Tree Seed Working Group News Bulletin

Canadian Forest Genetics Association
l'Association canadienne de génétique forestière

65
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GENE CONSERVATION

Featured in this Issue:

Banner photo by Jack Woods: whitebark pine (*Pinus albicaulis*) on Perkins Peak, British Columbia.

Armchair Report #65

The News Bulletin has reached the 65th edition, and in terms of anniversaries it is recognized by the blue sapphire. Thank you to everyone that contributed to this gem of an edition; your continued contributions will have us going platinum in a couple of years. The general theme of this News Bulletin is genetic conservation and seeds are uniquely suited to play a key role in this endeavour. Most of our seeds are orthodox and can be stored for long periods of time. During this last seedling production season in BC, an interior Douglas-fir seedlot collected in 1964 was still being used to produce seedlings. It originally had a germination of 85% and although it had a few small increases over time, the recent 2013 germination test was 84%–that's incredible! Not all seedlots or species store quite so well, but we are fortunate to have excellent inherent seed longevity capabilities with most of our major reforestation species. Investments and advancements in collection, processing, storage and testing practices (eRH) will only increase seed longevity when compared to our older collections. The other efficiency provided by seeds is their relatively small size. A handful of spruce seed (44 grams) can represent over 20,000 unique genotypes, making seed storage a very efficient means of genetic conservation. The classical saying of Aldo Leopold comes to mind in considering our seed banks, "To keep every cog and wheel is the first precaution of intelligent tinkering".

Regarding genetic conservation, the last News Bulletin featured an article and poster regarding butternut (*Juglans cinerea*) and genetic conservation efforts with that endangered species. This edition moves out west with a few articles related to whitebark pine (*Pinus albicaulis*). The other endangered tree species in Canada are *Betula lenta*, *Cornus florida*, *Magnolia acuminata* and *Morus rubra*, well represented by a submission from Sean Fox of the University of Guelph Arboretum. In terms of other genetic conservation web links, interviews, articles

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We welcome any comments, suggestions and article submissions and will solicit active, subscribing members on occasion for content. Submissions may be edited for length. Authors are responsible for the accuracy of the material in their respective articles. The mention of commercial products in this publication is solely for the information of the reader, and endorsement is not intended by the Canadian Forest Genetics Association (CFGA).

All issues of the News Bulletin are freely available here.

The Tree Seed Working Group News Bulletin is published biennially. The Group's principle aim is to promote tree seed science and technology through

1. seed research from bud initiation to seed utilization
2. identification of seed problems relating to tree improvement and forest management
3. the exchange of information on seed-related problems, and by
4. advising on implementation practices.

and videos we've included a dedicated section in this edition to allow you to explore the topic more thoroughly. Let us know which ones we've missed.

Genetic conservation has been considered one of the three pillars of our tree improvement program in BC (resilience and value are the other two) and we continue to invest in this activity. Our third genetic conservation strategic plan was released last year and provides the foundation for our program: http://www.fgcouncil.bc.ca/GCTAC-Strategic-Plan-2015-2020-28Nov2016-Final.pdf

In BC, we have had the benefit of being able to ask questions related to climatic variables with the ClimateBC program created at the Centre for Forest Conservation Genetics (CFCG) at UBC. The program has been championed by Dr. Tongli Wang who expanded the range to Western North America and then earlier this year a Climate North America program was made available. With only latitude and longitude information, this software allows one to very easily calculate and download climate variables, use a variety of climate time intervals (even to individual years), predict the future climate based on many of the current general circulation models and map outputs from these analyses. It's a great tool worth looking into further http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/. Another tool that may also be useful is the seedlot selection tool put together by Dr. Brad St. Clair https://seedlotselectiontool.org/sst/, which now includes climate data and climate change models for Eastern Canada as well.

The CFGA meeting occurred late June, and I've heard nothing but positive reviews. Enclosed in this edition is the Abstract of Dr, Fiona Hay, Keynote Speaker on seeds, who spoke on "What do we know about the genetics of seed longevity". Look for an extended coverage of her talk in the upcoming proceedings. There has been no confirmation of the next meeting site yet. I heard a large part of the Business Meeting was a discussion on the frequency and the possibility of some long-term scheduling with our two main USA counterpart groups (WFGA and SFTIC). It is my understanding that CFGA members will be receiving a survey or poll regarding this matter. An interesting initiative by the International Union for Conservation of Nature (IUCN) is the proposal for the establishment of a Seed Conservation Specialist Group to create a global directory for seed banking facilities, expertise and resources. You can find out more information at https://www.bgci.org/plant-conservation/scsg including the survey on how to add your facility to the directory before September 30, 2017.

I'd like to bring to your attention a wonderful seeds book that is available as a free PDF courtesy of the Taiwan Forestry Research Institute. Ben Wang and Ching-Te Chien put together a very well organized, clear and concise presentation of material relevant to the collection storage and use of "Seeds of the Economically Important Trees in Taiwan". It is available as a PDF in English here: https://www.tfri.gov.tw/main/news.aspx?siteid=&ver=&usid=&mnuid=5201&modid=550&mode – just select the title, and you have the option to download a PDF or jpeg version – enjoy! That was to be Ben's swan song as he suffered a stroke this spring that left him unable to speak. Thank you to Steve D'eon and family for facilitating communication with Ben during his hospitalization. I'm extremely sorrowful to report that Ben passed away on July 21, 2017. Additional information and condolences can be found at this link: http://mdbfuneralhome.com/tribute/details/2049/Benjamin-Wang/photos.html#content-start. Ben was the first Chairman of our Tree Seed Working Group and continued to contribute to seed science and technology until his passing. I'll remember Ben's incredible experience and knowledge, his jovial nature and desire to improve our reforestation system through a better understanding of tree seeds. Ben's scientific and practical contributions are only shadowed by his kind and caring personality. My deepest condolences to his family and friends.

This past winter Michael Carlson was diagnosed with ALS. Some of you may know Michael as the BC lodgepole pine breeder, but his PhD actually was on conifer reproductive biology, and Michael continued a keen interest in this area as well as the many other areas to which Michael contributed. Michael worked for the BC government from 1982 to 2010 and continued after as an emeritus scientist. In 2013, Michael was awarded the Queen's Diamond Jubilee medal for his service. On July 12th, to honour Michael there was a tree planting ceremony (*Pinus ponderosa*, Mike's favourite) and a dedication of the Michael Carlson Memorial Garden at the Kalamalka Forestry Centre where Michael spent the BC part of his career. Attached is a photo of Michael at the ceremony with his loving progeny. You can contact Michael at Mike.Carlson@gov.bc.ca.

This past winter I also received an email from George Edwards indicating that he had suffered a stroke that left him paralyzed on his right side. George had continued his interest in tree seeds and in the last year was proposing changes to pure seed definitions for tree seeds to the International Seed Testing Association (ISTA) as discussed in News Bulletin No. 63. You can contact George at de4757@telus.net. George and Ben were original members of our Tree Seed Working Group with George being the first Editor of the News Bulletin. They have both contributed greatly to the current state of our knowledge regarding tree seed science and technology. Thank you both.

I hate to leave on such bad news, so I'll provide a comical link from Patrick von Aderkas https://www.thebeaverton.com/2017/05/bc-green-party-form-government-whichever-party-leader-brings-pinecones/ and retell a story Donna Palamarek (AB Tree Seed Centre) told me. Some of you may know that at 89, Ben Wang moved to a care facility, and someone had sent him some red pine seeds. It didn't take him long before he had the other care facility residents doing germination tests and planting out germinants! I'll also put out kudos to Cathy Cook who is familiar to all in the seed industry in BC. She recently met her personal goal of cultivating and registering 100 million trees for reforestation. Check out the inspirational video that captures the passion and enthusiasm we are familiar with: https://www.facebook.com/WFPPeople/videos/720173548161515/

All the best to everyone.

Dave Kolotelo
TSWG Chairperson

Benjamin Shin-Phin "Ben" Wang, 1927–2017.

Michael Carlson with his daughters at the Michael Carlson Memorial Garden tree planting ceremony, Kalamalka Forestry Centre, July 12, 2017.

Editor's Notes

This issue became an impressive cross-country update and was both a joy and challenge to pull together. I apologize for the delay in getting it out; summer has been busier than anticipated, and I might claim climate change had something to do with it. The gene conservation theme is timely. The synchronicity of events since News Bulletin No. 64–from global efforts to personal experiences–has emphasized great urgency to act when biological diversity and scientific research of it is at risk. I never met Ben Wang but had emailed him early March to follow up on storage potential of the hybrid *Acer* x*freemanii* seed. He answered the next day, eager to discuss his research and the News Bulletin. He was encouraging, enthusiastic and above all, grateful the News Bulletin was continuing after Dale Simpson's retirement. Ben even offered to write an article for this issue about natural repair mechanisms in tree seed induced by moist chilling, especially in non-dormant species such as black spruce (*Picea mariana*). He thought it important for nursery managers to know, particularly when aging seedlots of lower vigour are an operational concern. Since Ben could not complete his draft article, I encourage anyone interested to read Wang and Berjak's (2000) paper here: 10.1006/anbo.2000.1150.

On the larger stage, I was fortunate to attend the US National Native Seed Conference February 13–16, 2017 in Washington, D.C. (https://nativeseed.info/) on behalf of the Forest Gene Conservation Association (FGCA). Though not focused on commercially important forestry species, principles of gene conservation throughout the land reclamation process were heavily emphasized. I attended the US-launch meeting of the aforementioned IUCN Seed Conservation Specialist Group, which will serve a global role in facilitating expertise and best practices for collaborative seed conservation projects. It was wonderful to reconnect with Dr. Michael Way from the Millennium Seed Bank who taught me genetic sampling techniques and to hear Dr. Sean Hoban of the Morton Arboretum quantify efficiencies in genetic sampling for allelic diversity in *ex situ* collections (pdf here). I discussed seed transfer tools with Dr. Brad St. Clair and Vicky Erickson of the USFS and heard from many practitioners working with native seed across the US to forward their ambitious National Seed Strategy goals: https://www.fs.fed.us/wildflowers/Native_Plant_Materials/documents/SeedStrategy081215.pdf.

Days before the conference, I found the "Resolution on Ecological Connectivity, Adaptation to Climate Change, and Biodiversity Conservation" signed at the 40th Annual Conference of New England Governors and Eastern Canadian Premiers in August 2016: http://www.coneg.org/Data/Sites/1/media/40-3-ecological-connectivity-en.pdf. The issue of fragmented, privately owned landscapes is of greater concern in the eastern half than western half of North America. Political borders are and should be of no concern to gene flow in the role of adaptation; we need to collaborate with our neighbours more than ever.

Almost on que, Spring 2017 brought an abundance of flowering and developing tree seed crops to Southern Ontario after the seed dearth of 2016. As such, the FGCA has been busy this summer developing seed banking strategies with our Central Ontario forest managers, focusing on collectable white pine (*Pinus strobus*) and white spruce (*Picea glauca*) cone crops across almost all the Southern Ontario clonal seed orchards. We grafted ten additional healthy butternuts (*Juglans cinerea*) this spring to add to our putatively resistant *ex situ* archives. Long-time Certified Seed Collector (CSC) trainers Brian Swaile and Ron Thayer officially passed the torch to the new guard to lead tree seed collection efforts across Ontario. As Donnie McPhee will elaborate on, the FGCA continues to work on ash seed conservation ahead of the Emerald Ash Borer front. Stands we collected from in 2013 around the Toronto-Hamilton-Niagara area are now dead or have been cleared in the wake of development. We preserved a sample of those populations just in time.

And while the west is under siege from wildfires, the east is awash. Last year, Peterborough had the second driest growing season since 1891; this year it's the wettest on record. The week of July 31st–August 5th alone, my little town received 179 mm of rain, of which two pop-up storms, each lasting less than two hours, dropped 96 mm and 63 mm in our rain gauge. As I frantically sand-bagged a flooding greenhouse to protect newly potted seedlings, I was sincerely afraid that all the adaptation reports in the world won't truly prepare us for the"new normal". How do you plan your day around the increasing possibility of a 100-year drought and 100-year flood at the same time? Are we psychologically and socially prepared to change? Operationally, which technology, what infrastructure upgrades, which species or species mix are "best bets, no regrets"? Do we have enough seed, enough capacity to meet these growing demands? As

Dr. Tom Kaye, Executive Director of the Institute of Applied Ecology, emphasized in closing remarks at the Native Seed Conference, "Diversity begets diversity, and diversity is ecological stability". What has tolerated (or not) these two extreme years back-to-back is valuable information. When the seeds rain, knowledge pours.

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British Columbia Tree Seed Bank Summary

The purpose of the provincial tree seed bank is to help conserve the genetic diversity of British Columbia tree species through the storage of seed samples at sub-freezing temperatures (a form of ex-situ conservation). The goal is to maintain a representative seed sample of adequate size and across each tree species' ecological amplitude. These samples are stored in plastic bags within glass jars at –18°C and form a discrete entity from our operational seed inventory. The seed bank complements existing clone banks, genetic tests (other forms of ex-situ conservation) and the system of protected areas (*in situ* conservation) designed to conserve biodiversity. The reserves in the field are susceptible to, or selected upon, by a variety of challenges and evolutionary pressures including wildfire, pest outbreaks, and climate change. A comprehensive genetic conservation program will incorporate samples subject to (for potential selection) and samples removed from (to maximize diversity) these selective pressures. The seed bank provides us with an insurance policy for the genetic diversity of our tree species removed from these selection pressures. The seed bank samples may be useful for population regeneration in the event of catastrophic losses to parent populations, the capture of unique genes useful for breeding purposes or for species lacking genetic information, studies of genetic architecture and diversity.

Currently there are 42 trees species that have been identified as being in scope by the Forest Genetics Council (FGC) and the Genetic Conservation Technical Advisory Committee (GCTAC). Enclosed in the references is a web link to our current and third GCTAC Strategic Plan for Genetic Conservation of BC tree species. The question of what is a tree and "in scope" was vigorously debated and although consensus was a pipe dream, we decided to move forward with 42 tree species which are presented in Table 1. The term 'commercial' here is used to separate those species in which operational seedlot samples contribute to the seed bank and 'non-commercial' species in which specific collections have been commissioned to obtain seed samples. Some so-called 'non-commercial' BC species are major reforestation species in other jurisdictions;it is simply a convenient term and likely someone will be offended. In BC, some species are also treated separately as coastal and interior varieties, like *Pinus contorta* or with *Pseudotsuga menziesii* they even have separate, large scale breeding programs. Taxonomy is also complicated with *Picea glauca* and *P. engelmannii* where introgression has long been accepted and operationally this spruce complex is simply termed "interior spruce" in harvesting and reforestation activities. The species in Table 1 are the accepted botanical names, although operationally some "lumping and splitting" is conducted operationally to meet practical forestry needs.

In terms of how we sample each species' ecological amplitude, we utilize our biogeoclimatic ecosystem classification (BEC) system (https://www.for.gov.bc.ca/hre/becweb/) and a matrix indicating cells in which greater than 1% of the species range occurs in that BEC zone. The matrix originates from the 2009 Forest Tree Genetic Conservation Status Report 1 (Chourmouzis et al. 2009) and still provides the foundation to species presence. The species × BEC zone matrix allows us to evaluate current seed bank samples and prioritize investments. What constitutes a 'full' cell or adequate size is a loaded question, but for our commercial species, based on operational seedlot samples we have decided that each cell should be represented by a minimum of three seedlots with a minimum of 1,000 viable seeds. For the seedlot samples we have the benefit of germination information, making an estimate of viable seeds possible. For most of our species × BEC zone combinations for commercial species we have many more samples per zone than three and we embrace redundancy at every opportunity to ensure we have robust coverage of the genetic variation present. The seed bank story is a little more complicated, but I'm keeping it brief for the News Bulletin–for those interested in greater detail I will be producing a Seed Bank Management Plan for our facility–just let me know if you would like a copy when it is completed.

Table 1. The 42 British Columbia tree species considered in scope for ex-situ genetic conservation activities.

BC COMMERCIAL CONIFERS
Abies amabilis
Abies grandis
Abies lasiocarpa
Callitropsis nootkatensis
Larix occidentalis
Picea engelmannii
Picea glauca
Picea mariana
Picea sitchensis
Pinus banksiana
Pinus contorta
Pinus monticola
Pinus ponderosa
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla
Tsuga mertensiana
BC NON-COMMERCIAL CONIFERS
Juniperus maritima
Juniperus scopularum
Larix laricina
Larix lyallii
Pinus albicaulis
Pinus flexilis
Taxus brevifolia
BC COMMERCIAL BROADLEAVES
Alnus rubra
Betula papyrifera
BC NON-COMMERCIAL BROADLEAVES
Acer circinatum
Acer glabrum
Acer macrophyllum
Arbutus menziesii
Betula neoalaskana
Betula occidentalis
Cornus nuttallii
Malus fusca
Populus balsamifera
Populus tremuloides
Populus trichocarpa
Prunus emarginata
Quercus garryana
Rhamnus purshiana
Salix lucida
Salix scouleriana

The first seedlot samples allocated to a separate genetic conservation seed bank occurred in the mid to late 1970s. These samples were obtained from the remnants of the submitted sample provided to the lab for standard seedlot testing. The standard process of using excess seed for a seed bank sample was discontinued on December 11, 2003 to move to a more strategic sampling of seedlots. Small fractions of seedlots that have relatively low commercial value due to size or redundancy issues are still donated to the seed bank. We also received some historic research collections from various provenance trials that are also considered part of our seed bank. The emphasis also changed from focusing on our currently commercial species, which generally have an abundance of samples to our non-commercial species, most of which had no seed samples.

The recent focus of obtaining collections of currently non-commercial species also uses the BEC zones to characterize ecological amplitude. Many of these species have very little information available on genetic variation patterns and collections have been performed and maintained by individual tree to allow for such investigations in the future. We are still looking for three populations per BEC zone as a first step towards 'adequate representation'. We started with guidelines of a minimum of 10 individuals per population, but have raised this to 20 individual trees per population and will take advantage of cases where we can easily collect more. For rare species comprising a small fraction of a forest stand, we may lower these tree number objectives and increase the number of populations, but at this point we are still working towards obtaining a minimum of three populations per BEC zone where the species occupies greater than 1% of its range. So, how are we doing? Table 2 provides a high level snapshot of the current status of the tree seed bank.

The commercial species are generally in good shape with 75% (63/84) of the coloured cells displayed in green, represented by over 6,900 distinct seed samples. A green cell indicates at least three seedlots exist with 1,000 or more viable seeds from the indicated BEC zone. In some cases the number is in the hundreds and generally conservative as many seedlots do not have a current germination capacity (GC) making viable seed determination difficult. If the operational seedlot has been totally used for reforestation then all that remains is the seed bank sample. For some of these yellow cells it is simply obtaining a more current GC to calculate viable seeds, if that makes sense with the quantity of seed left in the sample. For many of these commercial species, progeny tests, provenance trials and additional seed samples exist outside the provincial seed bank. Some of the apparent gaps are a priority for investigating further to see if operational seedlots exist to fill them via donation or purchase.

For the non-commercial species the green cells are a lower percentage, 17% (14/83), but is being reduced yearly with an annual budget of $25,000 for ex-situ collections. There are currently over 2,000 individual tree collections in the seed bank. For about 10 matrix cells, two populations have already been obtained, but 23 cells have no samples to date and some species do not even have any samples yet. *Quercus garryana* is considered our only tree species with recalcitrant seeds and therefore limited in its ability to conserve genetic diversity through seed banking. The species is also a component of the endangered Garry Oak ecosystem which is one of the rarest in Canada. There is a very active Garry Oak Ecosystems Recovery Team (GOERT) and much greater details on their program or volunteer opportunities can be found on their website: http://www.goert.ca/index.php.

Other species without collections can be attributed to taxonomic difficulties with the two *Salix* species providing taxonomic problems due to the large number of BC *Salix* spp. (roughly 40), but also the potential for hybridization between species. Restoration work with *Salix* often avoids taxonomy by using local *Salix* collections for their efforts without identifying to the species level. It has also been suggested that *Salix* spp. may be well suited to clone banks, although this is a far more expensive venture than collecting seed samples. A few other non-represented species may be surprising given their importance throughout Canada, like *Larix laricina* and *Pinus banksiana*, but these species are quite remote and with the latter species, hybridization with *Pinus contorta* also needs to be considered. Each year, investments in collections is a balance between existing crops, cost of collection and current matrix gaps and these species have ranked low due to cost and the natural abundance and presence of breeding programs in other parts of Canada. The other two species without collections (*Populus balsamifera* and *Betula neoalaskana*) are collection priorities.

Pinus albicaulis deserves specific mention as there has been a large investment in collections. This species is listed as Endangered under the Federal Species At Risk Act (SARA) and BC is the jurisdiction with the largest proportion of its range. Additional articles in this News Bulletin discuss the respective provincial programs more fully. *Pinus flexilis* is considered a rare species in BC, but it has many of the same challenges as *P. albicaulis* and also considered a priority when good cone crops are found.

A common question that arises when prioritizing collections is 'are collections from BEC zones representing <1% of a species range more or less valuable?' These represent the non-coloured numbered cells in Table 2. Are they unique populations or simply some spill over from an adjacent BEC zone? There isn't an answer that fits all situations, but I generally believe those collections add value, especially if an experienced collector recognizes the unique characteristics of a specific population.

The discussion thus far has totally focused on samples from natural populations. A further development in managing our seed bank has been the recognition that there is value is maintaining a sample from seedlots derived from seed orchards. Some of these samples (957) already exist with the original samples derived from remnants of the submitted testing sample. The goal is not to sample every seedlot, but to have a sample of each seed orchard at roughly five year intervals. New technologies may also allow the seed bank samples to provide a better understanding of the materials that have been used to reforest our province. This simply is not possible without a comprehensive and representative sample of our historic reforestation materials. In 2009 a summary was performed on the status of genetic conservation of operational tree species with respect to ex-situ, inter-situ and in-situ materials and populations and concluded that population diversity was well represented by these conservation methods (Krakowski et al. 2009).

Table 2. The species × Biogeoclimatic zone[1] matrix for the BC provincial tree seed bank. Commercial species' status (above triple line) based on operational seedlot samples and non-commercial species based on individual tree collections (indicated by number of populations and total number of parents in brackets). Coloured cells refer to where >1% of a species range exists – green colouring indicates initial goal is met and yellow indicates the need for additional collections. Non-coloured cells indicate samples obtained from BEC zones that compromise <1% of a species range.

Species \ BEC zone	AT	BG	BWBS	CDF	CWH	ESSF	ICH	IDF	MH	MS	PP	SBPS	SBS	SWB
Abies amabilis						1								
Abies grandis								1						
Abies lasiocarpa									0	2				0
Callitropsis nootkatensis						1	1							
Larix occidentalis														
Picea engelmannii														
Picea glauca														
Picea mariana						0						0		0
Picea sitchensis				7					0					
Pinus banksiana			0											
Pinus contorta														0
Pinus monticola						0		2	0	0				
Pinus ponderosa														
Pseudotsuga menziesii											2			
Thuja plicata				0		1				1				
Tsuga heterophylla				4		1								
Tsuga mertensiana														
Alnus rubra				1										
Betula papyrifera			2	1										
Juniperus maritima				2(14)	1 (2)									
Juniperus scopularum		2(21)						8(89)			1(12)		1(10)	
Larix laricina			0			0								
Larix lyallii	0					2(44)								
Pinus albicaulis	2(37)					26(303)								
Pinus flexilis						0		4(38)		1(17)				
Taxus brevifolia				0	2(16)		6(68)	3(29)		0				
Acer circinatum				1(20)	3(62)			0	1(20)					
Acer glabrum		0		1(13)	2(30)		1(16)	3(61)		1(25)	2(30)		0	
Acer macrophyllum				2(44)	1(20)			1(20)			1(20)			
Arbutus menziesii				3(39)	1(10)									
Betula neoalaskana			0											
Betula occidentalis		4(70)	0		0	0	0	5(79)		0	1(10)			
Cornus nuttallii				1(14)	3(38)			2(21)						
Malus fusca				1(14)	4(44)			1(12)						
Populus balsamifera			0											
Populus tremuloides			1(10)			0	0	0		0		0	0	0
Populus trichocarpa		1(16)		2(40)	2(22)	1	1(20)	1(20)		1(9)	1(20)	0	0	
Prunus emarginata				1(11)	2(22)		1(10)	1(11)			0			
Quercus garryana				0										
Rhamnus purshiana				2(33)	4(43)		3(28)							
Salix lucida			0		0		0	0					0	
Salix scouleriana					0	0	0		0				0	

[1]https://www.for.gov.bc.ca/hre/becweb/

The provincial seed bank is a dynamic work in progress. We have completed the non-destructive moisture testing of our backlog of individual tree seed samples and now all samples reside in the freezer at −18°C. We have used the conservative 0.3–0.4 equilibrium relative humidity (eRH) target for all of our samples. Our next objectives are housecleaning tasks associated with condensing and improving the inventory, filling any outstanding gaps with commercial species (natural and seed orchard) through a review of existing seedlots, continuing to chip away at the larger matrix of non-commercial species and initiate germination and/or viability tests on a sample of our species, especially those unfamiliar to us or have uncertain pretreatment requirements.

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BC Whitebark Pine Seed Inventory

Whitebark pine (*Pinus albicaulis*) is listed as endangered under the Federal Species at Risk Act (SARA). There is a great deal of literature on the species and good introductory documents can be found on the Whitebark Pine Ecosystem Foundation (WBEF) of Canada website: (http://www.whitebarkpine.ca/publications--links.html); the book *Whitebark Pine Communities: Ecology and Restoration* (Tomback et al. 2001) and as an update, the Proceedings of the 2010 High Five Symposium is a great resource (https://www.treesearch.fs.fed.us/pubs/38187). In the past year two summary articles have been written regarding pretreatment and growing requirements for whitebark pine (Overton et al. 2016; Riley et al. 2016).

Whitebark pine is a species that has proven to be problematic to regenerate artificially. Challenges start with relatively infrequent cone crops at the extreme climate this species grows in. These extreme locations are also challenged in ensuring conditions are appropriate for pollination, fertilization and seed development. There is also competition for the seeds from the Clark's nutcracker and various mammals. This has resulted in the standard practice of caging cones in summer and returning in the fall to harvest intact cones. This adds expense to the collecting costs that are already high due to the relatively inaccessible locations of many whitebark pine stands. Even under the best conditions the species does not appear to obtain fully developed embryos (>90% of corrosion cavity) very often. This complicates storage and processing activities as relatively immature embryos (<50% of the corrosion cavity) have, with appropriate pretreatments, the ability to produce a seedling.

In terms of seed processing the lack of a seed wing removes one potential step, but a critical decision needs to be made regarding final cleaning. Do you simply a) retain all seeds and accept a lower germination capacity b) only remove obviously 'empty ' seeds through some form of gravity separation which would increase germination or c) try and remove seeds below a certain maturity level (i.e. embryos <25% of the corrosion cavity) to try and maximize germination, but probably lose some viable seeds in the process. We have all three types of seedlots with the first probably being the most common to date. The decision on whether to incorporate nicking or sanding into the pretreatment may also influence the appropriate degree of processing required. It is recognized that embryo dormancy is deep in this species and due to the immature embryos almost all pretreatments incorporate a warm period prior to cold stratification. Standard pretreatment protocols are still under development in BC (a completed stratification trial didn't quite make this edition, but will be presenting it at the WBEF meeting in Jasper, contact me if you want an update). Seed pretreatment and ensuring cavity fill are labour intensive activities, so an actual standard germination capacity doesn't induce the same large-scale efficiencies as other conifer stock types. Some of the registered seedlots are quite small and to conserve seed, the proportion of viable seed has been estimated using x-rays on a 100-seed sample. Some of the registered seedlots have fewer than 500 seeds, so it makes no sense to sacrifice 400 of them for a standard germination test.

This article is intended as a summary of our current whitebark pine seed inventory. British Columbia had operational whitebark pine seedlots collected as early as 1958. Quality of collection through to the 1990's were poor and very few seedlings actually materialized from these seedlots. There have been extensive restoration plantings associated with mining activities that have generally used local seed. There has been renewed interest in registering seedlots for crown land reforestation and over the last year we have registered 16 seedlots representing over 22 kg of seed. The owners include BC Timber Sales, the Ministry, private companies and native bands. Some of these seedlots are already currently being used to produce seedlings for restoration and reforestation activities.

Seedlots vary considerable in quality with Figure 1 indicating the range observed this past year. The seedlot on the left illustrates poor pollination and/or fertilization success with hardly an embryo to be seen. Megagametophyte tissue appears fully formed in some seed, but generally appears to be in the process of deterioration. The seedlot on the right still has some non-viable seed present, but the majority of seeds display a mature and well developed embryo in association with a plump megagametophyte.

The current operational seed inventory is represented by 14 seedlots and 25.6 kg of seed. Seed quality is highly variable and Figure 2 provides an overview by 10 percentile increments. There is obviously a great deal of poor quality seed, but over 14 kg of seed with a viability estimate of between 40 and 50%. Very few seedlots are available with better quality, but both a 85% and 77% viable seed seedlots were registered this past year and are now being used to produce seedlings.

In addition to the operational inventory there has been a large investment in genetic conservation collections for this endangered species. These are collected on an individual tree basis and early collections focused primarily on finding crops

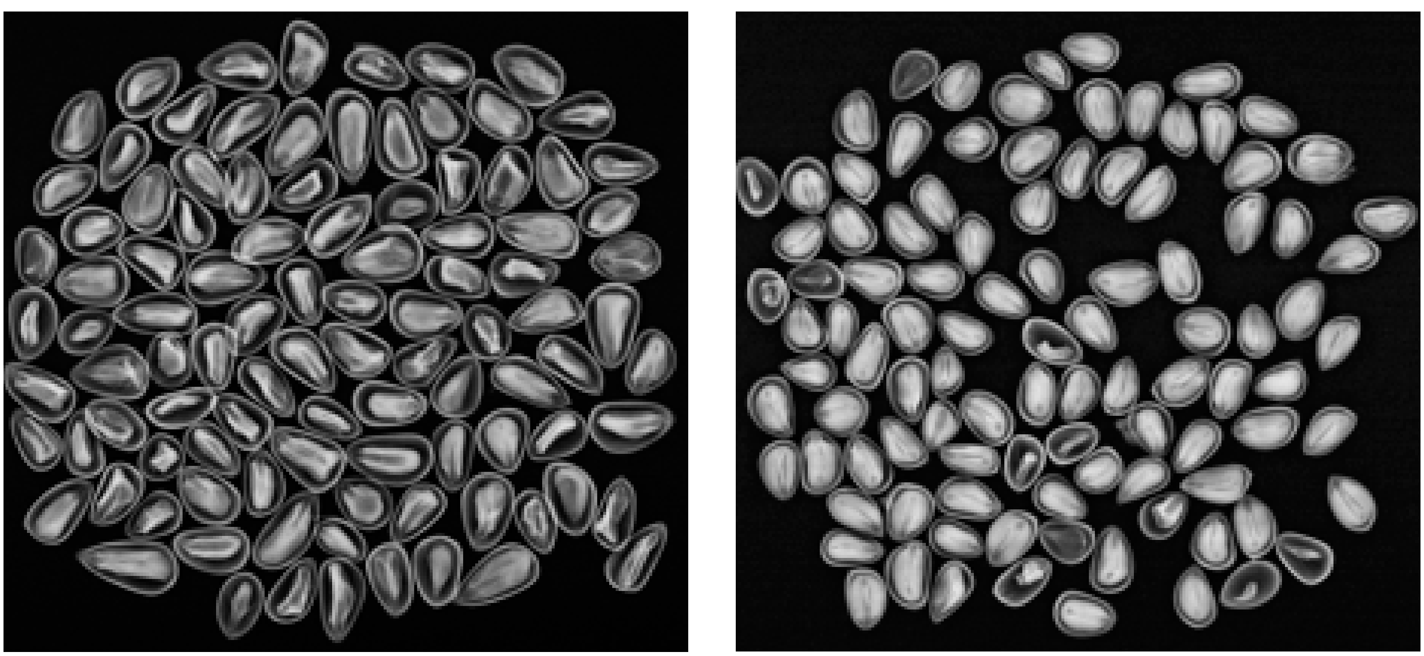

Figure 1. Examples of a poor quality (left) and good quality (right) operational seedlots of *Pinus albicaulis*.

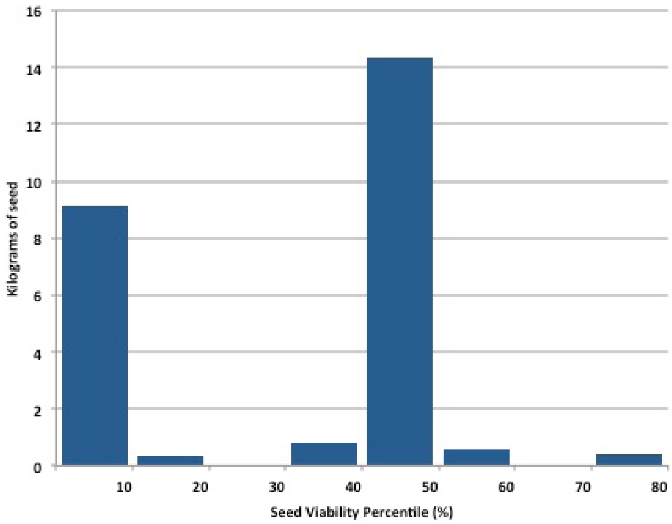

Figure 2. The breakdown of the current operational seed inventory (kg) of *Pinus albicaulis* by germination percentile.

widely distributed throughout the range of the species in BC. Current emphasis is on finding trees without evidence of blister rust and sampling stands with a high rust incidence (>50%) to allow for potential inclusion of the material into the blister rust screening program. The seed bank currently has 55 population collections representing 563 families amounting to over 34 kg of seed. We don't have x-ray viability estimates for all of these collections, but that is moving forward. On an individual family basis we are also storing 14.6 kg of seed from 101 families (some already part of the seed bank, others unique) for other agencies.

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One Piece of the Puzzle: 5-Needle Pine *Ex Situ* Conservation in Alberta

Introduction

Both limber pine (*Pinus flexilis*) and whitebark pine (*P. albicaulis*) are endangered species in Alberta. Approved provincial recovery plans are being implemented. With range-wide decline estimated at 80% over three generations, whitebark pine is federally endangered and a pending federal recovery plan, and limber pine is being assessed for endangered federal status.

Status and monitoring

Data on the national distribution and status of these species is limited, but status reports, ongoing monitoring, and published data all point towards continued decline without targeted actions. Given their slow maturity, requiring 40–50 years to reach cone production, recovery work must occur quickly and can be effective. Both tree species have evolved so that they rely entirely on a bird, the Clark's nutcracker (Fig. 1), for successful regeneration. If too few cone-producing trees remain in a stand, the birds will stop visiting the site and the stand will convert to a different ecosystem type.

Alberta has been collecting detailed monitoring and inventory data for 10–20 years to assess status and trends. Alberta has the easternmost Canadian populations of whitebark pine along the Rocky Mountain front ranges, and nearly 95% of Canada's limber pine throughout the Rocky Mountains and foothills. There are nearly 250 long-term monitoring transects, in large part thanks to the initiative and dedication of Cyndi Smith, Parks Canada Emeritus Scientist. These get reassessed every five years with the next measurement due in 2019. As in 2014, it will be a collaborative effort between the provincial Forest Health staff, Forest Area operational staff, Environment and Parks, and Parks Canada.

Figure 1. Clark's nutcracker.

Phenotypic selection and seed collections

The provincial recovery objective is to halt the decline and to sustain viable, functioning populations across the species' ranges (Fig. 2). Concerted recovery work will mitigate threats causing the decline. Currently Alberta's recovery program is focused on mitigating the threat caused by white pine blister rust (Fig. 3) through phenotypic selection, as mountain pine beetle, wildfire, and climate change are addressed through other provincial initiatives. Trees with apparent resistance compared to background stand disease levels or with phenotypic signs of tolerance or resistance are selected, documented, and protected. Seeds are collected for *ex situ* conservation (Fig. 4), rust resistance screening (Fig. 5), and restoration planting (Fig. 6).

Alberta has a large collection of seed collections for limber pine and whitebark pine, with 49 bulk collections and 475 single tree collections of limber pine, of which about 100 are putatively rust resistant; and three bulk and around 100 single tree collections of whitebark pine, of which about 15 are putatively resistant to blister rust. These figures exclude accessions with <100 seeds, and disregard viability. Nearly 100 more candidate rust resistant trees were selected in the field in 2016, but there was no cone crop, so these trees must be revisited another year.

The selection program continues to assemble a robust and diverse genetic base representing selected and tested rust resistant (or tolerant) trees from each region. Provenance trials will support delineation of revised seed zones, but that will take years, but genotypic data is available to assess population differentiation. Selections will be grafted in a clone bank that may double as a seed orchard subdivided by region. The USDA Intermountain Region leads the way with four established whitebark pine seed orchards, one per seed zone, consisting of screened material with resistant trees, and expects these to replace their field cone collections over time.

Alberta and the overlapping Rocky Mountain National Parks have agreements where the provincial tree seed centre may process and store the seeds collected in parks and produce some seedlings for restoration, in exchange for a share of the seed. The Alberta Tree Improvement and Seed Centre runs a program where samples of seed in long term storage are periodically re-tested for viability, and these seeds are subject to re-testing. Studies have also been done by Lindsay Robb, provincial seed specialist, to optimize collection, handling and germination of these valuable seeds.

Blister rust resistance screening

To date, 100 selected limber pine trees have been sent for rust resistance screening to Dorena Genetic Resource Centre in Cottage Grove, Oregon; results are pending as screening takes up to seven years from receipt of seed to the final year four seedling assessment . These assessments are very costly. At least one selected limber pine tree from the Castle region just north of Waterton has confirmed hypersensitive major gene resistance (Cr4 MGR), conferring total immunity to blister rust infection. We hope that more recent selections from that area also have this allele.

Seed from 10 unselected whitebark pine trees from the Castle Provincial Park and 10 selected whitebark pine trees from Waterton Lakes National Park were sent for screening to Coeur D'Alene Nursery in Idaho on an in-kind support basis. All of the unselected trees performed very poorly, while the selected trees varied from the lower 10th percentile up to the top 70th percentile of screened trees from that region, which would overlap the Missions-Glacier National Park in Montana. This highlights the importance of phenotypic selection to make the most of the high cost and long screening time.

Seed from 15 whitebark pine trees was also accepted for screening at Kalamalka Forestry Centre in Vernon, but no results are available yet.

Figure 2. Limber pine stand in a region with high blister rust infection – a good area to search for plus trees.

Figure 3. Signs of white pine blister rust in a whitebark pine tree – most infected trees will die, but rare individuals have heritable resistance.

Figure 4. Whitebark pine mature cones.

Figure 5. Screening seedlings for blister rust: each box has rows of seedlings from a parent tree; after rust inoculation parents are scored for resistance proportion and mechanism.

Figure 6. Whitebark pine germinants.

Next steps

Seed and seedlings are currently limiting in Canada – there are no seedlings available on demand for planting. To produce a plantable seedling takes about three years if there is a good seed crop, so advance planning is key. Inconveniently, funding cycles and cone masting cycles don't always align so it's best to have a few plans ready that be flexible regarding access, logistics, and plan objectives. To successfully recover these species, there must be an extensive planting program targeting stands that are declining, approaching, or even past ecological tipping points in order to provide a new cohort of seed bearing trees. We are just getting started, and this is a great opportunity for partnering with volunteers and non-governmental organizations.

Recovery is a multifaceted, long term program. *Ex situ* gene conservation is needed not only for traditional gene archiving, but is also essential here to sustain *in situ* conservation for preserving these high elevation unique ecosystems.

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The Rare Woody Plants of Ontario Program at the University of Guelph Arboretum

Ontario is home to a significant number of rare tree and shrub species that have been listed as at-risk and in need of monitoring activities. However, the majority of these species have populations that are quite secure in the United States, so why the concern? Is there really a need for conservation in Canada?

Conserving an organism at the species level is generally regarded as the most immediate and crucial objective of many conservation programs. In the case of a species that is critically endangered on a global scale, simply ensuring the survival of a few individuals is often a significant challenge. But even many globally common plant species have conservation needs. Often these species do not have a very high representation of diverse genetic material archived in *ex situ* collections simply because they are not considered to be a high priority for conservation. To compound this, the limited germplasm that is archived is often accessed from similar populations from the core of a species geographic range. By collecting from more provenances, including those at the extremes of a species' range, we can come closer to fully conserving and representing the genetic diversity of the species.

After the Laurentide Ice Sheet began receding nearly 12,500 years ago, the forests of eastern North America began their march northward. Species migration is a dynamic and ongoing process, and while many species have already pushed into the tundra region in the far north of Canada, most other species have only extended into southern Canada far more recently. These regional populations, on the forefront of a long migration into northern latitudes, must adapt to an array of environmental conditions that are often very different from those found at the core of the geographic range. Adapted gene complexes enable a plant to adjust to the timing of the local annual growth cycle, including bud break, root growth, shoot and leaf elongation, bud development, diameter growth, and cold acclimation. The genetic variation present in these range extensions is very significant from a conservation standpoint since these particular genotypes may provide crucial genetic material to allow a species to migrate and fill various regional niches. The Ontario populations of woody species, at the northern extent of their natural range, represent adaptations to our northern conditions. *Liriodendron tulipifera* from Ontario could prove far more valuable for forestry planting in extended parts of the province than seedling stock from a South Carolina source. *Cornus florida* from Ontario-based provenances have proven, in cold hardiness trials, to be more winter hardy in Canada than nursery stock sourced from farther south. As migration pressures increase due to a rapidly changing climate, it may become even more critical to conserve these northern genotypes. Unfortunately, the pace of abiotic change in the environment is likely to be far ahead of biotic survival for many species. The continued exploitation and segregation of suitable habitat adds another dynamic to an already challenging scenario for *in situ* conservation.

The Rare Woody Plants of Ontario Program

In 1978, the University of Guelph Arboretum first embarked on a conservation program to help evaluate and protect rare woody flora in southern Ontario. The goal was not simply to cultivate an *ex situ* accession of each species from an Ontario provenance, but to actually capture as much representation of the wild populations in Ontario as possible. With this target in mind, the Rare Woody Plants of Ontario Program was born.

The first phase of the program was lovingly dubbed "Picking up the Pawpaws" after one of Ontario's most unique and seemingly out-of-place native plant species, *Asimina triloba* (Fig. 1). The aim was to conduct extensive surveys of all of southern Ontario's rare woody species to better understand their distribution and relative abundance. This also doubled as an outreach program to educate the general public about some of Ontario's unique plant species that they had never even heard of before, let alone knew existed in Canada. Many property owners were excited to learn that the inconspicuous green shrubs in their back forty were actually rare and significant species. Much of the information gathered during these initial surveys continues to prove valuable in the ongoing development of legislatively-important COSEWIC assessments.

Excellent Situation for *Ex situ* Conservation

The second phase of the Rare Woody Plants of Ontario program revolved around developing a strong *ex situ* conservation program at the University of Guelph Arboretum, which spans 165 hectares (408 acres) with over 1,900 taxa of woody flora represented in its collections. The major emphasis is on the woody flora of eastern North America, with special attention being given to the rare woody flora of Ontario. After initial surveys were completed, provenance-based germplasm collections were made in order to capture as great a representation of a species' provincial population as possible. Vegetative propagules were gathered for the establishment of a germplasm repository at the University of Guelph Arboretum, in the form of living gene banks. The gene banks at the Arboretum were designed as seed orchards and serve two main purposes:

1) To provide *ex situ* backup for failure at *in situ* conservation efforts related to habitat loss and natural calamities. This is especially critical for many hardwood species that possess non-orthodox seeds that are difficult to store under conventional seed banking practices.

2) To produce enough seed, through open or controlled pollination, to take the seed collecting pressure off of natural populations in Ontario (Figs. 2 and 3). Seed produced provides a valuable and readily-accessible resource for restoration efforts, in addition to supplying material with promising horticultural attributes with respect to cold hardiness.

Today, a number of species that are at risk in Ontario have their germplasm archived within The Arboretum's gene banks and plant collections (Table 1). Much of the research conducted to develop germination and cultivation requirements for these rare species was published in 2008 in the book, *Growing Trees from Seed: A Practical Guide to Growing Native Trees, Shrubs and Vines*, by late University

Figure 1. The unusual ripening fruit of pawpaw (*Asimina triloba*).

Figure 2. Over the past 15 years, several bumper crops have been produced in the cherry birch (*Betula lenta*) seed orchard at the University of Guelph Arboretum.

Figure 3. A view from within the cucumbertree (*Magnolia acuminata*) seed orchard at the University of Guelph Arboretum.

Table 1. Accessions of known, wild, Ontario-based provenance for selected rare woody taxa under cultivation at the University of Guelph Arboretum.

Taxon	Risk Ranking[1]	Total Number of Accessions	Total Number of Individuals
Aesculus glabra	G5, N1, S1	5	20
Amelanchier amabilis	G4, N2N3, S2S3	2	3
Asimina triloba	G5, N3, S3	8	12
Betula lenta	G5, N1, S1	11	94
Campsis radicans	G5, N2N3, S2	3	4
Carya laciniosa	G5, N3, S3	6	25
Carya glabra	G5, N3, S3	3	7
Castanea dentata	G4, N2, S1S2	2	3
Celtis tenuifolia	G5, N2, S2	5	13
Cornus drummondii	G5, N4, S4	7	42
Cornus florida	G5, N2, S2	11	39
Euonymus atropurpureus	G5, N3, S3	9	49
Fraxinus profunda	G4, N2N3, S2	2	18
Fraxinus quadrangulata	G5, N3, S2	23	58
Gleditsia triacanthos	G5, N2, S2	7	38
Gymnocladus dioicus	G5, N2, S2	26	87
Juglans cinerea	G4, N3N4, S2	12	32
Liriodendron tulipifera	G5, N4, S4	12	19
Magnolia acuminata	G5, N2, S2	16	37
Morus rubra	G5, N2, S2	5	21
Morella pensylvanica	G5, N5, S1	3	3
Pinus rigida	G5, N2N3, S2	4	5
Platanus occidentalis	G5, N4, S4	10	18
Populus heterophylla	G5, N1, S1	1	4
Prunus pumila var. *pumila*	G5, N4, S3	2	14
Ptelea trifoliata	G5, N3, S3	25	62
Quercus ellipsoidalis	G5, N3, S3	3	5
Quercus ilicifolia	G5, N1, S1	1	2
Quercus muehlenbergii	G5, N4, S4	16	64
Quercus prinoides	G5, N2, S2	3	13
Quercus shumardii	G5, N3, S3	4	9
Rosa setigera	G5, N3, S2S3	7	26

[1] G-Global, N-National, S-Provincial (http://www.natureserve.org/conservation-tools/conservation-status-assessment)
G1-extremely rare, G2-very rare, G3-rare to uncommon, G4-common, G5-very common
N1-critically imperiled, N2-imperiled, N3-vulnerable, N4-apparently secure, N5-secure
S1-critically imperiled, S2-imperiled, S3-vulnerable, S4-apparently secure, S5-secure

of Guelph Arboretum Horticulturist, Henry Kock. The accessions established at the Arboretum hold a significantly representative amount of the genetic diversity for these very rare species at the northern extreme of their geographic range. Several of these accessions are from provenances that have already been lost in the wild.

In addition to this, many of the early provenance-based seed collections were distributed internationally to botanical organizations for more broad-based *ex situ* archiving. A look through the plant inventories of many botanical gardens and arboreta will display cultivated material of species from these Ontario provenances.

Planting Seeds for the Future

The Rare Woody Plants of Ontario Program was first initiated at the University of Guelph Arboretum nearly 40 years ago, and conservation efforts focusing on Ontario's native woody flora continue to this day. In addition to the endeavors already discussed, the Arboretum is currently engaged in several activities to build upon our conservation programs.

In 2006, after the early passing of our beloved Arboretum Horticulturist, Henry Kock, an endowment was established to help provide long-term, sustainable funding for our conservation programs. Henry's mission, to archive naturally-occurring Dutch elm disease-tolerant American elm (*Ulmus americana*) germplasm at the Arboretum, provided the incentive to refer to this as the Henry Kock Tree Recovery Endowment. This endowment provides the opportunity to not only work with elm, but also with any other woody species in Ontario that are in need of recovery efforts in the future.

To this end, Ontario's Elm Recovery Project is currently operated out of the University of Guelph Arboretum with an archival germplasm repository in active development. Provincial field studies and seed collection trips are ongoing for a number of species at risk in Ontario. The Arboretum is currently developing a management and restoration plan for Canada's *in situ* population of *Betula lenta*, with support from the Ministry of Natural Resources and Forestry.

As our existing seed orchards continue to produce increasingly sound crops, we have recently been in the position to better distribute this seed to nurseries and local conservation authorities to aid in their restoration activities. Seed crops have also been archived at the National Tree Seed Centre in Fredericton, New Brunswick. Seed will continue to be available to other research institutions for conservation and research purposes.

In this modern era, many botanical gardens and arboreta are facing tough challenges with budget and staff cuts. As the years have progressed at the University of Guelph Arboretum, we've also had to make difficult decisions regarding the activities that we have the capacity to successfully engage in. While we've had to scale back several of our display-based horticultural collections, we've found that our conservation programs have helped to further define the mission of our organization. However, as valid and critical as *ex situ* conservation programs such as these may be, it is only through collaborations and partnerships with others, to improve *in situ* ecosystem conservation, expansion and linkage, where Ontario's biological and genetic diversity will have the chance to thrive into the future.

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Genetic Conservation Status of Quebec's Forest Tree Species

Like other Canadian provinces, Quebec is currently in the process of determining the conservation status of the genetic resources for its 45 indigenous tree species (Table 1). The project leaders at the Direction de la recherche forestière are writing a document on this subject.

This research report will include a summary sheet for each of the 45 tree species, of which 36 have orthodox (desiccation-tolerant) seeds and nine have recalcitrant (desiccation-sensitive) seeds. Each summary sheet synthesizes basic species data such as name, family, type of seed produced, its inclusion (if applicable) in the list of plant species that are threatened or vulnerable in Quebec, distribution range, mode and frequency of reproduction, vulnerability to various biotic and abiotic factors, etc.

We compiled data from the 4th decadal forest inventory (as of November 2016) to establish each species' *in situ*

Table 1. List of indigenous tree species in the study.

DECIDUOUS			
RECALCITRANT		ORTHODOX	
Acer saccharinum	Silver maple	*Acer nigrum*	Black maple
Carpinus caroliniana	American hornbeam	*Acer pensylvanicum*	Striped maple
Carya ovata	Shagbark hickory	*Acer rubrum*	Red maple
Celtis occidentalis	Hackberry	*Acer saccharum*	Sugar maple
Juglans cinerea	Butternut	*Betula alleghaniensis*	Yellow birch
Quercus alba	White oak	*Betula papyrifera*	White birch
Quercus bicolor	Swamp white oak	*Betula populifolia*	Grey birch
Quercus macrocarpa	Bur oak	*Carya cordiformis*	Bitternut hickory
Quercus rubra	Northern red oak	*Fagus grandifolia*	American beech
		Fraxinus americana	White ash
		Fraxinus nigra	Black ash
		Fraxinus pennsylvanica	Green ash
		Ostrya virginiana	Eastern hop-hornbeam
		Populus balsamifera	Balsam poplar
		Populus deltoides	Common cottonwood
		Populus grandidentata	Big-toothed aspen
		Populus tremuloides	Quaking aspen
		Prunus pensylvanica	Pin cherry
		Prunus serotina	Black cherry
		Prunus virginiana	Chokecherry
		Sorbus americana	American mountain-ash
		Sorbus decora	Showy mountain-ash
		Tilia americana	American basswood
		Ulmus americana	American elm
		Ulmus rubra	Slippery elm
		Ulmus thomasii	Cork elm
CONIFERS			
RECALCITRANT		ORTHODOX	
		Abies balsamea	Balsam fir
		Larix laricina	Tamarack
		Picea glauca	White spruce
		Picea mariana	Black spruce
		Picea rubens	Red spruce
		Pinus banksiana	Jack pine
		Pinus resinosa	Red pine
		Pinus strobus	Eastern white pine
		Thuja occidentalis	Northern white cedar
		Tsuga canadensis	Eastern hemlock

protection status (in protected areas) and to produce a map to locate any shortcomings regarding conservation. We also determined the *ex situ* protection status for the 20 species that produce orthodox seeds and that have been or are still used in Quebec's reforestation program (based on stocks of the Berthier Tree Seed Centre seed bank in September 2016). For each species, the number of seed sources available for each ecodistrict was mapped in detail.

For these 20 species, the presence of a seedlot in cold storage (*ex situ*) can very well compensate for any shortcoming in *in situ* conservation. Therefore, we also produced a map combining both types of conservation to assess the global situation.

One feature of the work conducted in Quebec is the choice of scale to represent genetic diversity. Since genetic diversity is influenced by environmental factors, we chose to work at the scale of the regional landscape. This enabled us to discriminate between the main community-related and vegetation-related ecological factors. Each regional landscape unit was considered as a distinct population.

In addition to this basic information, we strived to make the most of the available data in order to guide an eventual risk assessment or species/provenance prioritization exercise which could lead to a genetic resource conservation strategy. Therefore, the summary sheets also include information about:

1) the spatial distribution of genetic diversity on the territory (within and among provenances);

2) the existence of distinct populations (e.g., the red oak population of Isle Royale, on Lake Superior);

3) the evolution of conservation status over time, as reflected by two CAFGRIS surveys (2003 and 2012); and,

4) the relative importance of the territory occupied by each species in Quebec, expressed as a percentage of its total distribution area.

Once these species summary sheets are completed, a provincial assessment will allow us to locate any shortcomings within the territory and to draw conclusions for certain groups of species (e.g., rare vs abundant species).

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National Tree Seed Centre Update

Since Dale Simpson retired at the end of March I have been operating the Seed Centre. I was extremely fortunate to have had the opportunity for Dale to mentor me for six months prior to his retirement. I still have so much to learn, but feel that Dale has put me on the road to success.

Annual germination testing remains a priority with a ten year retest cycle. For this year there are 515 seedlots from 43 species scheduled. At this point about one-half of the testing has been completed. This also provides an opportunity to identify seedlots with a prior moisture content of 8% or higher and condition them to less than 7% which is now the Seed Centre's maximum moisture content standard.

In December 2016, Dale, in partnership with Deborah Sparks and David Nisbet from the Invasive Species Centre (ISC) located in Sault Ste. Marie, submitted a proposal entitled "Citizen Science Ash Seed Collection and Storage to Support Ash Conservation and Regeneration" to the Canadian Forest Service's Assistant Deputy Minister's Innovation Fund. The objective of this Fund is to support creative, engaging, collaborative and innovative research proposals that further the CFS mandate. The project received funding and will rely on the ISC's network of citizen scientists to make seed collections in areas on Ontario currently under represented in the NTSC collection. Focused areas include Sault Ste. Marie and Thunder Bay. Ontario's Forest Gene

Conservation Association is also involved to provide seed collection training and to coordinate collections in southern Ontario. In addition three National Parks in Ontario will also be making collections.

In Quebec, the NTSC plans on partnering with the Kahnawà:ke First Nation in making collections on their land and the Ministry of Forests will also be involved with other collections in the province. All the seed will be sent to the NTSC for processing and storage in our Gene Conservation collection. The NTSC started an ash conservation program in 2004 and to date has over 800 seedlots in storage. We are hopeful for an abundant crop this year!

Donnie McPhee
Natural Resources Canada, Canadian Forest Service
National Tree Seed Centre
Fredericton, New Brunswick
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Ken Elliott, New Ontario MNRF CONFORGEN Representative

Hello, my name is Ken Elliott and I am in a new role with Ontario's Ministry of Natural Resources and Forestry (MNRF). I am the Senior Program Advisor, Biodiversity. This provincial position serves as the main contact for our three regional Seed and Genetic Resource Management Associations. I provide a liaison role for our operations division to connect to the policy and science folks in relation to forest genetics and climate change programs. I am currently supporting a Policy Division initiative to prepare a new seed transfer policy for the province which will update a directive that is no longer adequate given new technologies, changes in MNRF structure and advances in science and climate change modeling. As an Ontario forester with a depth of experience in science, operations and policy I am excited to be able to contribute to core biodiversity mandates and to have this great opportunity through CONFORGEN to interact and learn from experts across the country. I look forward to our discussions.

Ken A. Elliott, R.P.F.
Ontario Ministry of Natural Resources and Forestry
Peterborough, Ontario
Email: ken.elliott@ontario.ca
Phone: 705-755-1246

2017 CFGA/WFGA Conference

The latest meeting of the Canadian Forest Genetics Association and the Western Forest Genetics Association (US) was held the last week of June in Edmonton at the University of Alberta. 94 people attended for eight invited speakers, 38 oral presentations and 11 posters as well as field trips to the University of Alberta's Devonian Botanic Gardens, the Alberta Tree Improvement & Seed Centre and a guided tour of the University's genetics research labs. The Tree Seed Working Group meeting was absorbed into the main meeting this year as a themed session, with four accepted presentations in "Seed Biology & Management". Dr. Fiona Hay was the invited seed science speaker as Senior Genetic Resource Specialist at the International Rice Research Institute (IRRI) in the Philippines. Below are the abstracts for these presentations (some have been updated by the presenters) and email contacts are given with permission.

We thank all the people who took time to answer us.

Lindsay Robb
Alberta Agriculture & Forestry
Alberta Tree Improvement & Seed Centre
Smoky Lake, AB
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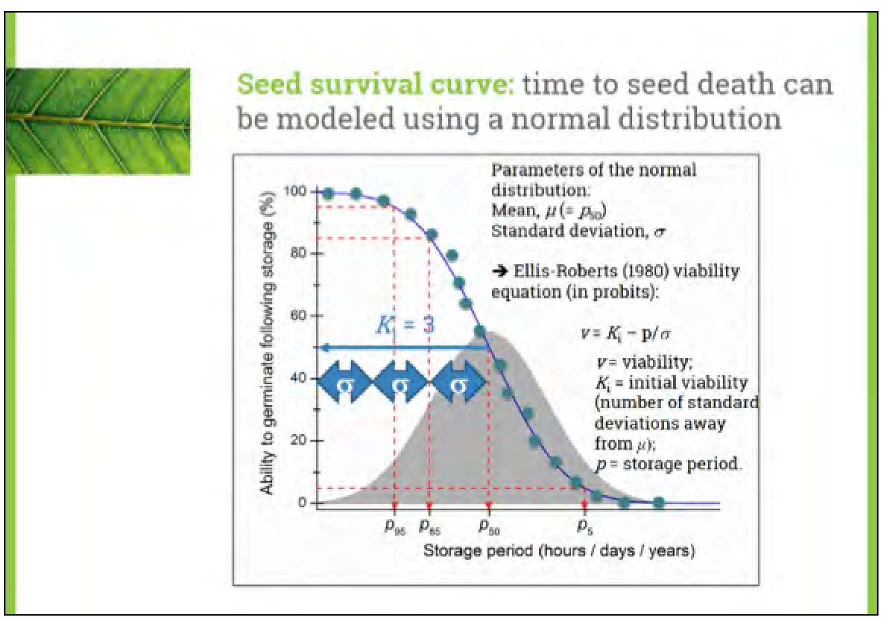
What do we know about the genetics of seed longevity?

Dr. Fiona Hay
International Rice Research Institute, Laguna, Philippines
Website: http://irri.org/about-us/our-people/specialists/fiona-hay
Email: f.hay@irri.org

Abstract:
The availability of high quality seeds, with high and vigorous germination, is essential for the production of healthy, high-yielding plants, be that an arable crop, a horticultural crop, a forest species, or any other useful plant species. Seed quality is inextricably linked with seed longevity, since it is the detrimental effects of seed aging that lead to declines in seed vigour and germination. Seed longevity depends on the conditions under which seeds are stored, most importantly, moisture content and temperature. But it is also a highly plastic trait that varies depending on pre- and post-harvest factors such as climate during seed development, moisture content at harvest and post-harvest drying regime. It also varies greatly between species, if seeds are stored under the same, standardized conditions. For different seed lots within a species, it was originally thought that variation in longevity would correlate with the initial viability of the seeds and that all seed lots of a species would age (lose viability) at the same rate. However, we are now starting to understand that the rate of aging can also vary between different seed lots within a species. This presentation will present our current understanding of the genetic basis of variation in seed longevity.

Biography:

Dr. Fiona Hay has been working in seed ecology and physiology for the past 20+ years and currently holds the position of Senior Scientist and Deputy Head of the T.T. Chang Genetic Resources Center at the International Rice Research Institute (IRRI) in the Philippines. She started her career with a PhD studying the development of seed longevity in wild plant species at the UK's Millennium Seed Bank (MSB). During her years at the MSB, her work included researching seeds of UK aquatic species, developing a comparative longevity protocol for wild seeds and enhancing our understanding of the relationship between seed moisture content and longevity, as well as supervising a number of undergraduate and doctoral students. Her MSc in Applied Statistics and Operational Research has enabled her to guide both students and colleagues around the globe in the correct use of statistics in seed research. Dr. Hay and her research team at IRRI study seed development, dormancy and germination in addition to seed longevity and optimizing genebank procedures. Fiona is the coordinator for the Global Strategy for the Ex Situ Conservation of Rice. She is also Chief Editor of *Seed Science and Technology*.



Slide explaining seed survival curve analysis of normally distributed seed death in a population. Courtesy of F. Hay.

Resin vesicles in conifer seeds: morphology and allelopathic effects.

Christopher I. Keeling[1]*, Andrew R. Lewis[2], David Kolotelo[3] and Allison R. Kermode[1]

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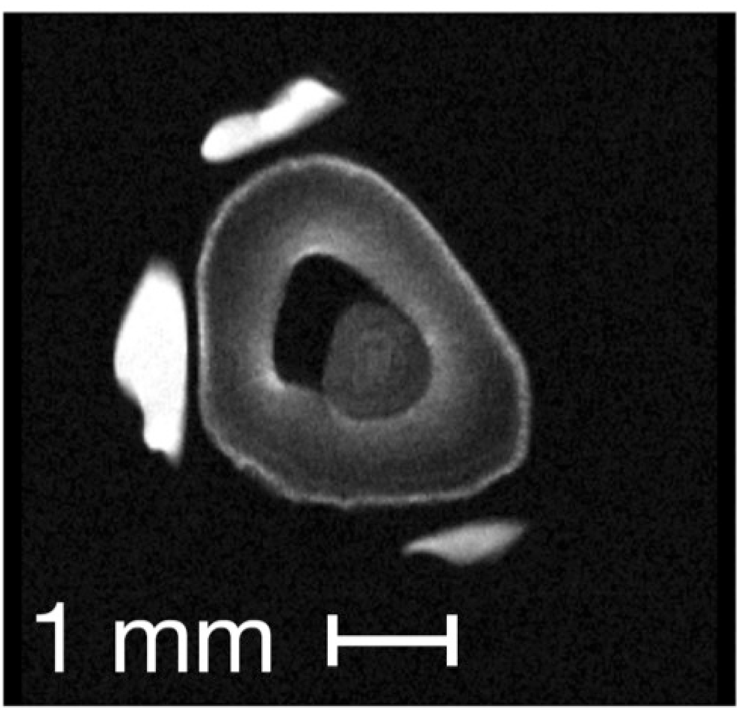
[2]Department of Chemistry, Simon Fraser University, 8888 University Drive, Burnaby, BC, Canada V5A 1S6

[3]BC Provincial Tree Seed Centre, Tree Improvement Branch, Ministry of Forests, Lands and Natural Resource Operations, 18793 32 Ave, Surrey, BC V3S 0L5

*Corresponding author's email: ckeeling@alumni.sfu.ca

Abstract:

Conifer seeds of many species of fir, hemlock, and cedar contain resin vesicles in their seed coat. Although there is limited information on the morphology and chemical ecology of these vesicles, their damage during seed processing can negatively impact germination success. We examined the resin vesicle morphology of intact dry seeds of western red cedar (*Thuja plicata*), eastern white-cedar (*Thuja occidentalis*), amabilis fir (*Abies amabilis*), balsam fir (*A. balsamea*), grand fir (*A. grandis*), and subalpine fir (*A. lasiocarpa*) by 1H magnetic resonance imaging to characterize the volume, shape, and quantity of resin vesicles. Germination assays confirmed that resin vesicle damage prior to stratification can significantly reduce germination success, but for some species this damage had a negligible or positive effect on germination success. Extracts of these resin vesicles from some of these *Abies* and *Thuja* species inhibited the germination of *Arabidopsis* Col-0 seeds in a dose-dependent manner, but the germination of *Arabidopsis* abscisic acid-insensitive (abi3-6) seeds were unaffected.



Magnetic Resonance Image (MRI) of a dry amabilis fir seed showing three resin vesicles surrounding the megagametophyte and embryo in axial cross-section. Courtesy of C.I. Keeling.

Reference seedlot monitoring program: What have we learned in 36 years?

Lindsay Robb

Alberta Tree Improvement & Seed Centre, Government of Alberta, Canada

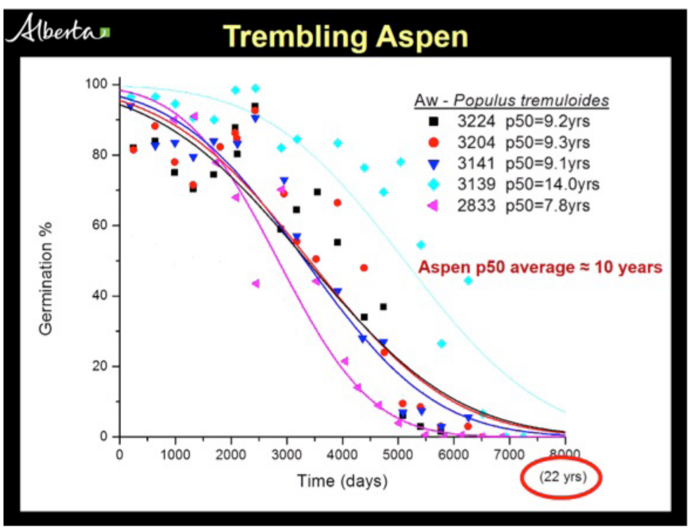
Email: lindsay.robb@gov.ab.ca

Abstract:

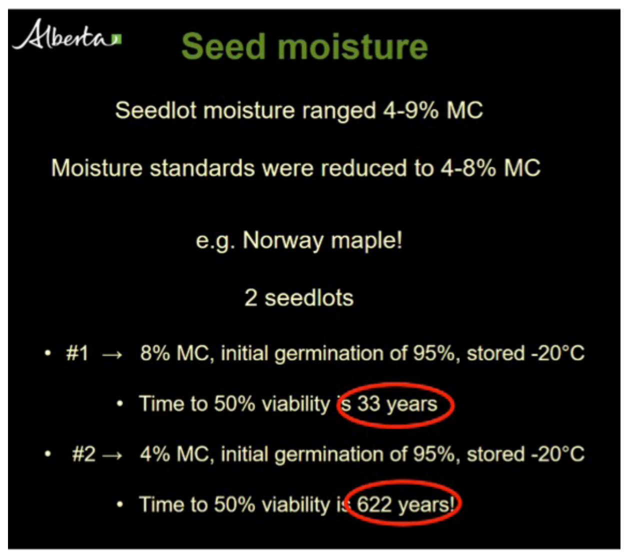
The Alberta Tree Improvement & Seed Centre (ATISC) has had a seed viability monitoring program as part of the long-term storage seed bank since 1981. Many changes and updates to the program have been implemented and the data yielded interesting results when it was statistically analyzed using probit analysis in 2013. These results, plus many developments in seed banking science, have provided a focus for the overhaul of the program going forward.

The original program included 80 collections of mainly single tree seedlots from 13 species and many seedlots spanning the switch from 2°C to −18°C in the mid-1980's. Most seedlots were retired and changes were made to the program after 2013, including the following: seedlot inclusion criteria switched to mainly non-economically important species, bulk instead of single tree collections are now the focus, only seedlots with high initial viability will be included, and testing intervals are now larger (2–10 years) and specific to each species based on previous p50 estimates and the presence/absence of significant decline in the seedlot. In addition, all long-term banked seed was transferred to hermetic storage containers in 2012 and acceptable moisture levels for new banked seed has been decreased to 15–20% eRH (~3–5% MC). These changes will provide a better overall picture of each species and prove more useful to researchers and industry in the future.

Results from the data analysis will be presented and changes in the long-term storage seed bank and viability monitoring program will be covered in more detail. The dangers of using dying seedlots and over-sowing will be discussed and supportive arguments based on genetic diversity and resiliency will be introduced for the implementation of new regulations on minimum viability standards for seed usage.



Aspen (*Populus tremuloides*) seed survival curve showing significant decline in long-term storage at ATISC. Note the average p50 value of 10 years that is achievable with correct seed handling and extraction methods. Courtesy L.Robb.



Slide showing the effects of drying on all orthodox seeds (i.e. all seed plants identified in Alberta thus far). The example is Norway maple (*Acer platanoides*) using the seed viability equation (Ellis and Roberts 1980). Courtesy of L.Robb.

Reference:

Ellis, R.H. and Roberts, E.H., (1980). Improved equations for the prediction of seed longevity. *Annals of Botany* 45, 13–30.

Challenges in a high elevation pine seed orchard in Alberta

B.R. Thomas

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Email: bthomas@ualberta.ca

Abstract:

Seed orchard production is fundamental to the success of any tree improvement program. In a lodgepole pine (*Pinus contorta*) orchard designed to produce seed for an area of 1,106,686 ha and an elevation operating range of 1,200–1,600m, production targets have never been met. With a target yield of approximately 6.6 million seeds/year, the crop has only reached 20% of its target each year in the last decade of production. To address this shortfall, in the summer of 2015, 34 of 110 clones were selected for treatment with gibberellic acid (GA4/7) with a total of 284 trees being treated (~3 ramets/clone × three injection dates) with three control trees per clone. The three injection dates selected were June 30t^{h}, July 20th and August 6/7th.

Two key results were obtained: 1) Six of the 34 clones showed sensitivity to GA4/7 regardless of the rate of application, which was based on stem diameter, and 2) female conelet production increased significantly in the spring of 2016 for the first two treatment dates.

In the fall of 2015 and 2016, all cones were counted on the treatment and control trees for the 34 clones and five cones per tree were randomly selected to further investigate the seed yield per cone. All cones collected to date represent 'untreated' yields and the 'GA4/7 treatment' harvest will be completed in the fall of 2017. Results will be presented on clonal sensitivity to GA4/7, seed and cone yields per clone, conelet development through GA4/7 treatments and conelet abortion rates measured on three branches per ramet in the spring and fall of 2016.

Breeding neem tree (*Azadirachta indica*) for multiple uses

S. K. Kundu

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Abstract:

The neem tree (*Azadirachta indica* A. Juss) is an important multipurpose species with enormous potential especially for protection of environment and developing sustainable agriculture and forestry. Individual neem tree exhibits great variation in morphological and chemical makeup. Rural people can easily get economic benefits through production of seeds, leaves and firewood within a short period of time from improved genetic material. Neem can be bred for higher fruit yield with more amount of bio-active compound (limonoids) as well as desired agronomic characters. Higher fruit yield usually related with the production of high amount of biochemical compounds. These compounds have high values in producing medicines, pesticides, fungicides, nematicides, cosmetics, animal feed and organic manure. Agronomic traits such as quality timber, fuel wood, agro-forestry species, shelterbelts, avenue trees, drought and disease resistance are of good choice for selection breeding. In this paper yield parameters such as provenance variation, cline, physiological and isozymes variation are reviewed. It is necessary to popularize the cultivation of neem by improved genetic materials to benefits and economic advantages on marginal, degraded and wastelands through social forestry and commercial plantation. Conservation of the genetic resources of this species is essential for the improvement of its genetic quality and adaptability in *ex situ* and *in situ* conditions. Genetic conservation and long term breeding plan are also suggested.

New Updates to Alberta's Forestry and Seed Regulations

In December 2016, the Government of Alberta released the newest updated versions of both the Forest Genetics Resource Management & Conservation Standards (FGRMS) and the Alberta Seed Testing Standards. There were a few changes made to the new FGRMS, such as the inclusion of shrub species within the regulations, the addition of equilibrium relative humidity (eRH) as an acceptable seed moisture measurement and also changes in seed testing requirements.

The Alberta Seed Testing Standards were updated to follow the latest ISTA (International Seed Testing Association) regulations. In addition, a section was added on acceptable methods for equilibrium relative humidity (eRH) measurements using a water activity meter, and another section on required equipment calibrations. Throughout the Standards, small changes were added to accommodate the growing number of shrub and other non-tree seed being registered and stored at the Alberta Tree Improvement & Seed Centre for revegetation projects on public land across the province.

FGRMS is now published in two volumes, Volume 1 being for Stream 1 and 2 seed and Volume 1A containing only Stream 1 regulations for those who do not deal with Stream 2 seed. The pdf's can most easily be found by Googling either 'FGRMS Stream 1 and Stream 2' or Googling 'Alberta Seed Testing Standards'. Direct links to the pdf's are also given below or you can follow the links on the Government of Alberta Forest Management Manuals & Guidelines webpage.

Alberta FGRMS 2016: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15749/$FILE/FGRMS%20Stream%201%202016.pdf

Alberta Seed Testing Standards 2016: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15749/$FILE/seed-testing-standards-manual.pdf

Lindsay Robb
Alberta Agriculture & Forestry
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Resin on Conifer Cones

Have you ever wondered where the pitch covering the cones of conifer species comes from? It seems like a simple question, but actually very little information is available on the topic. This is a call for additional information and a summary of what I've found. Resin is found in the stem tissues and foliage of all conifers making it one of the unifying characteristics of this plant group (Farjon 2008). Resin is generally produced in resin canals or ducts which are elongated, tube-shaped intercellular spaces surrounded by epithelial cells that secrete resin into the canal (Fig. 1). It is generally believed the resin of conifers functions as a defense mechanism against fungi and insects. So, what is resin, also sometimes referred to as oleoresin, pitch or rosin? It is a viscous and aromatic mixture consisting mainly of terpenoids composed of five-carbon isoprene units. These terpenes are subdivided into monoterpenes (C_{10}) or sesquiterpenes (C_{15}) which are both volatile, and diterpenes (C_{20}) which are non-volatile. The non-volatile diterpenes harden (i.e. to seal wounds) and are probably closer in composition to the pitch we observe on mature cones. Currently there are 30,000 different terpene compounds produced by conifers (Farjon 2008). There is a wide range of literature on resin, but these are my recommended readings to get started into the subject (Franceschi et al 2005; Keeling et al. 2006a and b; Langenheim 2003).

The classic work of Chamberlain (1935) discusses resin canals being found in the axis of female cones in the genera *Abies*, *Pseudolarix*, *Cedrus* and *Tsuga*. Farjon (2008) discusses

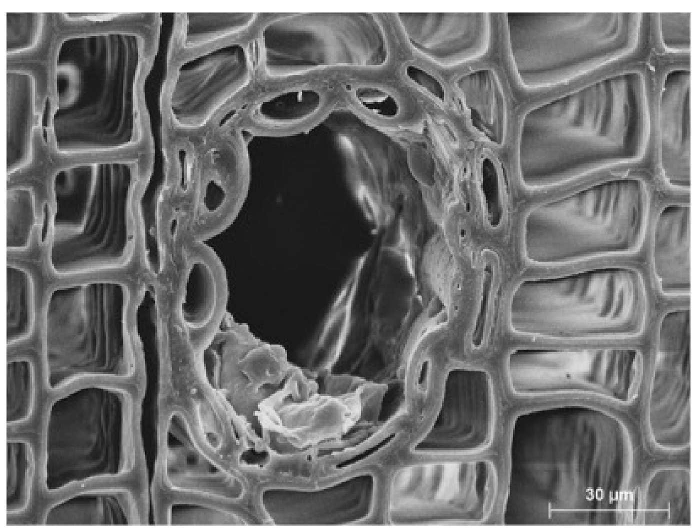

Figure 1. A resin canal in the wood of *Picea abies*. Source: Wikipedia Commons.

the cones of some species of *Abies*, *Pinus* and *Araucaria* exuding large amounts of resin resembling a candle dripping wax. That list is far from complete and I'm interested in additional information on the topic. To remain in the scope of reproductive biology, Table 1 was put together to identify genera with resinous cones and/or resin vesicles in their seed. It isn't exhaustive and I appreciate any additions, comments on specific species or other literature on the topic you might have.

Table 1. The presence of resin on cones or resin vesicles on seed for the North American conifer genera.

Genera	Resin on Cones	Resin Vesicles in Seed
Abies spp.	Yes	Yes
Callitropsis spp.	Yes	No
Juniperus spp.	Yes	Yes
Larix spp.	Yes	No
Picea spp.	Yes	No
Pseudotsuga	Yes	No
Pinus spp.	Yes	No
Taxus spp.	No	No
Tsuga spp.	Yes	Yes
Thuja spp.	No	Yes

References

Chamberlain, C.J. 1935. Gymnosperms Structure and Evolution. Originally published by University of Chicago, my copy is the 1966 unaltered republication by Dover Press, New York, NY USA. 484 pp.

Farjon, A. 2008. A Natural History of Conifers. Portland, OR, USA, Timber Press. 304 pp.

Franceschi, V.R., P. Krokene, E. Christiansen, and T. Krekling. 2005. Anatomical and chemical defenses of conifer bark against bark beetles and other pests. New Phytologist 167: 353–376.

Keeling, C.I. and J. Bohlmann. 2006a. Genes, enzymes and chemicals of terpenoid diversity in the constitutive and induced defense of conifers against insects and pathogens. New Phytologist 170: 657–675.

Keeling, C.I. and J. Bohlmann. 2006b. Diterpene resin acids in conifers. Phytochemistry 67: 2415–2423.

Langenheim, J.H. 2003. *Plant Resins: Chemistry, Evolution, Ecology and Ethnobotany*. Portland, OR, USA Timber Press. 586 pp.

Dave Kolotelo

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New Phone: 778-609-2001

Resin Vesicle Research Update

In addition to the presentation that Dr. Chris Keeling provided at the recent CFGA meeting in Edmonton, AB (abstract provided on page 23), Kristina Kshatriya presented her research at the Canadian Society for Plant Biology conference at UBC this summer and her abstract is included below. You can contact each for additional information at their respective e-mails: Christopher I. Keeling = ckeeling@sfu.ca and Kristina Kshatriya = kristinakshatriya@gmail.com. Congratulations to Chris on being offered a Research Scientist position in forest genetics at the Laurentian Forestry Centre.

Histology and biochemistry of resin vesicles in conifer seeds

Kristina Kshatriya[1,2], Justin G.A. Whitehill[1], Jörg Bohlmanni[1,2]

[1]Michael Smith Laboratories, University of British Columbia, BC

[2]Department of Forest and Conservation Sciences, University of British Columbia, BC

Canadian reforestation programs rely on orchards for seed production of most conifer species. The seeds of several economically important conifers contain an abundance of terpene rich resin vesicles that reduce germination of a seedlot when ruptured. Resin vesicles form on the outer layers of seeds and contain oleoresin. These structures are easily damaged during handling and processing for storage preparation, which significantly reduces the germination of a seedlot. The ecological and biological role of these specialized terpene-containing structures is largely unknown. We hypothesize that resin vesicles function in defense against seed feeding pests in addition to a potential role in germination biology. We evaluated the histological and biochemical features of resin vesicles from resin vesicle containing conifer species found throughout Canada. Our lab has developed a unique set of genomic resources for western redcedar. Therefore, we are focusing on resin vesicle development in western redcedar to identify resin vesicle biogenesis genes. Resin vesicles develop between the sarcotesta and the sclerotesta - two layers of the seed coat. Epithelial cells line the inside of resin vesicles, similar to axial resin ducts in cortex of young conifer stems. GC-MS analysis of resin vesicle containing seeds revealed a diversity of terpenes. Compound abundance and quality varied largely with seedlot and species. Western redcedar cones were monitored during the growing season to identify crucial timepoints in resin vesicle biogenesis. The ultimate goal of this project is to improve seed handling methods and selection of higher germinating seedlots based on terpene profiling approaches.

A New Life for Michèle Bettez

Michèle recently retired from the Berthier Tree Seed Centre. Here are the main point of her career at the Berthier nursery and Tree Seed Centre.

Michèle began her career at the Berthier Nursery in 1984. As an agronomist, she was in charge of testing different herbicides for weed control both in bare root and container production.

Then, her story with seeds began with the improvement of hardwoods production. She worked on the choice of a good container, type of seedling, substrate composition, stratification for the many different hardwood species produced at the nursery.

In 1993, she joined the Berthier Tree Seed Centre in charge of the development. When Normand Brault, Berthier TSC manager, retired in 2012, she was in charge of the technical aspects for both the TSC and the seed orchards on the nursery. She also led the management of the ISO9001:2008 certification of the TSC.

She now left for her second career: retirement!

After 18 years at the Research Branch (direction de la recherche forestière) I'm now "in her shoes" and very happy of it. Michèle was my mentor for the last year to prepare for a soft transition. People who met Michèle know that she is always ready for party, I especially remember Fredericton in 2006 for the IUFRO Tree Seed Symposium!

Do not hesitate to contact me for any seed or orchard topic.

Fabienne Colas
Centre de semences forestières de Berthier
Ministère des Forêts, de la Faune et des Parcs du Québec
Ste-Geneviève-de-Berthier, QC
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Ethiopian Seed Workshop

A Seed Quality Management Workshop was held May 22–26, 2017 in Ethiopia on the international organisation's campus and hosted by the International Livestock Research Institute (ILRI). I was honoured to be asked to join the group of instructors for the course: Fiona Hay (seed physiologist at the International Rice Research Institute (IRRI)), Katherine Whitehouse (post doc fellow at IRRI), and Jean Hanson, the forage genebank manager at ILRI.

The Workshop was presented by CGIAR (formerly the Consultative Group for Agricultural Research) with funding from The Crop Trust. CGIAR and their 15 global research centres are dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. There were 27 participants at the Workshop from 11 research centres across the globe, including the International Maize & Wheat Improvement Centre (CIMMYT – HQ in Mexico), the International Institute of Tropical Agriculture (IITA – HQ in Nigeria), and the International Potato Center (CIP – HQ in Peru) (Fig. 1). All of the organisations have genebanks focused on agricultural crops but also collect and store wild crop relatives for conservation and breeding programs. Agriculture's part in fighting poverty and climate change is complex, but without the genetic diversity found within existing crops and their wild relatives, it cannot fulfil its potential.

The Workshop was an intense five days covering topics such as seed sampling and bias, understanding storage longevity and predictions, and handling genebank data. There were also breakout session opportunities for people to discuss their specific seed problems and get valuable opinions and feedback from other genebank managers. Seed germination and dormancy, the importance of cut testing (Fig. 2), and tetrazolium viability testing were the three topics that I

Figure 1. Group photo of workshop participants.

was asked to cover for a day. It was absolutely thrilling to be asked so many probing practical questions by a room full of genebank managers and researchers who are so passionate and love what they do. I only hope that I could be helpful to them in some way and provide some basic information to aid them in the future of their own genebank.

We were in the capital of Addis Ababa with little time for exploring because of our packed schedule but did make it out to collect a few souvenirs! However, the campus was beautiful and quiet with friendly staff and the smaller setting allowed bonding between participants. I have to say that I fell in love with injera (flat bread made from fermented teff flour), berbere (an Ethiopian special chili spice blend) and brought back lots of coffee as presents!

A special thank you to Fiona Hay for the invite and to The Crop Trust for funding the trip. I hope they remember me for the next one!

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Figure 2. Learning to evaluate cut tests after a germination test.

Upcoming Meetings

IUFRO Seed Orchard Conference (see poster, pg 35)
September 4–6, 2017
Bålsta, Sweden
http://seedorchard2017.upsc.se/

International Society for Seed Science Conference
September 10–14, 2017
Monterey, California
http://seedscisoc.org/category/events/

Forest Nursery Association of BC
September 18–20, 2017
Prince George, BC
http://fnabc.com/

Whitebark Pine Ecosystem Foundation Annual Workshop
September 21–22, 2017
Jasper, Alberta
http://www.whitebarkpine.ca/jasper-2017.html

IUFRO 5th Annual Conference on Conservation of Forest Genetic Resources
October 2–7, 2017
Gomel, Belarus
http://www.forinst.basnet.by/2017/index_en.php

Genetic Conservation Links and Resources

To round out our genetic conservation theme, the following provides links to websites, articles, and even radio programs concerning genetic conservation. It is by no means complete and we welcome readers to send us additional links on genetic conservation or tree seed related items. Recent publications include many articles highlighting gene conservation.

Conservation Strategies and Registries

2020 Biodiversity Goals and Targets for Canada

Canada's Species at Risk Public Registry

Canadian Forest Genetic Resources Information System (CAFGRIS)

US National Seed Strategy

IUCN Red Lists: Global Tree Specialist Group

Plants 2020: Global Strategy for Plant Conservation Target 8 - Ex situ Conservation: Tools and Resources

Selected Conservation Organizations

UBC Centre for Forest Conservation Genetics

BC Conservation Data Centre

Whitebark Pine Ecosystem Foundation of Canada

Garry Oak Ecosystems Restoration Team

University of Guelph Arboretum

Hardwood Tree Improvement & Regeneration Centre, USDA Forest Service and Purdue University

Hardwoods Genomic Project, University of Tennessee

Morton Arboretum Conservation Biology and Genetics Research, focusing on oak species

International Network for Seed-Based Restoration (INSER – Society of Ecological Restoration)

Botanical Gardens Conservation International – Seed Conservation Specialist Group

Tropical Tree Improvement & Regeneration Centre

Seed Banks

Canada's National Tree Seed Centre

CBC Radio – Ideas with Paul Kennedy – "Seed banks: Re-sowing paradise"

The Millenium Seed Bank at RBG Kew Gardens

Plant and Animal Genetic Resources Preservation (Fort Collins, CO, USA)

Russian Seed Bank, Daily Mail News Article

Svalbard Global Seed Vault

Tasmanian Seed Conservation Centre and ABC Austratlia article on masting of rare endemic pines

A Collaborative Approach to Addressing Seed Challenges in

[*Lebanon* (May 8, 2017), INSER Blog post]

[*Seed Banking in New York City and Beyond* (May 22, 2017), INSER Blog post]

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Recent Publications

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Al Farsi, K.A.A.Y., Lupton, D., Hitchmough, J.D., and Cameron, R.W.F. 2017. How fast can conifers climb mountains? Investigating the effects of a changing climate on the viability of Juniperus seravschanica within the mountains of Oman, and developing a conservation strategy for this tree species. Journal of Arid Environments. doi:10.1016/j.jaridenv.2017.07.020.

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Dear Colleagues,

We would like to warmly invite you to the **IUFRO Seed Orchard Conference 2017**.

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We are looking forward to seeing you in Bålsta!
Sincerely yours, Organizing Committee

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