Tree Seed Working Group News Bulletin

Canadian Forest Genetics Association
l'Association canadienne de génétique forestière

68
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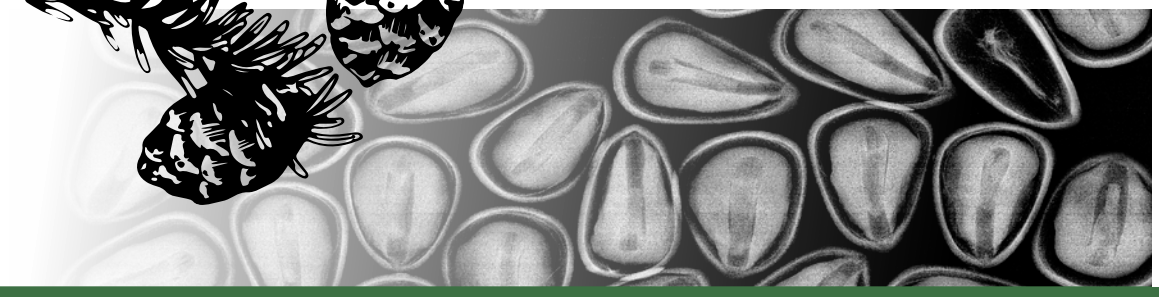

Featured in this Issue:

Banner photo of *Pinus albicaulis* (whitebark pine) seed being X-rayed for quality. Photo by Randy Pana.

Armchair Report No. 68

Hello TSWG Members. To many new subscribers, welcome.

At the BC Tree Seed Centre, we are still processing seedlots from our 2018 bumper crop year as predicted in the last Bulletin. We received 7,174 hl of cones for processing from BC with 76% of that volume being derived from seed orchards. 2,635 hl (37%) was from interior Douglas-fir, which is a relatively new breeding program not yet meeting the demand, so 58% of that volume was from wild stand collections. Coastal Douglas-fir accounted for 19%, interior spruce for 16% and interior lodgepole pine for 16% of the cone volume collected. Although smaller in volume, there were good crops that filled seed need gaps for western redcedar, yellow cypress, Ponderosa pine and western white pine. We also received 17 seedlots of extracted unprocessed seed for further processing and registration, primarily from interior Douglas-fir, western redcedar and Ponderosa pine. These seeds were either self-extracted by the collector or collected on tarps during seed dispersal. There were also 946 hl of cones received in the spring from Alberta with 95% of that being interior lodgepole pine of which 70% of that volume was derived from wild stands. Our last kiln was done just prior to the solstice and we will continue with seed processing for much of the summer. We are looking forward to some downtime for some much-needed maintenance of our aging equipment.

There was also an incredible whitebark pine crop this year and with a combination of funding sources and champions, there were collections performed on about 500 individual trees in BC. Some of this seed will be used for blister rust resistance screening, some combined into operational seedlots and some deployed as families. See the enclosed articles for further information on this and an update on some of the activities supporting the Provincial Recovery plans for whitebark

We are looking for new subscribers and contributors. Contact Dave.Kolotelo@gov.bc.ca

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Deadline for Issue No. 69: October 15, 2019

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 limber pine in Alberta.

In the last edition I spoke of the sowing of seed to produce 275 million seedlings in 2018 and that has jumped to 308 million seedlings for 2019. That is pushing the system to its limit! Some foresters in BC have had to go to Saskatchewan to get seedlings grown. Certainly enough orchard seed is a concern for some species and areas, but nursery capacity and the ability to obtain enough planters for the relatively short spring planting period appear to be much bigger problems. It is expected this spike in seedling demand will only last for between three to five years, so there is little incentive to invest in new greenhouses or even open new compounds.

This past season coincided with the 60th anniversary of the BC provincial Tree Seed Centre. To help celebrate we had an open house and visit from our Minister and then held a couple of technical exchange meetings at our facility. The first focused on our operational forestry mandate called "Connections Through Seed" on October 16th and 17th and was composed of six different themed sessions. All of the Powerpoint presentations can be found in PDF format here. To help celebrate the stewardship and genetic conservation component of our mandate we hosted a Whitebark pine workshop that was composed of presentations and hands-on exercises with the species; materials from that meeting can be found here.

Minister Doug Donaldson and Executive Director Shane Berg planting a whitebark pine tree to celebrate the BC Tree Seed Centre's 60th Anniversary.

Connections Through Seed Event at the BC Tree Seed Centre, October 16-17, 2018.

In addition to our own celebrations there are also some additional BC facility milestones with the Vernon Seed Orchard Company celebrating 30 years of activity (see enclosed article) and TimberWest Seed Orchards celebrating 40 years of operations (an article for the next issue). Congratulations!

In terms of extension events, I am hoping that many of you are able to attend the CFGA meeting in Lac Delage, Québec from August 19th to 23rd. A TSWG workshop geared towards our members will be held on Monday, August 19th. The theme for this years' Tree Seed Workshop is **"To reaffirm the importance of cone and seed service activities and identify knowledge gaps"** and the following are the topics that will be our focal points:

1. Crop Training, Development and Collection
2. Cone Crop Challenges
3. Genetic Conservation
4. Storage, Testing, and Seed Preparation
5. Appropriate Facilities and Expertise, and
6. New Tools

These are important and relevant topics with the recent decisions by the Ontario and Manitoba governments to close their cone and seed processing and seed storage facilities. There is also a decreasing number of personnel dedicated to cone and seed science, technology and extension and for many of those still involved, retirement is on the horizon. Many facilities in North America are also dealing with aging infrastructure and many supporting service providers have closed shop. In BC, there have been four processing facilities close their doors during my tenure at our facility. It is a very important function for successful and sustainable reforestation, but a poor business case for investment due to the high initial capital costs and unpredictability of annual cone crops. It is simply an area in which governments who are truly concerned about sustainable forestry should play a part.

It is also with great sadness that I have a list of obituaries to extend to you. Firstly, Heather Rooke passed away on November 1, 2018, rather suddenly. I have included a memorial to her and am dedicating this edition of the News Bulletin to her. Her dedication and contributions to seed science and technology in BC cannot be overstated.

It was another sad day when we learned of the passing of Dr. John Russell who headed up the western redcedar and yellow cypress programs for the BC government. Colleagues provided an appropriate memoriam which can be found in the March-April BC Forest Professional magazine that can be found in this link. I think they said it best, "Occasionally, people casually suggest 'anybody can be replaced.' In John's case, nothing can be further from the truth". See the attached photo of those in attendance for John Russell's Celebration of Life on April 27, 2019.

Attendees at the celebration of life for Dr. John Russell.

Another colleague from the Cowichan Lake Research Station (CLRS), John Ogg also passed away this past year. John retired in 2016 after 36 years with the provincial government, with 31 one of those at CLRS. John was the propagation specialist which is what he loved doing at work and at home.

Jim Corrigan who was the BC provincial Seed Orchard Pest Biologist also passed away earlier this year. Jim was an eclectic individual known for his passion for pest management, curling, fishing and fashion. Jim retired early and was able to realize his dream of living and fishing on the Miramichi River in New Brunswick, at least for a season. A detailed memorial was provided in the Bulletin of the Entomological Society of Canada by his friends. See pages 108–111 in this link.

Dr. Marek Krasowski, University of New Brunswick Professor in Tree Biology and Forest Ecophysiology, passed away in August 2018. I remember Marek's kind nature, pleasure in teaching others and love of friendly intellectual sparring when the opportunity arose. Further details on Marek can be found here.

Last, but not least was Dave Wallinger, who I never worked with, but was well aware of his contributions to cone collecting and tree planting in BC. A common theme amongst those who worked with him was to recognize Dave's helpful and humble nature and that he probably never got the recognition that he deserved for what he made happen. My condolences to others mourning the losses of those above, all taken from us far too soon.

There are also a few notable people from BC that retired recently and I want to wish them the very best after long careers with the BC government. Margot Spence, Seed Policy Officer, retired at the end of May after leading the introduction of Climate-Based Seed Transfer and other initiatives during 28 years of service with the BC government. Susan Zedel also retired after 35 years of service and I will miss her knowledge, dedication and pursuits of efficiency. A hearty 'bossy owl' salute to you – I know you will enjoy retirement and you deserve it. They were two of several recognized by the Association of BC Forest Professionals (ABCFP) as Climate Innovators for the introduction of Climate-Based Seed Transfer. The others are included in the photo and caption below – congratulations to all! In addition to those recognized I'd also like to extend my appreciation to Dr. Tongli Wang for his continued work on climate modeling which was instrumental to this work and many other analyses and projections. Click this link for the latest versions of available programs.

ABCFP Climate Innovator Award recipients (Left to Right: Brian Barber, Jack Woods, Leslie McAuley, Susan Zedel, Margot Spence and Dr. Greg O'Neill).

I'm sure there are other success stories, retirements and unfortunately deaths from across the country from those involved with tree seed. Please consider recognizing those individuals or groups in future editions of the News Bulletin. All the best in 2019 and hope to see many of you at Lac Delage this summer.

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Heather Rooke Memorial

I would like to dedicate this edition of the Tree Seed Working Group News Bulletin to the memory of Heather Rooke who passed away on November 1, 2018. Heather was involved in the BC Provincial Tree Seed Centre (TSC) for 41 years or over two-thirds of its existence as a provincial facility. It will simply be a feat that is never matched again. Heather leaves a deep imprint on the program, facility and people that she was so proud of and it was with great sorrow that we learned of her passing. This was especially painful as Heather had just retired in January 2018 and had gotten married to her long-term partner of 33 years, Steve, in August. Everyone hoped Heather would be able to enjoy life after work with the same dedication, love and energy she brought to the TSC. I'd like to first take a stroll through Heather's career.

Heather attended Selkirk College in Castlegar, BC and

in 1974 she received her Diploma in Forest Resource Technology. She subsequently joined the BC Forest Service, officially out of Williams Lake, but she spent most of her time working and living around Likely, BC. To provide some perspective, her monthly salary was $690, about $30 a day, $3.33 per hour. If she completed (survived) her first season, she would be reimbursed for transportation costs. Some of her early duties included cone crop surveys and seed production area layout, so a "conehead" was already in the making. Her offer of employment also indicated that the Forest Service would supply groceries and a four "man" trailer to live in. The macho nature of the forestry profession, especially in the 1970's, and her lacking an RPF would haunt Heather in various forms for her entire career. I believe this only added fuel to her fire for success and she drew on her intelligence, commitment, integrity, and drive to use those obstacles to prove herself and earn the respect of her colleagues, which she did admirably and with grace.

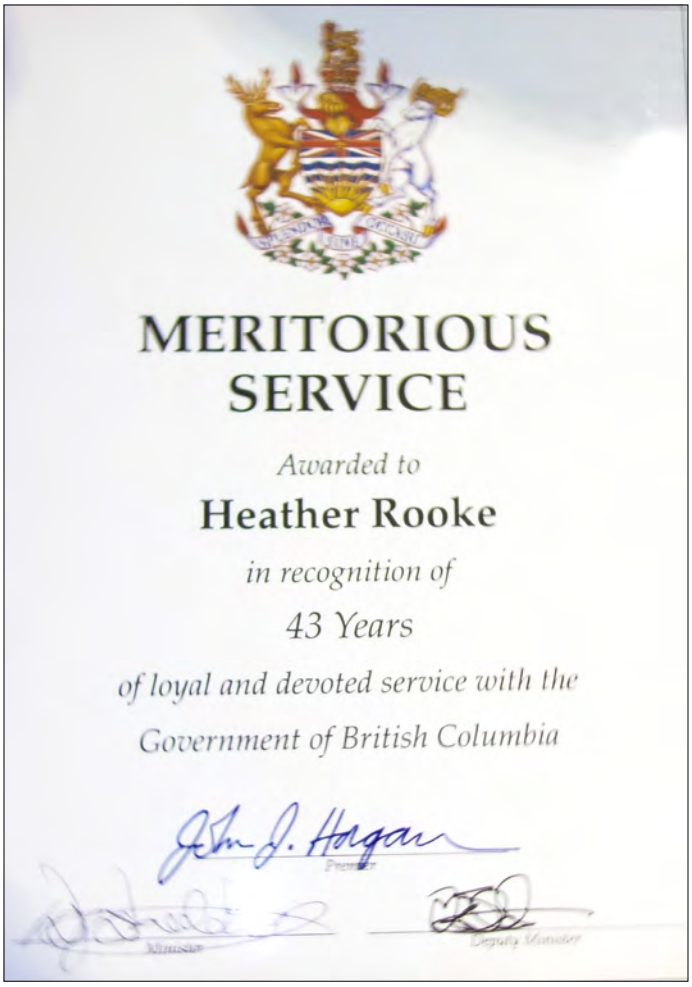
In 1976, Heather was the successful candidate for the Forest Assistant (FA) 3 position at the Tree Seed Centre in Duncan. She worked in various areas, but recalled that some of her greatest joys were on the gravity table, final cleaning of seedlots. This was a processing tool she would be an advocate of for the rest of her career. In 1983, she finally received her

An early photo of Heather from Duncan in front of the mobile seed processing trailer.

FA 4 reclassification, after considerable effort, and in 1986 became the Operations Manager. In 1986, Heather was one of seven TSC staff that made the big move from Duncan to the new, purpose-designed and built Tree Seed Centre in Surrey. As Operations Manager, Heather oversaw the cone and seed processing, testing, storage and seed pre-treatment areas bringing critical thinking and reviews of operational procedures to the new facility. Heather was active in the areas of education and extension regarding the transfer of practical cone and seed knowledge to field practitioners (i.e. Silvicultural Institute of BC, cone collection workshops). From 1992 to 1994, Heather was the acting Manager as Rob Bowden-Green (first official TSC Manager) was seconded to manage, design and implement the new Seed Planning and Registry (SPAR) system. When I joined the TSC in 1992, Heather was my Supervisor and, over the next 26 years, we build a great working relationship based on mutual respect, admiration and appreciation for both our similarities and differences.

In 1999, Rob Bowden-Green retired and Heather won the competition for the new TSC Manager and held this position until her retirement in 2018. In preparation for this next phase of her career Heather was accepted into the Foundation Program In Management for Women at Simon Fraser University. During her tenure as Manager, Heather was pro-active and ahead of the times in developing a TSC Succession Strategy (2009); putting together a Facilities condition report (2016), a new TSC service costing model and reviewing, updating and trying to re-classify all TSC positions. The last speaks highly to Heather's 'staff first' philosophy and although she didn't bat 100%, there are many Managers around who don't even make the effort to go to the plate for their employees. Heather truly cared for each employee – the high performers and those that required a special touch. Heather emphasized and reminded people about the "collective agreement" we are part of and that although we offer valuable cost-recovery services to BC, the TSC still has an incredibly important Stewardship mandate. Heather defended our facility and its stewardship responsibilities with passion and success through the various 'core' reviews different governments had undertaken. She took our Mission Critical status very seriously in ensuring all of the seed for crown land reforestation was secured, which is a key component to sustainable forestry in BC. Heather also listened and learned from our clients in terms of their needs and concerns and it was a key features that illustrated

Heather modeling the "Excellence in Cone and seed Services" vest from BCTSC's 50th anniversary.



MERITORIOUS SERVICE

Awarded to

Heather Rooke

in recognition of

43 Years

of loyal and devoted service with the Government of British Columbia

The meritorious service award that Heather received from the BC premier.

Heather enjoying some of the gifts from her retirement party.

Heather and Steve taking their wedding vows.

the "Excellence in Cone and Seed Services" mantra that she promoted (some may have noticed how this motto base was subsequently copied by many).

Heather was proudest and most comfortable with team recognition and one of her favourite sayings was that "it a takes a village". The TSC nomination for the 2010 Premier's Award was something she truly cherished and she always said being nominated was like winning. Heather was also nominated for the 2010 MINERVA Foundation for BC women in Natural Resources Award for "celebrating Leadership, Excellence and Philanthropy".

On Heather's retirement, I was involved in gathering well wishes from colleagues and friends and two messages were very common – "You have made a huge contribution" and "You deserve to retire with pride for your accomplishments". Heather was a great example of what it means to work in public service and the values we are supposed to embrace clearly described Heather – Integrity, Courage, Teamwork, Passion, Service, Curiosity and Accountability. I'd like to focus on courage as there were many times when Heather took the path less traveled, the one with the most obstacles, the unpopular stance, because it was the right thing to do. She always aspired to take the high road. I know I'll always admire her for not being afraid to go into a room and get a bloody nose (figuratively) for the TSC. I know those that did the same for her were the ones she admired most. It was great to work with Heather and I miss her, our conversations and feel badly that she was not able to enjoy the full retirement she most certainly deserved by being a true public servant for 44 years. Condolences to all others in mourning who were touched by Heather and the loss of a great life cut off far too short.

Dave Kolotelo
TSWG Chairperson

Editor's Notes

Though the Editor's Notes have almost always followed the Chair's, I am breaking with tradition to support the dedication to Heather. I never met Heather in person but spoke with her on the phone several times in her last year as Manager about her role in maintaining the BC Tree Seed Centre's "Mission Critical" status through core review. Reviews of public service value are happening everywhere and honest advice rarely shared as openly as she did. I admired the fire in her voice so close to retirement. My condolences to all who knew everyone Dave mentioned. For the record, I feel it my duty that any who knew Ian Smith, a seed cleaning technician at the Ontario Tree Seed Plant, of his passing many years ago now (2013, looking back on the email from Brian Swaile and Al Foley). Also, long-time Ontario seed collector Ted Cormier passed suddenly the summer of 2017. His efforts and private company, The Seed Source, were relied upon by many nurseries and seedhouses for sourcing common and difficult species. I wish I'd gathered tribute to them sooner.

Reading the latest issue of PRT's rePoRTer newsletter, several notable announcements are the operations at PRT Brighton (Michigan) beginning production, and retirement notices for Mike Wood (Great Lakes) and Marilyn Curtis (Coastal BC). We wish them and their successors the best.

Now to my editorial responsibilities. Dave and I are working hard to get the Bulletin publication schedule back on track. The contributions received are greatly appreciated. We also have leads on a number of excellent topics for the next issue but don't hesitate to get in touch with us. I know many programs are stretched to the limit with resources and time to participate in extracurriculars, my own included. I do want to impress upon readers that while the Forest Gene Conservation Association (FGCA) is supportive of my efforts with the Bulletin, I compile this on my own time and receive no compensation or IT support. I do it for the sake of information hard to find elsewhere, to gain technical writing skills and contribute in my small way. Hearing from you lets me know the extra effort matters.

Thank you to the initial responses to our 2019 TSWG Membership Survey and renewed Directory Listing. We decided not to publish the new listing just yet as there are only 44 responses out of 295 email contacts who receive our Bulletin, and many Canadian provinces and operational facilities lacking representation. Please represent yourself, whether private business or public service: https://forms.gle/eMkN6jxNZa9iQwrN7

As per a core TSWG mandate, a section of the survey asks members to rank their current and short-term operational and research priorities. Managing seed collection labour shortages is currently tied with upgrading seed storage practices from all respondents but we'd like more regional

votes. How to address these challenges will be discussed August 19th at our TSWG Workshop and add direction for future Bulletin content or themes. For those unable to attend, we will post the presentations online after the Workshop, and ideas for virtual extension between Conferences are brewing.

There are also questions and space for feedback on the Bulletin (also a test so we know who actually reads it!). Overall, everyone is quite happy, especially about the diversity of topics, practical application and research extension service. A few areas of improvement we want to address, but again, need the experts within membership to continually help us with:

- A greater geographic diversity of articles
- Advance notice of seed-related conferences with enough time ahead of registration (this is always a challenge)
- Recent publications, reports and relevant student theses (it helps when researchers send me their recent peer-reviewed seed publications)
- More articles related to hardwood seed challenges
- Ensuring the sense of community continues with retirements, facility closures and staff turnover. This means that if you are vacating a seed or genetics position for any reason, ensure your successors subscribe!

Immediately I can say we have checked off the first request, with this issue featuring content from Illinois, Quebec, Alberta and BC, and several updates from Ontario policy and programs. I am remiss there is not a National Tree Seed Centre (NTSC) update but I am sure Donnie McPhee's next submission will be substantial.

I was fortunate to attend Lindsay Robb's Seed Conservation Course at the Alberta Tree Improvement and Seed Centre (ATISC) in March 2019, along with Mark McDermid of Forests Ontario. Lindsay's course was a detailed look at the how and why of Alberta's seed quality and conservation standards, firmly rooted with data gathered from their long-time reference collections. For me, elements of the Millennium Seed Bank's course were reinforced with more familiar species and the hands-on labs (Figs. 1 and 2) featured a larger variety of seed types than I teach with in Ontario. As reclamation volumes of native seed increase, tree seed experts may be asked to provide advice so trouble-shooting unfamiliar seed morphology was a great exercise. I hope

Figure 1. Sam Fischer of Grasslands National Park (Parks Canada) examines cut tests under the microscope at the Alberta Tree Improvement and Seed Centre, March 8, 2019.

Figure 2. Comparing a cut test of *Viburnum trilobum* to Martin's (1946) internal morphology diagrams (inset) helped those new to cut testing identify healthy embryos, especially when endosperm is not characteristically white.

ATISC can continue to offer this fantastic technical course.

Lastly, there have been interesting developments in post-secondary institutions and programs investing in seed technology and applied research. Congratulations to the Northern Alberta Institute of Technology's (NAIT) Boreal Research Institute (BRI) on their $1.75 million grant towards their Plant & Seed Technologies Technical Access Centre (TAC) in Peace River, Alberta.

- NAIT Announcement here
- NSERC Announcement here

This TAC will focus on gaps in research, seed supply and deployment for a suite of native restoration species in northwestern Alberta and neighbouring BC First Nations communities, complementing foundational work done by the Oil Sands Vegetation Cooperative in the northeast since 2009. For example, the BRI released a Technical Note #27 (2019) for seed pelleting protocol for many small seeded-species, including willows (*Salix* spp.) and poplars (*Populus* spp.) to add to their list of accessible resources.

Kwantlen Polytechnic University's Seed Program may be in support of the organic agricultural seed production sector, but student exposure to a range of small-scale seed processing equipment and water activity tools may have potential spillover to our group. Sir Sandford Fleming College's School of Natural Resources and Environmental Sciences (Lindsay, Ontario) has also recently purchased some new and used seed equipment to supply their own seed for propagation labs and had faculty trained in FGCA's Certified Seed Collector program February 2019. We wish all these institutes the best in bringing on the new crop, with a wise caveat to keep connected to current industry needs and employment trends.

Reference

Martin, A.C. 1946. Comparative Internal Morphology of Seeds. American Midland Naturalist 36(3): 513–600.

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Vernon Seed Orchard Company (VSOC) Celebrates 30 Years of Operation

Vernon Seed Orchard Company (VSOC) has recently celebrated 30 years as a seed supply company. It is a joint venture company owned by Canadian Forest Products Ltd., Winton Global Lumber Ltd. and West Fraser Mills Ltd and operates seed orchards at two sites in BC–Vernon with 13 orchards and Quesnel with 3 orchards, with more being planned for this site. The success of VSOC is a result of its long-term collaboration with industry, Government and other partners like Select Seed Ltd. Seed produced by VSOC has produced close to a billion trees for reforestation in BC! The company's success is a testament to the ongoing commitment and strength of tree improvement In BC and it's improved seed that helps BC deal with its current timber supply issues caused by the mountain pine beetle and heavy fire years. In addition to our current workforce pictured below, I would like to recognize Ron Pearson and Tim Lee, former VSOC Managers, who were instrumental in building the foundations for our success today. VSOC looks forward to continuing and expanding operations to meet the seed demands of its partners and others in BC.

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The 30th Year Celebration at the VSOC Site in Vernon, British Columbia. Photo by Dave Kolotelo.

Current VSOC employees left to right: Tony Miedema, Tia Wagner, Angie Mendes, Grace Doesburg and Dan Gaudet.

An Operational Seed Dryer Ruled by Water Activity

Since nearly a decade, interest has been increasing in water activity (A_w) or equilibrium relative humidity (eRH) applied to forest tree seed. At the Berthier Tree Seed Centre, we converted our Hilleshög dryer (final drying), to "dry" with relative humidity instead of heat. This allows us to avoid over-drying of our seedlots, and better organize our work, since seeds can be left in the dryer for a night without harmful consequences.

For small seeds samples, and for pollen, we used a dryer ruled which concept was designed by Patrick Baldet (see Baldet and Colas 2013 for details). This equipment is very efficient and cost effective. The disadvantage is the need of a saturation tank, i.e. a pressured cylinder. Regulations for the use of such device can be restrictive depending on the jurisdiction, since it raises health and safety issues. Also, the eRH delivered depends on the water level in the tank, and it changes over time, especially if the use is prolonged, and the cabinet is often opened. The need for compressed air required also a lot of energy.

Daniel Desrosiers, who works at the Tree Seed Centre as a mechanic, proposed a new dryer that uses the air of the room where it is installed. Daniel converted an old G30 Conviron chamber (Fig. 1) where he left the bottom fan and a new switch was installed (Fig. 1a). First he installed an Omron controller (Fig. 1b) connected with a solenoid (Fig. 2) which controls a humidity probe inside the cabinet (Fig. 3). On the screen, eRH target appears in green, and the ambient value in white (Fig. 4).

When the eRH in the cabinet is lower than the target, which is usually 30 to 40% (0.3 to 0.4 of A_w), water is sprayed through a micro sprinkler (Fig. 5), installed at the bottom of the cabinet, connected to the electric valve. The fan distributes the humidity into the cabinet, until the reach of the target. At that point, the solenoid switches off.

When the eRH is too high, the fan circulates the humid air that will be evacuated through the two outlets on the side (Fig. 1c). To ensure the air circulation, the original Conviron shelves were replaced by wired shelves from a refrigerator or Permafil (see Parts List, and Fig. 1e).

The advantages of such a dryer are: high accuracy of the eRH requested, no compressed air required, a single small motor ($\frac{1}{16}$ hp) that runs instead of four large motors on the Hilleshög continuous dryer, and re-use of an existing unit.

But, this device works with ambient air, if its eRH is high (i.e. >50%), we cannot reduce the eRH of our seed samples. Therefore, we can use it only when the building's heating is on (the eRH is then quite low). This is just enough for our needs.

Figure. 1. The modified G30 Conviron chamber for use as an operational seed dryer, showing a) the power switch, b) display of the water activity in the chamber, c) outlets for humid air evacuation, d) location of the Omega HX71-MA water activity humidity probe and, e) new wire mesh shelving from Permafil.

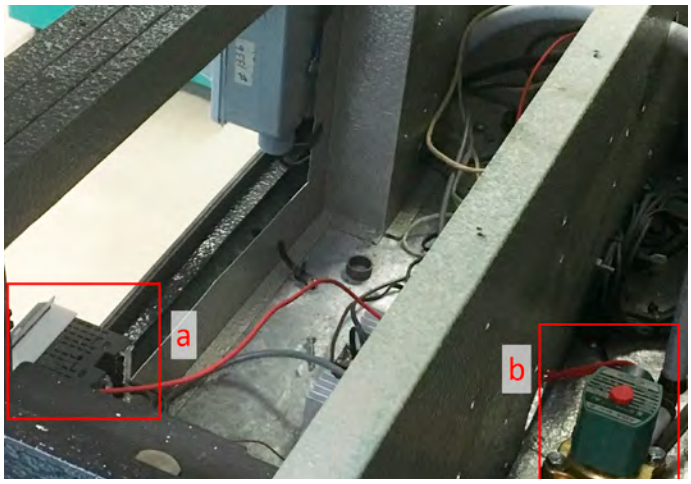

Figure 2. The new Omron E5CC RX3A5M digital controller connected to the Asco Red Hat 8210G009 solenoid, which controls the humidity probe inside the cabinet.

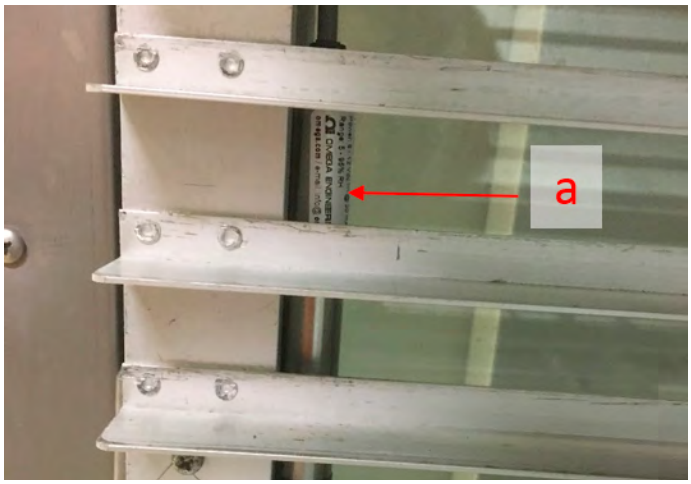

Figure 3. Location of the Omega HX71-MA water activity humidity probe.

Figure 4. A display reads the ambient eRH (%) value in white (above) and target eRH (%) value in green.

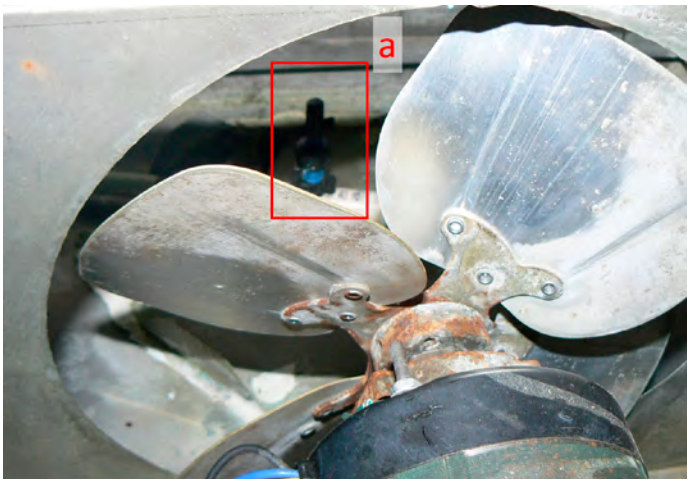

Figure 5. Water is sprayed through a microsprinkler (a) when the eRH in the cabinet is lower than the target.

If you need more explanations on the building of this dryer, please contact us.

Parts List and Prices (in CDN dollars)

- Digital controller Omron E5CC RX3A5M ≈ $300.00
- Humidity probe Omega HX71-MA = $148.00
- Solenoid Asco Red Hat 8210G009 ≈ $200.00
- Shelves: https://permafil.ca/en/domestic-storage/shelves/

References

Baldet, P. and F. Colas, 2013. A water activity-regulated dryer: how to dry seeds or pollen with water and no heat. Tree Planters' Notes 56 (2): 43-49. http://www.rngr.net/publications/tpn/56-2

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Using Provenance Test Data to Update the 'Local is Best' Seed Use Mantra

For over 100 years, the use of properly sourced tree seed has been known in Canadian forestry circles as an important part of artificial regeneration. Farrar (1969) reported Canadian foresters were exposed to European and American ideas on the importance of seed origin prior to the 1920's. Thrupp (1927) called for scientific seed collection as the basis of Canadian silviculture of the future. Thrupp speculated demand for local seed would occur once forest managers realized the benefits of using seed obtained from a climate similar to their planting sites. Bates (1929) reported to the Canadian Society of Forest Engineers in Winnipeg that at least half of the plantings in the United States using "any old seed" were without future promise. In speaking about seed transfer, Bates predicted "almost certainly the general outcome of a better knowledge of the matter will be to restrict the transport of seed to comparatively short distance." Although not using the term, these early authors were espousing a local-is-best (LIB) mantra for seed supply.

Despite Bates' warning, Canadian foresters showed little interest in seed quality as there wasn't a large tree planting program in Canada until the late 1950's and early 1960's (Holst 1962). In parallel with increased tree planting, jurisdictions began adopting seed transfer rules such as Ontario's broad seed zones based upon Hills (1959) site regions. Other jurisdictions in Canada adopted similar seed transfer and quality control regulations, periodically updated, to ensure better adapted seedlings were planted.

Further research confirmed the LIB policies. Using early results from range-wide provenance tests, Carlisle (1970) found local adaptation to be a safe and sure way to grow seedlings that would survive and provide the benefits one expects from planting trees. Yeatman (1976) provided a more detailed analysis concluding 'local is best unless proven otherwise'. Wang and Szikai (1969) argued seed accounted for such a small portion of the investment in artificial regeneration it didn't make sense to risk the future forests by using maladapted seed sources. The volume of tree seed collected, processed, and used for artificial regeneration is in the billions. For example, by 1975 Ontario was using approximately one billion tree seeds per year in its reforestation program (Lane 1976). Morgenstern and Wang (2001) reported approximately 2.5 billion tree seeds were collected in Canada in 1999. In 2018, the Ontario Tree Seed Plant held 778 seedlots containing 5.2 billion viable seeds documented by seed zone. The enshrining of LIB in the policies of various agencies greatly impacted seed collection, handling, and distribution.

Foresters are often said to be looking 40 years to the future and on that horizon climate change looms large. McKenney et al. (2009) indicated substantial changes in temperature and precipitation have already occurred in many Ontario seed zones with more change predicted. Changes in climate are expected to exceed the pace of natural migration rates for northern trees species (Pedlar and McKenney 2017). Pressure has been growing to transfer seed from the south to the north in conflict with LIB policies (Ste-Marie 2014).

To evaluate climate change impacts on seed transfers, scientists turned to the same provenance tests that provided the proof for LIB. Many of these provenance tests were established starting in the 1950's under the lead of the Genetics and Tree Breeding program at the Canadian Forest Service's (CFS) Petawawa Forest Experiment Station and implemented with a long list of collaborators. Maintenance, upkeep, and remeasurement has been sporadic as program priorities and budgets changed. Peter Copis of Petawawa and Dale Simpson of the National Tree Seed Centre became the long-term keepers of the records.

In 1999, a gathering of provincial and federal experts was held at Petawawa to, "examine the possible uses of provenance tests for predicting and quantifying the impact (both positive and negative) of future climate change. A perceived missing niche from currently funded climate change work is future forest management; how to take advantage of and/or adapt managed forests to future climate," (D'Eon, 1999). Gerald Rehfeldt distributed an unpublished report titled "Idle Thoughts – Provenance Testing" that stated, “Nowhere else in the biological sciences are there tests established in multiple climates within which populations have been transferred varying distances along the climatic gradient.”

In the early 2000's Bill Parker and his students from Lakehead University in cooperation with the Ontario Forest Research Institute (OFRI) along with the CFS took up the challenge and measured and analyzed three of the provenance test series focusing on Ontario sites: the 255

series in jack pine (established 1966), the 353 series in black spruce (1974), and the 410 series white spruce (1985). The partnership between Lakehead, OFRI, and CFS led to ten journal papers, four non-peer-reviewed reports, and two masters theses. More importantly the work demonstrated the potential for evaluating seed transfer for climate change (Thomson et al. 2009, Yang et al. 2015). Results sometimes show dramatic differences between where a seed source currently performs well and where it is expected to survive and grow well under future climate change scenarios.

Seed transfer policy has been cautiously progressing. As of 2011, the general philosophy for Ontario's Crown forests remained LIB, "local seed sources will be best adapted to an area, regardless of the effects of global climate change" (Eskelin et al. 2011). Six years later provenance tests were providing some of the evidence for policy makers to reassess seed transfer guidelines (pers. comm. Betty Van Kerkhof, OMNRF, Dec. 2017). Elliott (2017) indicated the policy was being updated, "Policy Division has an 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". Ontario expects to soon post for public review a new policy using dynamic seed zones founded upon the provenance test re-measurements.

The 'Local-is-Best unless proven otherwise' mantra, has served Canadian reforestation needs for over 50 years ensuring deployment of properly sourced planting stock. But as Yogi Bera once said, "the future ain't what it used to be." The implementers of the provenance trials probably envisioned their experiments impacting good seed management in the past century (the 1900's), but I doubt they envisioned the same experiments would make an entirely different impact in the current century (the 2000's). Writing about CO^2 and forests, Pollard (1985) stated, "... it would be a brave forester indeed who volunteered new silvicultural prescriptions, particularly seed sources for our planting programs, for the twenty-first century." The 21st century has come and we are already 19 years in. Pollard's "brave forester" is emerging.

Tree seed specialists and foresters across the country acting to mitigate the impact of climate change should salute the wisdom of the researchers who designed provenance experiments, the efforts of the technicians that implemented the designs, and the dedication of those that kept them up these many years. Personally, I had the honour of working with many of the people referenced in this paper. For that I am forever grateful.

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Development of Climate-Based Seed Transfer Policy in Ontario

In 2017 Ontario updated the Forest Operations and Silviculture Manual (FOSM), one of four regulated manuals mandated by the *Crown Forest Sustainability Act*. FOSM now includes a section on Forest Genetic Resource Management (FGRM) that replaces former paragraphs on Seed Zones. The FGRM section makes provision for updating seed zone policies as well as developing policies on other aspects of forest genetic resource management. The FGRM section states that: "Managing genetic diversity, and ensuring an effective planting and direct seeding regeneration program, requires the use of well adapted plant material." It also notes that "movement of tree seed and stock beyond defined seed transfer areas may be necessary or desirable to respond to challenges such as seed supply shortages, or as part of a climate change adaptation strategy".

Ontario currently has a system of fixed breeding zones for its improved seed and fixed geographic zones for its wild seed to ensure seedlings are planted where they are adapted to growing conditions. However, a changing climate may result in a mismatch between where tree seed is collected and where optimal growing conditions will exist as trees mature. Ministry of Natural Resources and Forestry (MNRF) has been collaborating with the Canadian Forest Service, using advances in science to explore a modernized seed transfer approach for Ontario such that seed sources and planting locations have a reasonable probability of producing trees that are adapted to their growing environments now and in the future. Some of the areas of exploration include:

- Examining the similarities and differences between the climate at seed collection sites and projected future climate at seed deployment sites;
- Using historical forest genetics trials to help assess risks to survival and growth of moving tree populations too far or too soon given the uncertainty associated with how the climate will change and how trees will respond over the course of the coming century; and
- Continuing to collect, analyze, and report on field trials examining the ability of various seed sources to adapt to sites with differing climate conditions.

Ontario continues to provide support through the Forestry Futures Trust to the three regional forest genetic associations that manage the province's forest genetic assets. This includes funding for staff and projects. Project work includes the establishment, maintenance and measurement of genetic tests or archives, management and pest control in orchards, establishing assisted population migration trials, and information management.

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Seed Challenges with North America's Largest Municipal Tree Planting Program

In 2004, The Green Legacy® Programme was just a simple idea to plant 150,000 trees to celebrate the County's 150th anniversary. That idea has grown to over two million trees planted in the County of Wellington by community partners, making it the largest municipally-funded tree-planting program in North America.

The Green Legacy Programme aims to increase the amount of forest cover in Wellington County from 17% currently to a respectable 30–35%. To do this, seven staff (four full-time) work with volunteers to grow and distribute free seedlings to private landowners, schools and community groups, Conservation Authorities, and our member municipalities. The program operates two nurseries, the Bradford Whitcombe Green Legacy Tree Nursery, located in Puslinch, Ontario, and the Northern Green Legacy Tree Nursery, located in Damascus, Ontario. We are proud to have 100% of the Wellington County elementary student population (Kindergarten to Grade 8) participate in our program and learn what it takes to grow trees from seed. We annually propagate and offer over 200,000 conifers and 60,000 hardwood seedling plugs, and 10,00 larger potted trees to our community (Fig. 1).

The Green Legacy Programme had been a dedicated client of the Ontario Tree Seed Plant (OTSP) since 2006. It acted

Figure 1. A diversity of native potted hardwoods and conifers, grown from Ontario Seed Zone 32, 33, 34 and 37 seed sources, at the Wellington Nursery. Photo by Melissa Spearing, 2012.

as our primary seed source for conifer seeds of white spruce, Norway spruce (Fig. 2), eastern white pine, red pine, eastern white cedar, tamarack, and European larch, since we cannot process cones on site. On occasion, we purchased hardwood seeds that were more difficult to source, because of either poor local seed production or a lack of accessibility to trees.

The closure of the OTSP has and will continue to greatly impact our program. It's not just about losing the ability to purchase the final product. What was one simple step of placing an order, is now many tasks. It takes a significant amount of time sourcing, forecasting, collecting, drying, extracting, cleaning, and then storing seeds, which is now our responsibility to complete in-house or out-source to various people/places. Being able to place an order, have choice of selection and know the quantity and quality for sowing the upcoming season was invaluable to organizations like ours working with limited resources.

In response to hearing of the OTSP closure, in the fall of 2017 we collected our own spruce cones and set out to see what we could manage ourselves. Finding a suitable location with the right temperature and humidity level to allow the cones to dry and open proved to be difficult, as we have extremely limited heated space. We transferred trays around to various buildings to accommodate other needs of the facility. We even resorted to filling our heated washroom facilities. Once dried, the cones were further processed (by volunteers, shaking by hand over screens) to give a reasonable yield. Now we know what is possible, but is it the best use of our time? Luckily, we were able to

Figure 2. Norway spruce (*Picea abies*) seed is artificially stratified in the cooler, seeded with a seeding machine into Styroblock 160/90mL and covered with mulch.

Figure 3. Black walnut (*Juglans nigra*) seed is dehusked, washed, artificially stratified then sown in bulb crates. Successful germinants are then transferred by hand to Styroblock 28/340mL for growing on.

purchase additional seeds from the OTSP surplus sale that will hopefully keep us going for the next couple of years. That being said, we are just buying ourselves a little time while we continue to look for a feasible solution.

Beyond the conifer seed purchased from OTSP, the remainder is collected by staff and a few volunteers. Many of our hardwood seed sources are located within the County of Wellington or further south of us. As seed is collected, it is cleaned, processed, and stratified on-site at our nursery in Puslinch. We clean most of our seed using a conventional blender or Dybvig seed cleaner and store it in our 2.4 m x 3 m walk-in refrigerator at 2°C. Seed is sealed in a heavy plastic bag, placed inside another plastic tub. We joined the Tree Seed Working Group to learn more about extending seed life and better storage, with the best low-tech solutions available.

Native species diversity is very important to us, and appealing to our clients. Being close to the northern edge of the Carolinian Forest region, our area is becoming ideal for establishing more Carolinian species. Our regular inventory includes species such as hop tree (*Ptelea trifoliata*), Kentucky coffeetree (*Gymnocladus dioicus*), Ohio buckeye (*Aesculus glabra*), redbud (*Cercis canadensis*), and tulip tree (*Liriodendron tulipifera*). The selection of other available hardwood species varies each year and could include birch (*Betula* spp.), elm (*Ulmus* spp.), hackberry (*Celtis occidentalis*), locust (*Gleditsia triacanthos*), maple (*Acer* spp.), hickory (*Carya* spp.), oak (*Quercus* spp.), and black walnut (*Juglans nigra*, Fig. 3).

In closing, the longevity of this program is a testament to the community that supports it, and the reality that increasing and diversifying forest cover takes a long time. Most importantly though, this program is fostering a new generation that has an understanding of and hands-on experience with investing in healthy forests in their community.

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A Bumper Whitebark Pine Seed Collection in British Columbia

Cone collections form the foundation of recovery for whitebark pine (*Pinus albicaulis*). Although the species has been listed as endangered under SARA since 2012, there was very little seed available to support recovery and restoration planting. 2018 was a good to excellent seed year for whitebark pine at many locations across its range in BC, and major collections were made in the southern and northern Interior. Attempts were made to collect from areas where no collections had previously been made in order to increase the diversity of seed in the provincial rust screening and gene conservation programs. As a result, the BC Tree Seed Centre now has significant collections of registered and unregistered seed of this endangered coniferous tree species.

Methods

In all cases, collections were from putatively resistant trees, that is, healthy trees in highly infected populations; thus, even if trees were not tested for rust resistance, the probability of some level of resistance in the seedlings was increased.

To collect cones, a multi-phased approach was required. As the cones are highly sought after by wildlife, cones must be caged early in the summer to protect them from these foragers. Once the seed inside the cones has matured, the trees are revisited and the cages along with the cones are removed.

In early summer, once a candidate collection tree was identified it was surveyed for rust to ensure it was in the healthiest cohort of the stand. The tree was then climbed, and cages were affixed around cone clusters (Figs. 1 and 2). All climbing was done using a safety harness and lanyard when above 2 m, and in some larger trees, rope access and egress was required.

In mid-September, cones were collected and cages retrieved. Cone sacks were stored in racks with good airflow for a six-week drying period (Figs. 3 and 4).

Once cones were dried, seeds were removed by hand by "shucking" seeds out of each cone; seeds were then dried down further by airflow over seeds trays (Fig. 5); and were then air separated to remove debris and empty seeds (Fig. 6). Since whitebark pine is a wingless conifer seed, dewinging is

Figure 1. Placing cages on cones with appropriate safety gear in place. Photo by Don Pigott.

Figure 2. Cone caging, showing typical whitebark pine habitat. Photo by Don Pigott.

Figure 3. Sacks of cones with good air circulation prior to seed extraction.

Figure 4. Cones laid out to dry, note screens on top to protect cones from rodents.

Figure 5. Drying whitebark pine seeds in a single layer on mesh screen.

Figure 6. Air separation of debris and empty seeds using a zig-zag aspirator. Photo by Sybille Haeussler.

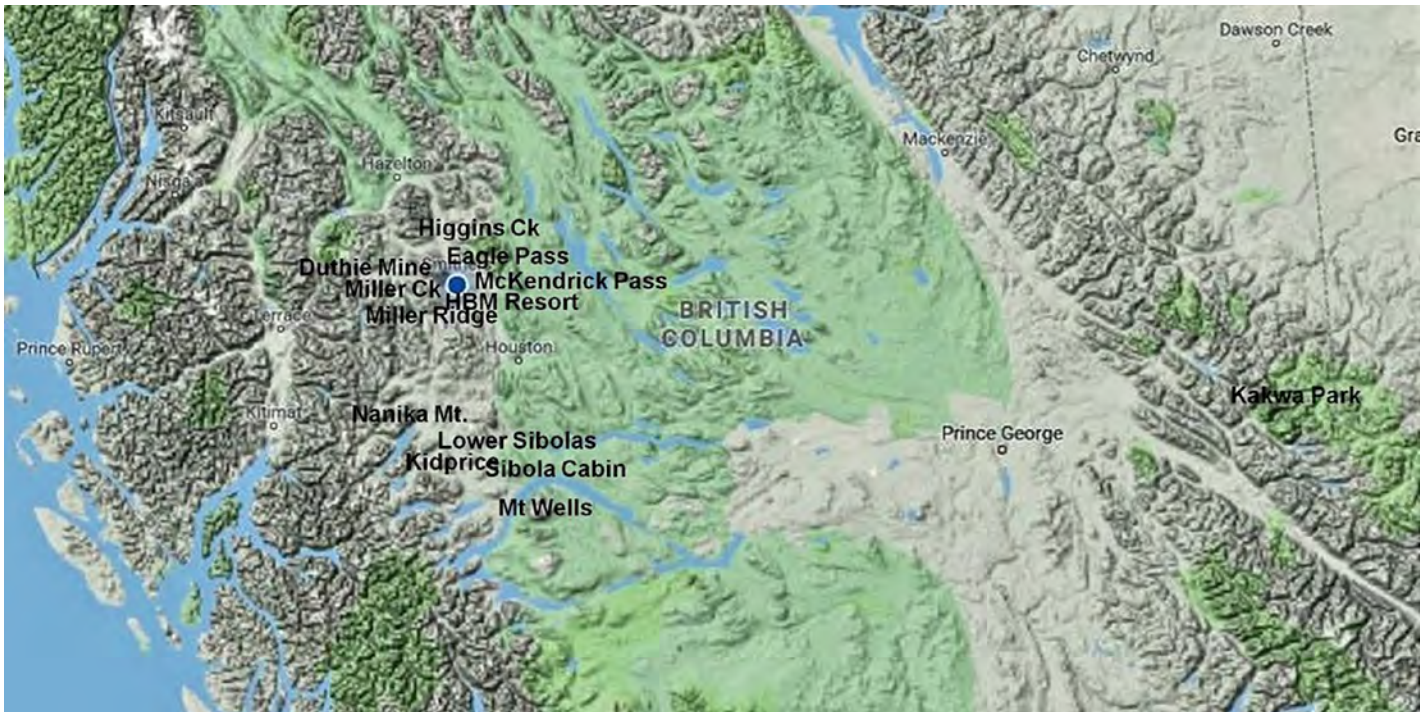

Figure 7. 2018 whitebark pine seed collections from the Skeena Region and Kakwa Park, British Columbia.

not part of the seed cleaning process. Simultaneously during this process, seed samples were shipped to the BC Tree Seed Centre to test for water activity to ensure appropriate moisture content prior to storage. Seed destined for storage were sent to the Tree Seed Centre for Provincial Registration and Storage; seed to be put into seedling production were sent to nurseries for seed stratification and seedling production.

Results

Northern BC

In the southeastern Skeena Region the Bulkley Valley Research Centre, based in Smithers, collected seeds for use in four Provincial Parks as well as for other users on Crown forest lands outside of the parks. Seeds were collected at 12 locations in the ESSFmc and ESSFmk biogeoclimatic subzones[1] extending from northern Tweedsmuir and Morice Lake Provincial Parks south of Houston, to Babine Mountains Provincial Park north of Smithers (Fig. 7). Most collections were made within the territories of the Wet'suwet'en Nation with the support of the Office of the Wet'suwe'ten.

In total, the 2018 Skeena Region whitebark pine seed collection involved five certified arborists, 34 part-time workers and 31 volunteer or in-kind participants. We installed 1,899 cages on 108 apparently rust-resistant trees, harvested 9,220 cones and extracted 483,000 seeds of which approximately 385,000 are currently stored at the BC Tree Seed Centre for restoration use. Total seeds per cone averaged 53; filled seeds per cone (after blowing) averaged 42. A smaller collection of whitebark pine seeds led by Kevin Hoekstra was also made in the Omineca Region at Kakwa Provincial Park (Fig. 7) from five trees showing no sign of blister rust infection.

Southern BC

Cones were collected from 41 sites and 16 subzone/variants in the IMA, ESSF and MS biogeoclimatic zones across southern BC (Fig. 8) and a documented total of 373 trees[1]. An estimated 950,000 seeds were extracted. The number of seeds per cone was 30–40% higher in southern than in northern BC, ranging from 53–78.4 with an average about 64.5 seeds per cone. Seeds from 15 sites were submitted to the Tree Seed Centre for registration. To meet the registration requirements, a minimum of ten collection trees were required. Seed from 33 trees were also sent to the provincial rust screening program in Vernon, BC.

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

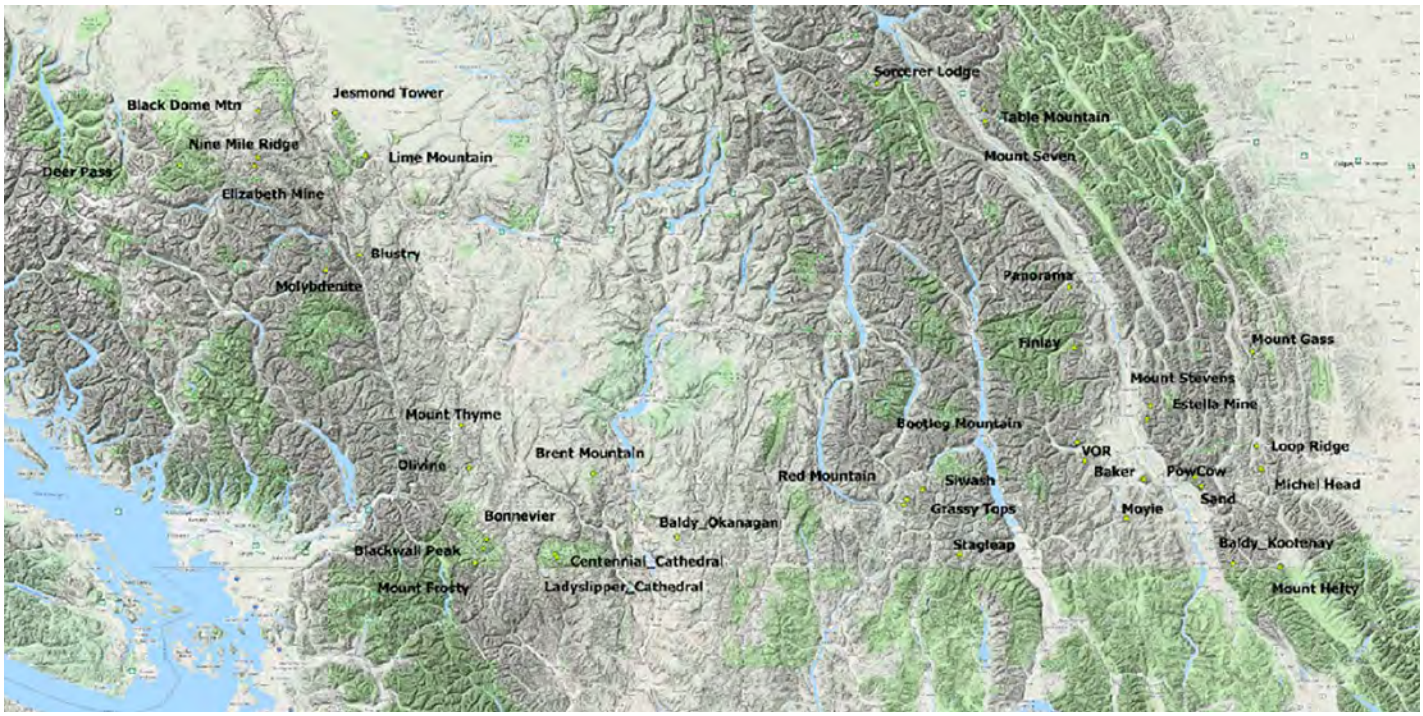

Figure 8. 2018 whitebark pine seed collections from southern British Columbia.

Potential Seed Uses

The seed collected this year will provide a sound foundation for several years of recovery and restoration work. The following seed uses are recommended:

- Rust screening: seed collected from high rust stands should be submitted to blister rust screening programs. A small selection of seed has already been submitted.
- Provenance trials: to determine growth and environmental tolerances should be conducted to aid in refining seed transfer zones.
- Gene conservation: seed should be contributed to the provincial gene conservation program based on identified gaps.
- Operational restoration: seed should be used for both dedicated whitebark pine recovery and industrial needs such as post-timber harvest planting and mine reclamation work.
- Carbon capture: whitebark pine may be an important carbon capture species as it occupies locations typically inhospitable to other species and it is non-merchantable thus is unlikely to be harvested in the future.

Acknowledgements

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Alberta's 2018 Endangered Pine Seed Collection and Restoration Planting for Recovery

Seed collections from plus trees: logistics, new cages, challenges, results

To support implementation of the Alberta recovery plans for whitebark and limber pines, seed collection was a priority for the 2018 field season as 2017 field surveys indicated a good potential crop. Logistics were coordinated based on these prior year field surveys. These two species have strong masting behavior, where there is only a collectible cone crop every 2–4 years (limber) or 3–5 years (whitebark). No confirmed pattern or cause has yet been identified to enable planning beyond the prior year.

Because of their very large and nutrient-rich seeds, animal predation is ubiquitous on these species. Cones must be protected by installing wire mesh cages early in the season (May to August), and then collected when mature (after mid-September). We found no uncaged whitebark pine seed remained in the fall, everything had been eaten. Their montane and subalpine habitat make access a costly challenge with safety risks, since each tree must be accessed by driving, flying, and/or hiking and then climbed twice. All field staff are certified in technical tree climbing methods. Parks Canada and ArborCanada coordinated a training program and supported Alberta crew attendance in 2018 at Jasper National Park where mountain pine beetle protection and collection is urgent (Fig. 1). The team also developed a train-the-trainer program for whitebark pine technical tree access and rescue methods in 2019 that Jodie attended with partnership program support of Parks Canada (Fig. 2). The resulting equipment lists and safe work procedures have been adopted as occupational safety and hazard control methods.

Seeds were collected from 100 limber pine and 13 whitebark pine plus trees that were identified during earlier surveys based on tree and stand health data (i.e. healthy trees in highly blister rust infected stands) (Fig. 3). Each plus tree was re-assessed for health before caging. A couple plus trees succumbed to repeated severe summer drought (Fig. 4). Where putative plus trees had new cankers, these were updated for health status in the provincial database, and no

Figure 1. Verbenone and green leaf volatiles for mountain pine beetle protection in Jasper National Park.

Figure 2. Climbing safety training.

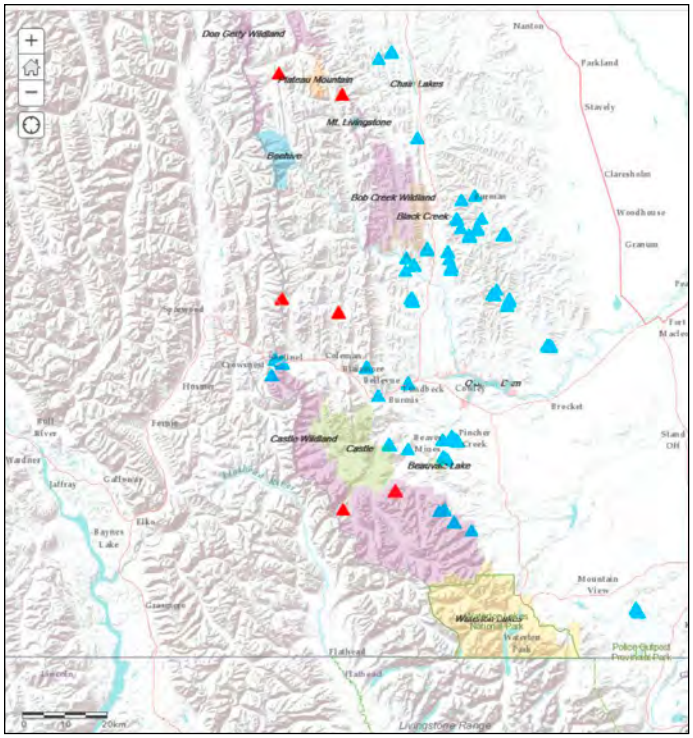

Figure 3. Map of trees assessed in 2018. Red triangles are whitebark pine, blue triangles are limber pine.

Figure 4. Limber pine plus tree drought mortality.

Figure 5. Caged whitebark pine cones.

new seeds were collected. Where these trees already have seeds in blister rust screening, the results will be tracked to ascertain if the parent trees have elevated levels of heritable rust resistance compared to susceptible trees. If they do, seed collections will continue. If not, these trees will be dropped from the plus tree database. Screening takes around seven years from when seed is sent to when final results are received.

Alberta developed a new method to quickly build durable rectangular box cages out of light gauge spot welded ⅛" mesh hardware cloth, stapling the sides and zip tying the tops (Fig. 5). All cages installed remained securely on the trees until cone collection, beginning in late September, and no cages were damaged by animal predation. The finer mesh is essential for limber pine, whose cones open upon maturity, releasing seeds. The cages are large enough so cones were able to properly develop, which had been a problem with smaller cage designs.

Altogether roughly 5,000 cones, yielding 175,000 limber pine and 15,000 whitebark pine seeds were collected (final numbers pending). These seeds will be used for provincial genetic archiving ex situ, restoration planting in priority sites, and sharing with researchers for projects consistent with recovery plan objectives.

Restoration planting with plus trees

In fall 2018, 1,050 limber pine seedlings that had been screened for single gene and multigenic blister rust resistance at Dorena Genetic Resource Center were returned to Alberta and planted in a paired monitoring trial in southwestern Alberta, half in Waterton Lakes National Park and half in Castle Wildland Provincial Park, a joint effort by Parks Canada and Alberta. Thanks to the USDA Forest Service for returning these very valuable seedlings. The severe and extensive 2017 Kenow fire burnt 70% of the forested area of Waterton, including extensive areas of whitebark and limber pine, many plus trees and restoration plantings. Annual and periodic monitoring of these high value restoration seedlings will inform future restoration methods.

Another 8,000 limber pine plus tree seedlings are planned for planting fall 2019 in various stands in need of restoration. Monitoring has identified numerous sites in the region where mortality and rust levels are high and regeneration is absent, reflecting the cumulative decline of some stands past their ecological tipping points where the obligate avian seed dispersal agent Clark's nutcracker will not return to stands that have low cone bearing potential. These stands cannot recover without active intervention and will convert to other habitat types that cannot support whitebark or limber pine.

Recovery planning update

Following the release of the draft federal recovery strategy for whitebark pine, Open Standards recovery planning workshops were held in early 2018, and followed to completion in spring 2019. Stakeholders responsible for implementing recovery and developing recovery plans in Canada identified recovery targets, objectives, and steps required to achieve the desired outcomes.

Alberta is currently updating the separate species recovery plans into a combined, updated 10-year plan. The Open Standards workshop outcomes are reflected in this plan.

Seed orchards

A major gap identified during recovery planning is the need for seed orchards of screened plus trees to produce operational amounts of seed for each seed zone and species that will have durable resistance. A workshop to assess seed needs, plan for seed orchard development, and identify agency responsibilities is anticipated in fall 2019. These species have broad adaptive ranges so there are good opportunities to share resources among agencies, including germplasm and facilities.

Several agencies, including Alberta, have collected scions from plus trees in anticipation of seed orchard establishment. Whitebark pine scions have been grafted at Kalamalka Forestry Centre. Limber pine scions have been grafted at Alberta Tree Improvement and Seed Centre. Bonnyville Forest Nursery is planning to also begin grafting in the coming years as rootstock matures. While five-needle pines are generally cross-compatible, results tend to be most durable if the rootstock and scion have generally similar phenology and growth rates. In 2018, Alberta collected scion material from 30 limber pine and 14 whitebark pine plus trees for grafting. Scions were collected during cone collection to minimize access costs and safety hazards related to winter scion collection.

Grafted orchards have several benefits: valuable, rare disease-resistant (or tolerant) genotypes are duplicated and seed production maximized; they serve as ex situ conservation sites; each genotype can be established in multiple sites to protect against disasters; they enable seed collection in a more safe and efficient manner than from dispersed, tall in situ parents growing in remote sites; orchard layout randomization minimizes inbreeding and maximizes seed set; and grafted scion from mature trees produce pollen and cones decades earlier than from seedlings.

Conclusion

Alberta's multifaceted approach to limber and whitebark pine recovery is guided by approved recovery plans. These plans are being consolidated and updated to reflect new knowledge and progress. Seed collections in 2018 will be used to support ongoing restoration efforts, in collaboration with other agency partners. Monitoring is essential to ensure plus tree health, planting method success, and prioritize recovery actions across regions and sites.

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New Analysis of Ex Situ Seed Collection Sampling Sizes

A persistent challenge in seed banking is to decide how much seed to collect, from how many plants, and from how many and which populations. Guidance on minimum collection sizes has been developed over the years for helping to conserve as much genetic and phenotypic diversity as possible, but guidance has been rather general, such as 50 sampled plants from 50 populations (Brown and Hardner 2000) or 10,000 seed per population (Way 2003).

I recently revisited this challenge in a publication titled "New guidance for ex situ gene conservation: Sampling realistic population systems and accounting for collection attrition". I generated realistic simulation models of threatened species (total population size from a few hundred to twenty thousand plants) to determine how minimum sampling sizes should vary based on a species' characteristics such as population sizes, number of populations, habitat connectivity, and rates of recent decline. I determined that the minimum recommended sample size does depend on species' characteristics and can range from 100 to 1,000 plants, but he also found that sampling from 200 to 300 plants should suffice for many rare species to preserve the vast majority of genetic diversity. This information helps guide the collection plans especially for space-limited living collections like seed orchards and botanic gardens.

However, I also demonstrated that sampling rates must be increased if a collection aims to have multiple copies of each genetic variant for backup or sharing among institutions. If they wish to preserve five copies of each allele, the collection size needs to be increased by roughly a factor of five, a very intuitive finding but one that had not been shown before.

Lastly, I point out that minimum sampling sizes depend strongly on the type of genetic diversity that we wish to preserve; most previous work has focused on relatively common genetic variants, but important elements like disease resistance alleles may be rare and need different sampling.

These novel results emphasize that collectors, curators and geneticists need to discuss the type of genetic variation they seek to conserve, the intended uses of the seed, and the biology of the target species when designing a collection plan.

If you would like a copy of the paper, which contains a useful summary table for practitioners that shows how seed collection sizes depend on various factors, you are welcome to contact me, or find the paper in the journal *Biological Conservation*.

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2018–2019 Forest Gene Conservation Association Update

It's been another period of looming change and quiet accomplishments after FGCA's 25th year in operation. As of the Ontario Tree Seed Plant (OTSP)'s official September 2018 closure, FGCA remains focused on operational seed supply management and advisory services for our members. There is still a need for high-quality seed and seed source control for long-term results in any planting program, and two white papers produced in 2018–2019, the latter by our partner Forests Ontario, underscore these mandates:

- Tomorrow's Forests: Tree Seed Management in Ontario (October 2018)
- The Economic Value of Tree Planting in Southern Ontario (February 2019)

FGCA's members and Sustainable Forest License holders have transferred seed banks to new private storage facilities at Millson Forestry Service (Timmins, Ontario), Somerville Seedlings (Everett, Ontario) and Ferguson Tree Nursery (Kemptville, Ontario). New freezers were specified to –20°C given the concerns about average seedlot age, vigour and volumes remaining in stock relative to planting plans. Surplus seed purchased from MNRF's former public account is easing some gaps in transition while processing capacity and new relationships continue to develop in the region.

To challenge demand further, in April, the Ontario government canceled funding for the 50 Million Tree Program's private land afforestation incentives, which threatened seasonal tree planting and nursery jobs, and 7.5 million seedlings of over 20 species already sown and growing. It is not many seedlings compared to Crown land restocking requirements but nevertheless, a complex seed and stock planning operation working with over 4,000 private landowners since 2007. This program had also been underwriting seed collection capacity and expertise succession that will be needed to deliver assisted migration solutions to Crown land in the near future (Erickson et al. 2012). The Government of Canada's Low Carbon Economy Fund gave some relief with short-term funding to ensure the trees in progress will be planted. Certainty is certainly a currency unto itself these days.

Facing south, new forest health issues are piling up at the Ontario-Quebec-Maritime border. Oak wilt is now present in 70% of Michigan's counties (http://www.michiganoakwilt.org/), a new beech leaf disease is expanding in Ohio, Pennsylvania and Ontario (Ewing et al. 2019), and both hemlock woolly adelgid and southern mountain pine beetle are modeled to move north soon as minimum winter temperatures warm (Emilson et al. 2018, Cancelliere 2015, Dodds et al. 2018). *Dendroctonus frontalis* could become a serious pest of all *Pinus* spp. in the Northeast, and has also been found attacking Norway spruce and Scots pine in Long Island, New York (Cancelliere 2015). It's preference for pitch pine (*Pinus rigida*) combined with a small US border-edge Eastern Ontario population is worrisome. The need for a proactive approach ahead of and after these threats is rising (in pitch!).

CONFORGEN Ex Situ Survey

Almost on cue in February 2019, FGCA and our partners were asked to participate in Kathleen Forbes' recent update CONFORGEN survey of provincial seed conservation efforts, which was heavily focused on Carolinian and Great Lakes-St. Lawrence species identified in the 2012 survey. FGCA received a copy of the Ontario Tree Seed Plant's database for archival purposes, so we queried seed testing metrics for candidate species' seed collections from 2009–2017. Notable highlights from 35 species ranked as ex situ conservation priorities in 2012:

- Only 10 species had been collected, registered and tested by OTSP from 2009–2017; the oldest germination test series were for *Pinus strobus* (48 years), and *Gleditsia triacanthos* (30 years). No reference collection remains; most seedlots were sold to the open market.
- One private nursery has collected, grown and sold 26 of the candidate species since 2009, but did not have standardized germination tests to compare to OTSP's metrics. Typical nursery short-term storage ranged from 1–4 years, not unusual for hardwood seed.
- The University of Guelph Arboretum's long-running Rare Woody Plants program (detailed in Bulletin No. 65) contains many living accessions of known-Ontario-provenances planted in small seed production orchards, but staff also have little capacity for standardized germination testing. Some seedlots have been sent to National Tree Seed Centre.

- Guelph Arboretum's and FGCA's Seed Collection Area Network database of high-quality seed collection sites offer the first metrics to identify stands at mature reproductive age and minimum viable population *Ne* values (i.e. >30 as per Alberta's standards for minimizing inbreeding coefficients in conifers). More research is needed for hardwood species *Ne* values.

For future surveys, seed trends and quality metrics may become more difficult to gather from the private sector not engaged with Crown land FMPs, as first documented by Morgenstern and Wang (2001). Many non-commercial and recalcitrant species can only be counted on the stump going forward in botanical collections or healthy FGRM archives (as some may argue they should be). For species most at risk, intensive seed orchards could stem further genetic erosion and *Ne* researched, rectified and infused with southern populations in advance of climate change.

Butternut Recovery Program

With funding from Endangered Species Act permits and a new grafting facilities at the Ferguson Tree Nursery (Kemptville, Ontario) ready for use in Spring 2018, our Butternut (*Juglans cinerea*) Recovery program tallies 117 putatively canker-tolerant parents selected as of May 2019. We have established two new orchard locations, for a total of five across Southern Ontario, and are beginning to allow our oldest grafts to produce seed. One orchard management partner, Upper Thames River Conservation Authority, produced a great promotional video of a typical archive installation (Fig. 1). The fenced orchard also contains seedlings from Ontario's American Chestnut Council's controlled breeding program.

This spring, FGCA was also contracted to deliver several Butternut Health Assessor workshops on behalf of MNRF in the midst of responsibility for Ontario's *Endangered Species Act* (ESA) being transferred to the new Ministry of Environment, Conservation and Parks (MECP) as of April 1st. Ontario's ESA has undergone considerable review to modernize its approach and make it easier for those seeking permits to navigate the process. A provincially managed Species Conservation Trust fund was proposed to be set up to accept payments in lieu of on-the-ground activities required by the former Act. We are still waiting for details from MECP on how that will affect or expand our recovery programs.

Figure 1. Youtube promotional video and drone imagery of FGCA's and Upper Thames Conservation Authority's Southern Ontario Butternut Seed Orchard.

Seed Orchard Revitalization: White Pine and Beachburg-Douglas White Spruce

Thanks to MNRF's Forestry Futures Trust (FFT) 2017–2022 project funding, FGCA, SFLs and contractors continue to revitalize eight grafted first-generation white pine (*Pinus strobus*) and the Beachburg-Douglas source white spruce (*Picea glauca*) seed orchards. Orchard blocks of both species were planted 1982–1991, and are over or approaching the oldest calculated seed production prescription (32 years+) in the Tree Improvement Master Plan for Ontario (MNR 1987). Due to limited funding, white pine progeny testing data has been minimal and orchard maintenance a challenge, but recent support from FFT is improving the latter.

Genetic gain the original objective is now replace by gene conservation. Southern Ontario's history of over-harvesting and intensive land development has eroded the white pine populations in our operational area. The hundreds of plus trees in the seed orchards are valuable as a broader gene pool which gives opportunities for realized gain under proposed assisted migration policies. Retaining as many clones as long as possible also provides opportunities for re-grafting or intensive selection if industry or policy priorities change. Health, height to live crown, form and ramet survival counts informed an ArcMap-based thinning plan to assist tree markers with adhering to the following rules:

Table 1. Central and Southern Ontario's Eastern white pine (*Pinus strobus*, Ontario forestry code Pw) seed collection operations and clonal representation remaining after thinning in 2018. Seed yield data provided by the Ontario Tree Seed Plant.

Orchard	Breeding Zone[1]	1971–2000 Mean Annual Temperature (°C)[2]	No. Original Plus Trees	No. Plus Trees Remaining 2018[2]	2017 Cones Collected (hL)	2017 Germination %	2017 Viable Seeds/hL	2017 Viable Seeds (000s)
Cayuga	7E	8.4	216	203	205.6	96	53,435	10,989
Conger	Georgian Bay	5.3	153	129	0			
Crowe River	Algonquin	5.0	279	197	0			
Glencairn	6E West	6.7	220	197	35.6	96.75	47,963	1,283
Grattan	Algonquin	5.1	281	264	30	93.25	112,700	3,381
Scugog	6E West	6.4	192	178	0			
Snowdon	Algonquin	5.0	267	265	85	87	68,813	5,849
Taylor Lake	6E East	5.6	216	212	80	77 OTSP / 85.6 FTN[3]	74,175	6,156
Total					430			27,659

[1] White pine breeding zones have been variously defined by Hills Site Regions, late-1980s MNR Administrative Districts and/or all or portions of 1996 Seed Zones (not shown). Cayuga, Conger and Taylor Lake feature unique clonal collections. [2]Data from http://www.seedwhere.ca/ [3]All but two clones lost since establishment are due to natural mortality, blister rust infection or loss of original clonal identification records. [3]Same 60-day cold stratification period used by both the Ontario Tree Seed Plant (OTSP) in 2018 and Ferguson Tree Nursery (FTN) in early 2019 greenhouse sowing.

- Remove trees severely affected by Blister Rust
- Keep 1–2 ramets of each clone, of the best health and manageable size to top and collect cones
- Keep 1–2 ramets per block to preserve planting design
- Release remaining ramets on at least two sides
- Reduce form issues contributing to storm breakage

Management goals are to increase the longevity of orchard seed production (to at least 50 years, i.e. 2032–2040), particularly of the southern and unique collections at Cayuga, Scugog, Glencairn, Conger and Taylor Lake. FGCA will continue to assess seed needs of our members or new inquiries under climate change. Results from our 2017 clonal assessments and cone collection operations are summarized in Table 1.

OTSP historical yield data indicates the 2017 Cayuga white pine bulk orchard collection was the largest in Ontario's history, yielding 259.8 kg of clean seed. 163 open-pollinated clonal conelots (5–20 litres per parent) were also collected for future trials and progeny testing. Cayuga parents have the warmest mean annual temperature (MAT) of any natural breeding population in Canada. FGCA's clonal seedlots are now stored at the National Tree Seed Centre.

Ash Seed and Survivors

The Emerald Ash Borer continues is destructive progress across Ontario, last measured in 2016 at 242,283 ha of stand decline and mortality (MNRF 2017). In 2017 it was detected in Sault Ste. Marie and Thunder Bay. The dioecious nature of Ontario's native ash species (except *Fraxinus quadrangulata*, blue ash) makes seed production after EAB even more challenging. Shifting gears to locate possible resistant phenotypes, the Forest Gene Conservation Association was able to assist Dr. Nathalie Isabel from the Laurentian Forestry Centre to sample lingering ash survivors from Guelph to Windsor in October 2018. Thanks to a broad outreach effort with professionals and engaged woodlot owners, we gathered DNA samples of 36 candidate trees of all five native species (*Fraxinus americana*, *F. nigra*, *F. quadrangulata*, *F. pennsylvanica* and *F. profunda*) and remarkably, three seed collections from the original EAB epicentre. In communication with recent seed collectors and propagators of pumpkin ash (*F. profunda*), most experts suspect all reproductively mature adults are now dead, with only 1 seed collection saved at NTSC, though saplings do

exist. This species was only discovered in Ontario in 1992 (Waldron 2003).

For fall 2019, it looks to be an excellent ash seed year ahead of EAB, so we will refocus on gaps in NTSC's collection. Sean Hoban's article in this issue provides a realty check against just how much more work there is to do for any species' future genomic work and working collection utility. More information is available here.

Annual work program achievements are documented in our annual reports here.

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Directories of Tree Seed Expertise and Supply

From a historical and curiosity perspective, this article expanded beyond Editor's Notes as background to our current TSWG Membership survey. Our new Directory Survey and resulting list of TSWG Members is intended to develop our own network, but I encourage you to review or opt-in to others below if they would also or better suit your needs. The list of URLs also provides still-accessible historical archives for anyone with interest in significant changes in this sector over time (or to reminisce).

In the early days, TSWG News Bulletin No. 3 (March 1985) listed 104 interested and active "seed workers" and members surveyed by Chairman Ben Wang and Editor George Edwards, with pain-staking manual data compilation by Francine Ackerman and Doug Taylor. Hugh Schooley kept an updated digital TSWG list in the early 1990s but no

updates were published as per TSWG No. 3.

In 1995, the US National Tree Seed Laboratory (Dry Branch, Georgia) published and still hosts a listing of Commercial Tree and Shrub suppliers, and some of these still persist.

In 1998, the USFS Pacific Southwest Research Station and IUFRO published an extensive Global Directory of Forest Geneticts and Tree Breeders, featuring 125 Canadian experts with systematic indexes of each person's taxa and subject focus, comparable to TSWG No. 3. A quick scan of the Canadian cohort suspects more than half of this 1998 list is retired or deceased, the remainder no longer active and a small proportion still pushing on.

Currently, the TreeGenes Colleague Directory is seemingly the most complete opt-in database of forest geneticists and researchers similar to the 1998 Directory, but is not well populated with operational seed experts or facilities to deliver said genes. There are 79 Canadians listed here but some are also retired or deceased. Anyone new to this group can create and update a profile any time.

Coming from a landscape restoration perspective, the Global IUCN Seed Conservation Directory of Expertise recently utilized the Tableau Public online platform to survey seed conservation expertise to taxa including trees. This resource has captured categories of many specialized seed collectors beyond trees, classified facility storage types and those with specific ex situ capacity such as cryopreservation. There are 12 tree seed experts noted in Canada, 103 across the United States, and 104 more noted globally in this directory.

I also offer for those who don't regularly read the CFGA Conference Proceedings archive is the list of active members, which captures most of the current forest genetic councils, cooperatives, orchard and program managers across Canada. Kathleen Forbes (Natural Resources Canada) will have the 2015 and 2017 proceedings posted soon. Dave looked back on a 2004 CFGA motion to form a "Canadian Forest Genetics Council Working Group" but it seems the lack of support and common cross-jurisdictional issues failed to coalesce efforts. While the CFGA and TSWG News Bulletin is a platform, maybe it is time to reconsider the potential benefits of such a group?

In the last year, one of the fallouts of losing the Ontario Tree Seed Plant's coordination services and open seed catalogue has been individuals or institutions contacting FGCA (and likely others), searching for operational and research-grade seedlots. There was talk of but not currently the means to post surplus seed to an open marketplace. Until such a time, I think this is a good space to list additional catalogues of seed curated for quality and (most with) known provenance or breeding value information available.

While some commercial seed suppliers are well known in North America and easily found on the Internet, compiled databases are useful for filtering multiple sources. Please read the mandates of each source carefully, particularly when it comes to available volumes, agreements for non-commercialization, and current phytosanitary or import/export regulations across jurisdictions.

1. The Canadian Forest Service's National Tree Seed Centre provides small seedlots for research and educational purposes. Use the Canadian Forest Genetic Resources Information System map or the Seedlist Database to request specific species and seedlots.

2. The US National Plant Germplasm System lists all available accessions, including some tree seedlot of commercial, ornamental and conservation research value that can be requested.

3. Additional research collections (with some duplication from #2) are catalogued in PGRFA's Genesys Global Gateway to Genetic Resources

4. The US Department of Transportation's Ecoregional Revegetation Application (ERA) is an interesting tool with a 2015 list of vendors of genetically-appropriate seed and stock, which contains many trees and shrubs: https://cpb-us-e1.wpmucdn.com/sites.northwestern.edu/dist/9/451/files/2018/09/ERA-Vendor-Table-FINAL-low-res-2kfekyd.pdf

5. Botanical Garden Conservation International's Plant Search Database is a global database of accessions from 1,117 institutions, of which some maintain seed banks. Material is only shared under non-commercial use agreements.

6. World Agroforestry Tree Seed Suppliers Directory, which also contains many useful resources for African and tropical countries looking to develop seed supply, i.e. outputs from the Provision of Adequate Tree Seed Portfiolio in Ethiopia to support reforestation efforts:

http://www.worldagroforestry.org/project/PATSPO/outputs

7. USDA Forest Service's RNGR.net (Reforestation, Nurseries & Genetic Resources) National Nursery Seed Directory, including Canadian suppliers, many of which are commercial enterprises.

8. The Native Seed Network website via the Institute of Applied Ecology includes some specialists in woody plants for commercial sales.

9. The European Union's FOREMATIS (Forest Reproductive Material Information System) database of registered seedlots by origin was working last year but link is currently broken. This system was designed for commercial entities to access larger volumes.

If I have missed any other resources or ideas, please send me a note to include in the next Bulletin.

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Upcoming Meetings

2019 Canadian Forest Genetics Association Conference: "Applied Forest Genetics"
August 19–23, 2019
Lac Delage, Québec, Canada
https://cfga-acgf.com/

Joint AGM of the Forest Nursery Association of BC and Western Forest and Conservation Nursery Association
September 30–October 2, 2019
Mary Winspear Centre, Sidney, BC
http://fnabc.com/

IUFRO Seed Orchard Conference 2019 – Seed Orchards and Climate Change
October 14–16, 2019
Registration deadline: August 25, 2019
Nanjing, China
http://seedorchard2019.njfu.edu.cn/index.html

Training workshop on "Concepts and tools for optimum selection in forest tree breeding"
October 28–30, 2019
Stiftsgården Åkersberg, HÖÖR, Sweden
Note: registration is currently full but email Tim Mullin if you are still interested in a second possible workshop: tim.mullin@skogforsk.se
http://www.gentree-h2020.eu/events/event/training-workshop-on-concepts-and-tools-for-optimum-selection-in-forest-tree-breeding

Climate Change and New Challenges in the Production of High Quality and Well Adapted Forest Reproductive Material≠
December 3–4, 2019
Early registration deadline: September 20, 2019
Jastrebarsko, Croatia
http://www.sumins.hr/sjemenarstvo60/?lang=en

ISTA Workshop on Quality Assurance and ISTA Accreditation for Beginners
December 17–19, 2019
Registration deadline: October 1, 2019
Bangalore, India
https://www.seedtest.org/en/event-detail---0--0--0--110

Australasian Seed Science Conference
April 5–9, 2020
Canberra, ACT, Australia
https://seedscience2020.com.au/

Job Postings

The B.C. Tree Seed Centre is hiring a Cone & Seed Processing Supervisor; details may be found at:
https://bcpublicservice.hua.hrsmart.com/hr/ats/Posting/view/63145

Research Assistant I - Full-Time (2 positions available: Forest Ecology and Tree Conservation Biology)
Morton Arboretum, Lisle, Illinois
Start Date: Fall 2019 preferred
https://careers.hireology.com/themortonarboretum/316802/description

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