic Plan objective of 75% by 2014 was not met. Council is currently reviewing objectives as it renews it's 5-year Strategic plan for the period 2015 to 2019.

The 2014 sowing year resulted in the highest ever use of Class A seed, at 165 million (Figure 3). Most of the rise in Class A seed use is due to an increase in interior spruce sowing, a species for which substantial inventories of select seed are available. Seed from superior provenance sources (Class B+), primarily lodgepole pine, also rose to 20.9 million from 17.8 million in 2013.

Class A seed use for western larch, coastal Douglas-fir, western redcedar (coast), western white pine, Sitka spruce, and western hemlock was high due to generally adequate orchard seed supplies. Orchard seed use for interior Douglas-fir continues to rise as orchards mature. Lodgepole pine Class A seed use remains at about the same level (37 million) as orchards continue to struggle with low levels of filled seed production on some sites (Figure 4).

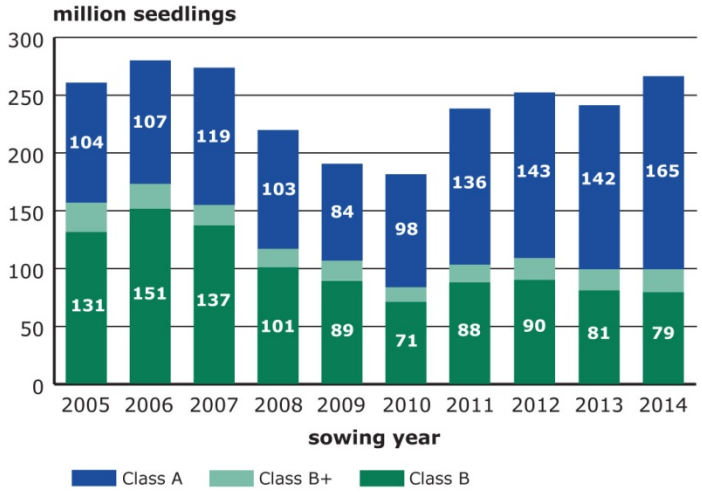


Figure 3
Provincial sowing of orchard (Class A), wild-stand (Class B), and superior provenance seed (Class B+) from 2003 to 2013.

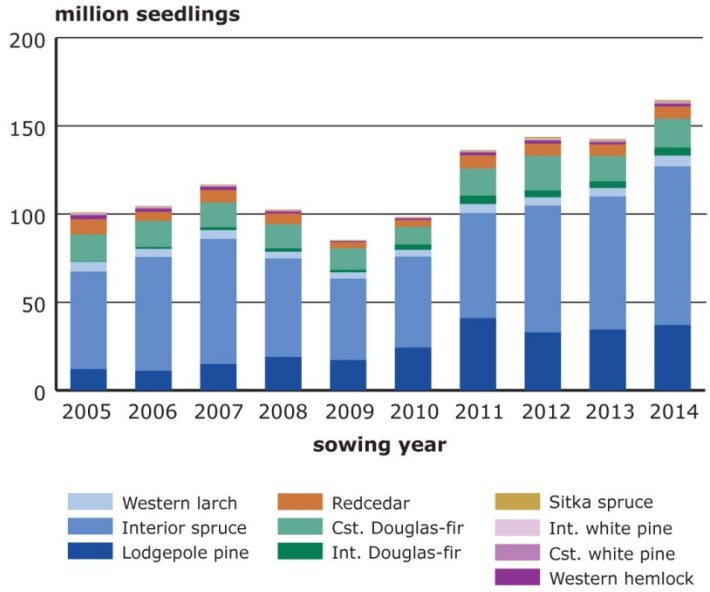


Figure 4
Provincial sowing of orchard seed (Class A) by species from 2003 to 2013.

Class A western redcedar seedlings ready for lifting and cold storage at the Western Forest Products Saanich Forestry Centre.
The Centre celebrated their 50th anniversary in 2014.

(photos J. Woods)

Feature:

Western larch: a tree improvement success story

The western larch tree breeding and seed orchard program in southeastern BC is one of the most successful in the world. Although western larch is a relatively minor reforestation species in BC, accounting for about 6 million of 250 million trees planted annually, it is highly productive and locally important to the economy and environment of southeastern BC.

Started in 1987, the western larch program benefitted from the experience and knowledge gained from programs already underway in BC. FLNRO scientist, Barry Jaquish, implemented a simple but effective strategy of selection and progeny testing that capitalized on the silvics of the species. Starting with open-pollinated seed collected from over 600 parent trees selected in naturally-occurring forests in the East and West Kootenay areas, over 100,000 seedlings were established in field-based progeny trials throughout the region. Western larch, an early-seral species, grew quickly in these tests and exhibited large levels of genetic variation in growth rate and wood quality. These trials provided the data needed to select parent trees with characteristics desirable for reforestation and timber production.

Concurrent with the selection of parent trees in natural stands, grafts were made for seed orchard development in 1990 at the FLNRO Kalamalka Forestry Centre near Vernon. Western larch at this site proved to be a prolific cone and seed producer, and within just over a decade most of the western larch seed used in reforestation was derived from orchard seed.

As progeny tests matured, they provided high quality data on the performance of offspring from the selected parents. This allowed estimates of parental breeding values and provided the opportunity to remove orchard trees with less desirable breeding values, boosting the average breeding value for growth traits of the remaining trees to over 25%.

Subsequent research in realized-gain trials has verified the gains expected from progeny test selections. Matings are now underway among the better parent trees to develop a second-generation population for field-testing and the subsequent selection of parent trees with higher levels of gain. In seed orchards, the replacement of inferior trees with higher-breeding-value trees continues. The success of this program is attributed to a fortunate combination of species biology and silvics, good seed production in the north Okanagan, high levels of genetic diversity, and an effective and well-implemented strategy by FLNRO staff.

Left - Western larch stand in the Kettle Valley area *(photo J. Woods)*; Top right - Harvesting cones in a western larch orchard *(photo C. Walsh)*; Bottom right - Barry Jaquish in a young western larch realized gain trial near Burton – elite on right, wild stand control on left *(photo V. Ashley)*.

As the BC climate warms, the natural range of western larch is expected to expand northward. Field trials, established over 30 years ago in areas that are climatically similar but not in the natural range of the species, have been very successful. These trials, combined with results from western larch bioclimatic modeling, led to a recent change to the provincial *Chief Forester's Standards for Seed Use* that allows the limited use of western larch for reforestation in specific areas outside the species' natural range. There is every expectation that western larch will continue to become a larger and more important component of the provincial timber supply, with the associated jobs and economic activity. These opportunities are only now possible because of the vision, skill, and effort of Barry Jaquish and others from FLNRO, industry, and the research community.

3.3 Adequately conserve genetic diversity

Objective

Adequately conserve the genetic diversity of key populations of all forest tree species native to BC by 2015, through a combination of *in situ*, *ex situ*, and *inter situ* conservation.

Performance

BC is fortunate to have a wealth of genetic diversity in the indigenous tree species found in provincial forests and parks. Genetic conservation work catalogues this diversity to help ensure it is maintained. This work includes inventory of natural populations (*in situ*), genetic tests such as progeny and provenance field trials (*inter situ*), the long-term storage of seed in a provincial seed bank at the Provincial Tree Seed Center, and clonebanks of selected trees (*ex situ*). A total of forty-one indigenous tree species are considered in scope for conservation work. Where the threat of a loss of genetic diversity occurs, projects are implemented to mitigate the problem or other agencies are informed.

In 2013/2014, 208 seedlots from seven species were added to the conservation seedbank maintained at the Provincial Tree Seed Center, bringing the total conservation seed bank to 9,054 seedlots representing 34 of the 41 indigenous tree species.

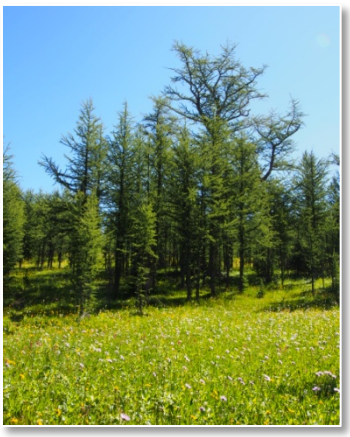
Whitebark pine is listed as endangered under the Canadian Species at Risk Act, due to the combined effects of white-pine blister rust, mountain pine beetle, and fire control that allows greater competion from other species. Under the general direction of the FGC and the Genetic Conservation Technical Advisory Committee, a plan was developed for the genetic selection of rust-resistant whitebark pine. Two projects to test blister-rust resistance levels of specific families were initiated. These include sowing for long-term field trials and rust innoculation screening of seedlings at the FLNRO Kalamalka Forestry Center. In addition, collections of seed from natural populations continues.

Projects undertaken by the UBC Center for Forest Conservation Genetics (CFCG) included a literature search on the adaptive genetic diversity of all BC tree species, the analysis of Garry oak trials to determine the geographic pattern of genetic diversity, climate modeling work in support of both conservation and climate-based seed transfer, and the development of an online provincial Big Tree Registry that will make information on the largest provincial trees of each species broadly accessible.

A project was also supported at the University of Victoria that will provide information on the geographic patterns of genetic diversity in sub-alpine larch. Sampling of 44 stands (1293 trees) throughout its range is complete. These will be examined to characterize the diversity exhibited by the species.

Whitebark pine cones on a higher-elevation tree growing in the west Chilcotin area. Seed collections for conservation or rust screening require caging of cones to prevent Clark's nutcrackers from harvesting the large seeds that form an important part of their diet. Heavy whitebark pine cone crops have also been associated with larger grizzly bear litter size, illustrating the importance of this species to wildlife.

(photo J. Woods)



Subalpine larch in the southern Rocky Mountain area of BC.

(photo S. Aitken)

Feature:

Provincial Tree Seed Center; 57 years of meeting clients needs

Opened in modest facilities in Duncan in 1957, the Provincial Tree Seed Center (TSC) has provided valuable services to nurseries, seed orchards, the forestry community, and the public through over five decades of change in forest resource management. Currently located in Surrey, this world-class facility is a model of client-focused public service.

The TSC fills two key roles in provincial reforestation. The first is to provide a full range of services related to quality-assured cone and seed processing, testing, storage, inventory management, and preparation of tree seed. The second is to protect the public interest by maintaining a seed registry and seed-use records that support the provincial *Chief Forester's Standards for Seed Use*[1] and help ensure that the quality of the provincial forest-tree genetic resource is maintained.

In BC, 200 to 260 million trees are planted annually on Crown lands. Most of this planting is done by forest companies (licensees) as part of their forest management obligations, and some is done through various provincial government reforestation programs. Seedlings are all produced in private nurseries working under contract to licensees or government. There are 22 reforestation species being grown for planting across several dozen seed zones, creating a complex mix of operational and silvicultural needs that results in a highly dynamic and diverse pattern of seed use. All of the seed for these many operations is prepared and shipped to nurseries at the request of clients, while meeting rigorous requirements that are tailored to each sowing request.

At the other end of the TSC business, cones are received from clients operating over 100 seed orchards in BC and from those making cone collections in wild stands. Nearly all cones harvested in the province go to the TSC for extraction, cleaning, testing, and seed storage. Carefully monitored freezers store over 78,800 kg of seed capable of producing 8.04 billion seedlings on behalf of clients. This dynamic seed bank is constantly changing as new seed collections are added and seed is removed for preparation and sowing in nurseries.

At the current planting rate of about 250 million trees per year, the TSC prepares seed for approximately 2,600 sowing requests per year. In addition, seed is extracted, cleaned, tested and stored for about 240 seedlots with cone volumes processed of about 4,400 hectoliters per year. Seed inventories are maintained at the TSC on behalf of all clients. These numbers, while impressive, do not speak to the biological complexity of managing and storing seed from many species and seed zones while also meeting the exacting sowing schedules of more than 30 nurseries that are growing seedlings to meet the equally exacting requirements of their clients.

Top - Seed extraction and cleaning equipment at the TSC Center. Bottom - TSC staff. *(photos D. Kolotelo)*

In addition to filling a key role in provincial planting programs, the TSC maintains, organizes and conducts testing of approximately 9,000 seedlots for genetic conservation purposes. This seedbank is a key component of the provincial genetic conservation program organized under the FGC. The TSC is a globally respected leader in seed processing and distribution management, and is one of only a few centers in the world that is leading operational research and development in this key area of reforestation.

Much appreciated by their clients and the Provincial Government, the TSC has received several recognition awards over the years. The best testament to the value of this organization, however, is the ongoing reliance and trust placed in it by their many clients.

[1] The *Chief Forester Standards for Seed Use* set out public land standards for the use of tree seed and the maintenance of the genetic quality of planted forests.

Feature:

Weevil damage in spruce: solutions through genetic selection

Dead leaders caused by the white pine weevil (*Pissodes strobi*) result in slowed growth, stem deformation, and delayed free-growing status in many areas planted to spruce in southern and of central BC. Genetic resistance now offers a solution in many parts of the province.

Adult weevils overwinter in the forest floor and climb to the top of young spruce trees in the spring where they feed, mate, and oviposit in the upper section of the previous year's leader. The eggs hatch within about 2 weeks and larvae feed in the young stem, killing the top 2 or 3 years of growth. Larvae pupate under the bark and emerge as adults in the late summer to feed and return to the forest floor to overwinter.

Genetic resistance to weevil attack was first observed in Sitka spruce provenance trials established in the late '70s by the BC Forest Service. This resistance was much higher in sources from the Qualicum area of eastern Vancouver Island and from specific areas of the Fraser Valley. Some trees within these sources showed more ability to resist or avoid weevil damage than other trees. Further research into this resistance revealed a number of mechanisms, including a large number of resin cells to produce pitch that interferes with the weevils ovipositing and feeding, sclerid cells (or stone cells) that are hard bodies which make feeding difficult and reduce the nutritive value, and suppression of weevil ovarian development.

The differences in resistance between seed sources and between trees within seed sources is genetically based, providing the opportunity to select individual trees with greater weevil resistance. Work by Cheng Ying and John King from the FLNRO, René Alfaro from the Canadian Forest Service, and others, led to the testing and selection of parent trees that passed on high levels of weevil resistance to their offspring. These trees were grafted into seed orchards and are now producing seed for operational planting.

Following the Sitka spruce experience, interior spruce testing was started by Gyula Kiss and Alvin Yanchuk from the FLNRO, with support from Alfaro, and has been carried on by Barry Jaquish and Ward Strong from the FLNRO. This work revealed the same resistance mechanisms observed in Sitka spruce, and studies were successfully implemented to test interior spruce families for resistance to weevil damage. This allowed the selection of resistant parent trees and the development of a seed orchard by Vernon Seed Orchard Company Ltd. that now produces resistant seed for the Prince George area.

Selection and breeding for genetic resistance to the weevil is done in a complex background of both host and pest patterns of genetic diversity. Complete resistance is not feasible; rather, seedlings from resistant orchards of both Sitka and interior spruce exhibit lower attack rates than seedlings grown from non-selected or wild seedlots. A weevil resistance rating (GWr) of 86 means that about 86% of the trees will avoid or repel attack in a given year. This increased resistance provides foresters with an option that can be used in combination with silvicultural techniques such as mixed species planting to increase plantation success and better secure future wood supply.

Right - Weevils mating on a spruce leader *(photo T. Sexton)*;
Left - Weevil damage on spruce *(photo W. Strong)*;
Bottom - Weevil larva in a spruce leader *(photo W. Strong)*.

Genomics research being led by Jöerg Bohlmann and Timothy Sexton at UBC, in collaboration with the FLNRO, is now leading to accelerated identification and selection of resistant parent trees through marker-aided selection.

3.4 Climate-based seed transfer

Objective

By 2020, high-quality genecology[4] research information will guide operationally efficient climate-based seed transfer policy and practice for all trees planted in BC.

Performance

Tree seed contains the genetic code that has been selected through millennia by climate, competition with other trees, and pests. The flow of seed and pollen between stands and geographic areas serves to reduce local adaptation. Unraveling the complex information in the genes of our native tree species is the challenge of the science of genecology.

(photo J. Woods)

Genetic diversity is structured by adaption to climate across broad geographic areas. Climate-based seed transfer (CBST) organizes seed-transfer policy for provincial planting using climatic patterns as the primary driver. This system allows changes in seed movement that recognize shifts in climate. Implementation of a CBST system requires information on the genetic diversity of reforestation species across their natural range and high-resolution climate modelling that can be used to predict the complex climatic patterns and how these are changing. The FGC-led program supports work in both areas.

Long-term field-based genecology trials are the primary source of information on patterns of genetic diversity for tree species. During the period of this report, maintenance and measurements were carried out on over 100 field-based genecology trials, including the Assisted Migration Adaptation Trial. Most field-based trials are managed by the FLNRO Tree Improvement Branch. In addition, substantial data analysis was undertaken to better understand how to interpret data to optimize the operational value of CBST policy.

At UBC, the AdapTree project, funded primarily by Genome Canada and supported by FLNRO LBIS funding, completed short-term phenotyping on over 200 natural stand seedlots of both lodgepole pine and spruce from across BC and Alberta. Large amounts of genomic data were generated with the sequencing of nearly 30,000 genes per species in hundreds of seedlings. Data analysis is underway and is beginning to reveal patterns that will support climate-based seed transfer. Work under AdapTree also investigated public and forest professional acceptance of a CBST system and found high levels of acceptance.

A CBST framework to guide provincial policy was further advanced this year. Working in conjunction with projects funded under the Genetic Resource Decision Support subprogram, online systems continue development towards a final CBST system for operational use. The objective is to implement a policy framework that integrates the best available science with a user-friendly online seed ordering and record-keeping system that can be readily updated with new information and with the minimum of disruption to operational seed use.

[4] Genecology is the study of the geographic distribution of genetic differences among populations.

3.5 Coordinate stakeholder activities

Objective

Coordinate stakeholder activities and secure the resources needed to meet Business Plan priorities.

Performance

During the period of this report, the FGC led completion of

- An activity plan and associated budget recommendations for the Land Based Investment Strategy Tree Improvement Program for 2014/15,
- A published Business Plan and full set of species plans for 2013/14,
- A published FGC Annual Report and Projects Report for 2012/13,
- Ongoing management of committee work and collaboration on issues,
- A comprehensive review of SelectSeed Ltd. activities.

Council met four times during the fiscal year, including a field trip to the Kettle River seed orchard operation run under contract to Council-owned SelectSeed Ltd. These meetings, in combination with subcommittee work done under the overall FGC structure, resulted in the efficient coordination of activities among a broad range of stakeholders, including the FLNRO, major licensees, smaller licensees, universities, the Canadian Forest Service, other provincial ministries, and non-licensee private firms. Council also provided direction to the SelectSeed Ltd. board of directors, oversaw SelectSeed operations and financial reporting and initiated consultations with the forest genetics community of practice and stakeholders in preparation for the development of a new five-year strategic plan.

Members of the FGC and seed orchard site owners at the Kettle River seed orchard operated under contract to SelectSeed Ltd. *(Photo J. Woods)*

3.6 Monitor and report progress

Objective

Monitor and report progress in genetic resource management activities.

Performance

This objective was met through the development and publication of a comprehensive Business Plan for 2013/14, including species plans that outline breeding programs, seed orchards, historic seed use and production, and other data relevant to an efficient multi-stakeholder provincial program. Performance indicators for objectives set out in the FGC Strategic Plan are reported in this document. Project level reporting is summarized in the Tree Improvement Project Report for 2013/14.

Table 2
Seed orchards in BC, summarized by site.

Site and owner[5]	Number of seed orchards	Total #of ramets established	Ramets under contract with SelectSeed Ltd.
Vernon Seed orchard Company Ltd. (including Quesnel orchards)	17	31,160	8,357
Kalamalka Seed orchards (FLNRO)	16	18,454	
Skimikin Seed Orchards (FLNRO)	15	18,699	
PRT Growing Services Ltd.	6	10,121	7,993
Kettle River Seed Orchards	2	7,730	7,730
TimberWest Forests Ltd.	7	5,587	
Tolko Ltd.	4	5,910	4,980
Sorrento Nurseries Ltd.	2	5,065	5,065
Western Forest Products Inc.	11	3,605	
Saanich Seed Orchards (FLNRO)	6	3,255	
Prince George Tree Improvement Stn. (FLNRO)	3	3,212	
Small private (2 sites)	5	1,867	
Canadian Forest Products Ltd.	1	700	
Total	95	115,365	34,125

Interior spruce seed orchard operated by Tolko Ltd. in partnership with SelectSeed Ltd. This orchard produces seed for higher elevations in the Thompson Okanagan seed zone.

(photo J. Woods)

[5] Excludes yellow cypress hedge orchards for rooted cutting production owned by Western Forest Products Inc. and the FLNRO, Cowichan Lake Research Station.

4.0 2013 Orchard Seed Crops

Cone and seed crops in 2013 were modest to low for all species due to a generally poor flowering year. This is the third year with poor interior spruce crops, a normally high producer (Table 3; Figure 5). Lodgepole pine orchards had acceptable seed set (filled seeds per cone) from some orchards, but seed-set issues continue to impact production.

Overall, the total harvest of 498 kilograms of seed is sufficient to grow approximately 40 million seedlings, with lodgepole pine and coastal Douglas-fir making up most of this production. Lodgepole pine and interior Douglas-fir continue to fall below expectations for seed production, limiting the use of high-genetic-worth seed in some seed zones.

Table 3
Summary of 2013 seed crops from provincial orchards.

Species	Seed produced (kg)	Seedling equivalents (million)
Interior spruce	47	4.5
Lodgepole pine	175	23.6
Western larch	7	0.6
Interior Douglas-fir	103	3.8
White pine	17	0.3
Western redcedar	8	1.9
Sitka spruce	0	0
Coastal Douglas-fir	126	5.3
Western hemlock	0.3	0.1
Ponderosa pine	15	0.1
Total	498	40.2

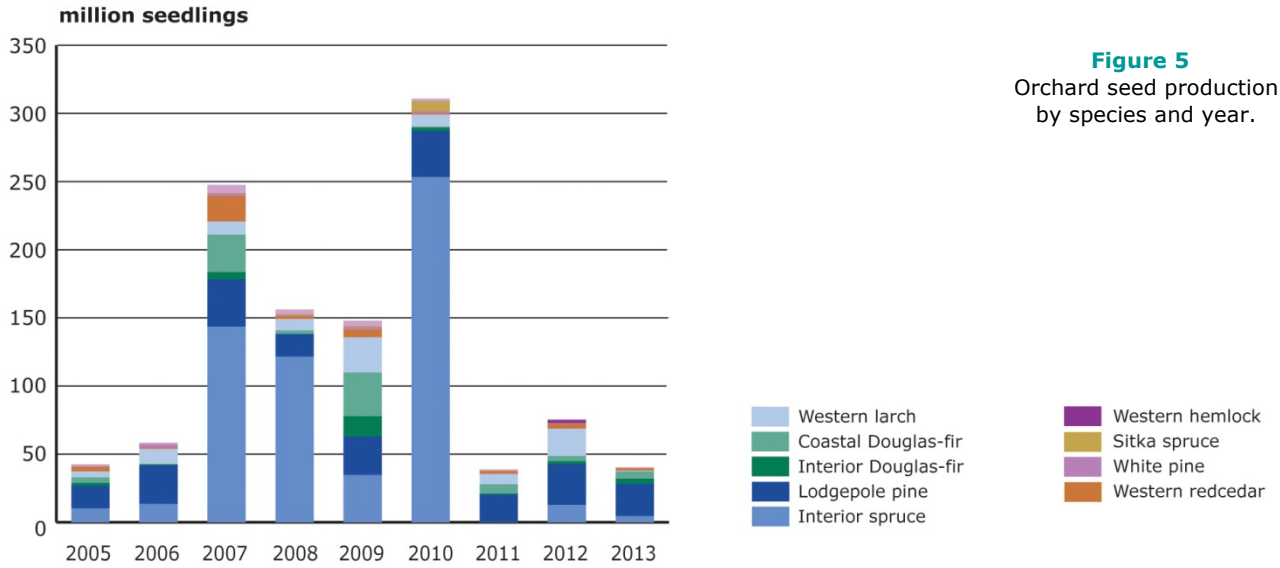


Figure 5
Orchard seed production by species and year.