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MATERIAL HANDLING

Featured in this Issue:

Banner photo of wall-mounted air separators and seed sieves at Yellow Point Propagation, Ladysmith, British Columbia. Photo by Melissa Spearing, June 2022.

Armchair Report No. 73

Hello and Happy New Year to all. I hope 2022 was good to you and allowed you to do some things you haven't been able to do for the past few years.

One of my highlights in 2022 was the workshops and field tours associated with the theme of "Challenges to Our Future Tree Seed Supply" that occurred on Vancouver Island and the lower mainland last summer. It was such a joy to have so many tree seed-focused people together for some technical exchange, relationship building and fun. A separate article in this News Bulletin provides more details – thank you to everyone who helped and participated!

Just as we recovered from putting on last summer's workshops and field tours, we started planning the next Tree Seed Working Group workshop in association with this summer's CFGA meeting in Vernon. The Tree Seed workshop will occur on July 10th, 2023 and if you have any thoughts on presentations or a theme, please discuss them with Melissa or myself. The rest of the week will be a joint CFGA/WFGA conference with two days of presentations and one day of tours. The theme is "Discovery & Innovation in Changing Climates" and updates can be found here: https://cfga-acgf.com/conferences/.

Thankfully, we have had a resurgence of live meetings in BC since the last News Bulletin, with the BC Seed Orchard Association (BCSOA) and Forest Nursery Association of BC (FNABC) hosting meetings in Vernon (SilverStar Mountain Resort) and Prince George, respectively. The CFGA also hosted a one-day field trip after the BCSOA meeting to the Skimikin seed orchard to view orchard practices and field trials.

We are seeing a changing of the guard at the BC Tree Seed Centre (TSC) as our Manager, Michael Postma, retired on January 20th, 2023. Michael has brought great enthusiasm for method and efficiency improvements to our facility. This has involved, with facility staff, a

CFGA Tree Seed Working Group

Chairperson

Dave Kolotelo
British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, Tree Seed Centre
18793 – 32nd Avenue
Surrey, BC V3Z 1A5
Email: Dave.Kolotelo@gov.bc.ca
Phone: 778–609–2001
Fax: 604–541–1685

News Bulletin Editor

Melissa Spearing
Natural Resources Canada, Canadian Forest Service, National Tree Seed Centre
1350 Regent Street
Fredericton, NB E3C 2G6
melissa.spearing@nrcan-rncan.gc.ca
Cell: 416–909–9755

Deadline for TSWG No. 74: April 30, 2023

We welcome any comments, suggestions and article submissions and will solicit active, subscribing members for content. Submissions may be edited for length and clarity. Authors are responsible for the accuracy of the material in their submitted content. 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).

The Tree Seed Working Group News Bulletin is published biannually. 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
4. Advising on implementation practices

All past issues of the News Bulletin are freely available here.

great effort at modernization and safety improvements required for our 36-year-old facility. We have certainly taken on a more industrial facility mentality under his leadership. One of Michael's biggest legacies will be laying the groundwork for the large capital project of building new seed storage freezers. In today's world, this project is equivalent to the price tag for the entire facility in 1986. Michael has also played a key role in our computing systems (Seed Planning and Registration (SPAR) and Cone and Seed Processing (CONSEP)) construction, maintenance and on-the-go fixes to keep operations going. Michael has a long association with the TSC as our Systems Analyst in the 1990s and continued to help develop various systems and IT projects for several different Ministries before returning to the TSC as Manager in 2018. Working with Michael has been a pleasure, and I wish him all the best in retirement and whatever projects he decides to take on. Thank you for all your efforts!

Retired BCTSC Manager Michael Postma.

We are in the middle of one of the largest cone and seed processing seasons we have ever seen. We expect to process 8,200 hectolitres (over 23,000 US bushels) of cones representing 120 seedlots, with an ability to produce over 400 million seedlings. We expect 2023 seedling production in BC will likely be in the ~300 million range again.

"Material Handling" is a wide-ranging topic focused on the operational handling practices associated with cones, pollen, seed and other materials that are part of our processes. Many of our practices are simple, but the volume of materials we are dealing with requires solutions defined by existing infrastructure, working environment, staffing and equipment restraints. This results in some unique implementation practices, and sharing those practices is the goal of this edition, although contributions on that topic are always welcome. It may result in method improvements elsewhere or at the operational facility of origin with new eyes and perspectives. Our highly specialized tree seed community is all about sharing information. In this themed News Bulletin edition, we try to focus on the very practical material

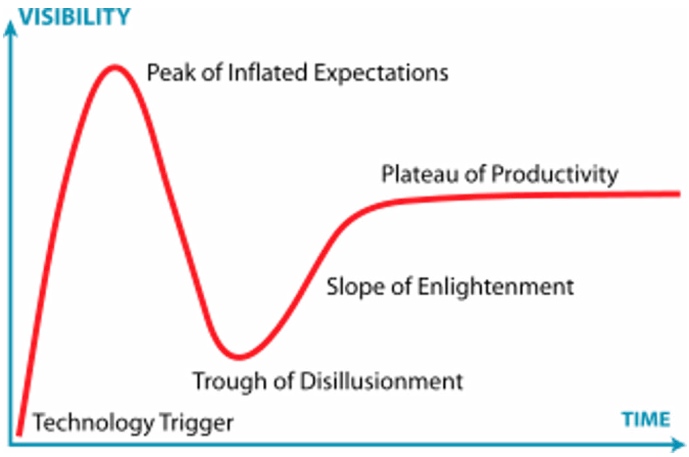
handling aspects that are the foundation of our tree seed and cone operations.

I'd like to share an image that polarizes those I show it to, the Gartner Hype Cycle. It has been criticized for not being a cycle (think life cycle vs. loop); its subjective terms, lack of a quantitative model and that it is simply a comment on existing trends. It is the last part that I find attractive, especially as it relates to research investments (time and money). I view it as one of many means to continue a dialogue on the challenges to our future tree seed supply and feel free to substitute interest or funding as the y-axis label.

The inflated expectations aspect becomes the normal way to obtain research funding by overselling your 'competition'. It is common for me to see inflated expectations with tree seed being justified by the technological advancements in agricultural seeds and their use. This fails to consider the greater genetic diversity and benefit of maintaining this diversity in our long crop rotations. There is also generally a much more limited environmental specificity (aka transferability) of our seedlots and, therefore, a relatively small market for each "variety" compared to agricultural crops.

Many new tree seed technologies require species or variety-specific calibration or development work, and the inherent diversity and limited global transferability complicate this development aspect. It doesn't make it impossible, but this inherent variability and limited range of use need to be recognized up front to temper expectations or the efficiency of introducing the new technologies/information. This conflicts with the educational experiences of many pursuing research with seed predominantly from agricultural schools, with very little attention being provided in forestry or general botany curricula.

Unfortunately, overselling may be the only current avenue available to obtain funding for investments in tree seed 'technology.' Research funding for work on tree seeds is minimal but also very distorted to the latest technologies, creating a poor research portfolio for balancing the capital invested and the actual risk of a return. It often seems like the process is to find a problem with the latest technology instead of identifying the most critical issues and selecting the appropriate technology. I'd argue that we need a more diversified research investment portfolio for public funds as this will create the best overall return, just like your stocks.



The Gartner Hype Cycle (https://en.wikipedia.org/wiki/Gartner_hype_cycle)

All of these factors contribute to what I see as a vicious cycle of "**no funding, no research, no trained people, no teaching, no progress"** an area which doesn't really hit the radar of most funding agencies. I'm not sure about the solution, but the current emphasis on increasing tree planting globally is probably the best way to increase awareness and support.

Can we avoid disillusionment? Can we be more realistic about the impact of technology on today's problems, and can we help ensure our services and products are not taken for granted?

Dave Kolotelo
TSWG Chairperson
Email: Dave.Kolotelo@gov.bc.ca

Editor's Notes

Happy New Year. I hope you feasted, drank, hugged your family lots and slept over the holidays—we all deserved it!

As always, thank you to everyone who heeded the call for articles and meeting summaries. I know how busy 2022 was for everyone, especially those short-handed. We have contributions from Dr. Ehren Moler and Steven Kiiskila as a follow-up on direct seeding challenges (last issue, but focus on challenges with cone crops) and seed use efficiency (last major review TSWG No. 47). Thanks to Newton Philis for his photo reminder about cone shipping and handling. Patrick von Aderkas shared a lovely tribute for Dr. Will Hintz, and I note Dr. Michael Black's passing. The National Tree Seed Centre staff and extended team are helping towards small-scale seed equipment manufacturing, and exploring a new seed storage system for our Gene Conservation collection. I have also come good on TSWG membership survey data and demographic tidbits I've been gathering during the "Great Retirement & Reshuffle".

Back to when Dave proposed this very practical and necessary theme, I assumed some equipment manufacturers would be interested in submitting content or even a focused "advertorial" on their services. I inquired but received minimal interest from most manufacturers I have seen in current use on recent tours. Some were short-staffed, or perhaps I didn't know the right salesperson. General responses were to check their websites and request a quote.

For posterity's sake, here's a non-exhaustive list of important tree seed equipment suppliers I'm aware of:

- Fandrich Cone Harvesters (British Columbia)
- BCC (Sweden)'s cone handling line
- AT Ferrell Company (Indiana), including Clipper Seed Cleaners; REL Equipment (Quebec) now distributing
- SeedBuro (Illinois)
- Hoffman Manufacturing (Oregon)
- Dybvig Macerator (Oregon) and pail screen set
- Luterra Enterprises (Oregon); see their Winnow Wizard plans are posted online
- Jim Rockis (West Virginia) offers tree seed-related equipment consulting and training
- While Yellow Point Propagation (British Columbia) has improved on these units, the designs for the original George Edwards' 1979 aspirator are still posted online: https://cfs.nrcan.gc.ca/publications?id=3994
- While it's not depicted on the website, Phair Grain and Seeds Equipment Solutions (Ontario) has made or refurbished wall-mounted aspirators I've seen in use.
- I've had a few conversations with Terraformation who are offering a mobile "seed bank in a sea can" that may be suitable to diverse reclamation and remote projects. I also include their free training courses later this issue.
- The BC Seed Handling Guidebook (2001), pages 95–96 contain a substantial list of suppliers, though some may be closed now or contact information changed.

Perhaps it is just as important to list once everyday material handling items that no longer manufactured:

- **Petawawa Germination Boxes:** the NTSC has been trying to initiate a new manufacturing run, but the original plastic quality is difficult to emulate.
- **IPL cone and seed drying trays:** 103 cm × 81 cm × 20 cm tall, gray with mesh screen, forklift stackable. If anyone has extra or a similar system, please let me know.

At the October 2022 Atlantic Forest Nursery Association meeting, Simon Bocksette prodded me to think about how we can inspire engineering students or programs to design robust middle-of-the-road sized equipment to span bimodal "farm-style" and industrial volumes. I pose this challenge to the entire TSWG. Please reach out to Dave or myself if you know some good MacGyver-ers with spare time.

Lastly, I'm still doing my best to get back to the biannual publishing schedule maintained by former Editors. 2022 was the busiest year I could've imagined, as my "Reflections" article eludes to. I am going to poke a number of you well in advance of the No. 74 April 30th content deadline, in order to have the next Bulletin out before the July 10th workshop. I certainly rue the day Dave retires from his Chair position, with the decades of energy and leadership he has given us. We need more TSWG members excited to help keep this going, and willing to share their blood, sweat and tears. Speak up, don't be shy, we rarely bite!

Melissa Spearing
TSWG Editor
Email: melissa.spearing@nrcan-rncan.gc.ca

Meeting Recap: Challenges to Our Future Tree Seed Supply

From June 22nd to June 27th, 2022, a meeting themed around the challenges to our future tree seed supply was held in British Columbia. The organizing team included:

- Dave Kolotelo and Victoria Lei, British Columbia Ministry of Forests Tree Seed Centre
- Don Pigott, Yellow Point Propagation
- Melissa Spearing, National Tree Seed Centre

The purpose of this tree seed meeting was to address a key bottleneck in the highly ambitious global reforestation goals – the sustained availability of high-quality and adapted tree seed.

Challenges to our future tree seed supply are real and begin with a lack of educational coverage, research funding, interest, and continued infrastructure investment. An area of particular concern is the reduced global capacity for cone and seed processing and currently limited capital investment in this critical stage of reforestation, especially with increasing tree planting expectations. One of the meeting goals was to build stronger relationships between organizations involved in this highly specialized field including but not limited to:

- IUFRO 2.09.03: Seed Physiology and Technology
- International Seed Testing Association Forest Tree and Shrub Committee
- International Seed Federation Tree and Shrub group
- Canadian Tree Seed Working Group

Attention: The tree seed supply system is taken for granted and unsustainable in its current form.

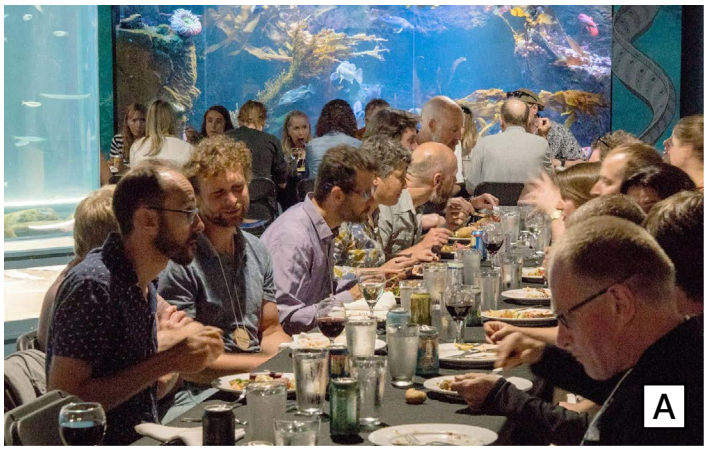
The meeting attracted people from Great Britain, Norway, Sweden, Holland, Hungary, the Czech Republic, the United States of America, and across Canada. The program included two stationary workshop events and field tours showcased "beautiful British Columbia", highlighting our coastal forests and tree seed-related facilities. Seed-related facility tours included:

- Mount Newton Seed Orchard and Arbutus Grove Nurseries in Sidney
- Cowichan Lake Research Station
- Yellow Point Propagation in Ladysmith
- BC Tree Seed Centre in Surrey

Our Thursday evening dinner was unique as it took place within the Shaw Centre for the Salish Sea, an aquarium focused on displaying and educating our local sea life. Several individuals provided short slide shows of their processing facilities for our Saturday night entertainment to encourage discussion on this important topic. Other tour stops included the Butchart and UBC Botanical Gardens, Goldstream Provincial Park, Malahat Skywalk, Port Renfrew, nearby old-growth stands, and a salmon hatchery.

The workshop presentations are listed in Table 1, and presentation PDFs and recorded videos of most can be found here: https://cfga-acgf.com/2022/08/13/2022-challenges-to-our-future-tree-seed-supply/.

A special thank you to Don Pigott for producing the lovely wooden name tags, which were a big hit with the participants. Thanks to Melissa for organizing and running the virtual sessions, recording the videos and getting all the material uploaded to YouTube and the CFGA website. The emphasis was on the live event, but adding the virtual component allowed us to break even (actually $42 to the CFGA) and greater accessibility to participate.



Selection of photos from the June 22–27, 2022 "Challenges to our Future Tree Seed Supply" meetings and field tours in British Columbia. (a) the unique dinner experience at the Shaw Centre for the Salish Sea (Sidney), (b) bus tour stop at the Cowichan Lake Research Station (Mesachie Lake), (c) tour of Yellow Point Propagation with owner Don Pigott (Ladysmith), (d-f) June 27th BC Tree Seed Centre equipment demonstrations, workshop lectures and operational processing tour. Additional photos shared by organizers and participants are available at: https://photos.app.goo.gl/gAGYNBZgg4sPcMRu8

Table 1. Summary of "Challenges to our Future Tree Seed Supply Workshop" presentations and demonstrations.

June 23, 2022 Workshop	Speaker
Introduction to the ISF Tree and Shrub Group	Øyvind Meland Edvardsen
Ensuring Seed Quality by Uniformity in Seed Testing (video)	Dr. Steve Jones
TSWG / IUFRO 2.09.03 / ISTA FTS Overview	Dave Kolotelo
Tree seed production and use in British Columbia: Past, Present and Future	Brian Barber
OECD Forest Seed and Plant Scheme in Canada: 2020-2022 Updates	Melissa Spearing
DIY Climate-Based Seed Transfer	Dr. Greg O'Neill
BC Seed Planning Tools Overview	Sabina Donnelly
Reproductive Biology – Why is it important??	Dave Kolotelo
Seed Production Efficiency Practices	Dr. Michael Stoehr
Genetic population assignment: potential for seed provenance ID?	Dr. Hayley Tumas
Demonstration of the field PCR tool for seed pathogen detection	Dr. Nicolas Feau
June 27, 2022 Workshop	**Speaker**
Evolution of Seed Extraction Practices	Dr. Marilyn Cherry
The History of Seed Collection and Processing in BC and Looking to the Future	Don Pigott
Challenges with Processing, Storage and Pre-treatment of Recalcitrant Tree Species	Fabienne Colas / Dr. Sylvie Carles
Continuous Improvement: beyond the buzzwords	Dave Kolotelo
Greenhouse evaluation of lab-tested seed: a feedback loop	Nabil Khadduri
Cone and Seed Processing Panel Q & A • Jeff deGraan, State Reforestation Specialist, WA USA • Johanna Gårdebrink, Svenska Skogsplantor • Don Pigott, owner Yellow Point Propagation Ltd. • Michael Postma, Manager BC Tree Seed Centre	
Genomic tools for tree pathogen detection and surveillance (video)	Dr. Richard Hamelin
DroneSeed presentation and static UAV demonstration	Dr. Ehren Moler
Fandrich Cone Harvester Equipment Demonstration	Helmut and Martin Fandrich

The meeting allowed for scientific and technical exchanges on the whole spectrum of activities from tree seed science to production and processing and, ultimately the provision of the best seeds and information to the global reforestation community. During the meeting, we asked for feedback on these five questions and appreciate any further input you may have:

1. What is your highest tree seed research priority?
2. What is your biggest concern with tree seeds?
3. What is your biggest tree seed extension/information need?
4. What is your most critical infrastructure need to secure your required tree seed supply?
5. What tree seed information is critical to have in professional or post-secondary courses?

Melissa set up an online form to support the hybrid meeting, if you'd like to respond that way: https://forms.gle/1XGXQ2DgQkU6oJ3q9

To address our common challenges, we hope to build on the momentum from this meeting to inform decision-makers. Worldwide, these people need to hear from those who want to cooperate and improve the existing tree seed systems currently in place. This should create synergies and opportunities to ensure a clear and informed message.

Anyone wishing to join the party, please get in touch with myself or Melissa.

Dave Kolotelo
British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Tree Seed Centre, Surrey, BC
Email: Dave.Kolotelo@gov.bc.ca

Cone Monitoring, Procurement, and Handling in a Rapidly Changing Climate: Past patterns and future concerns

Demand for post-wildfire reforestation is growing as climate warming increases the area of land burning at high severity (Iglesias et al. 2022). This demand can only be met given sufficient tree seed production and collection. But biological and logistical constraints routinely pose serious challenges to adequate tree seed collection and storage. This article reflects on past and present challenges and experiences concerning conifer seed cone procurement, particularly in the Western United States. We also highlight the need for strengthening networks of seed collectors and buyers for developing logistical solutions and sharing information regarding seed crop abundance and health.

During a tour of the Pacific Northwest in the 1960's, Maxwell and Aldhouse (1967) interviewed tree seed industry professionals to document regional patterns and practices of conifer seed procurement. Numerous challenges to seed procurement highlighted by Maxwell and Aldhouse (1967) remain applicable to woods-run (aka "wild stand" or BC's "B" class) seed collections today, and are expected to remain a concern. These include the volatility of tree cone production schedules, which preclude reliable collection from any given seed zone across years; the large number of bushels required to render a cone collection lucrative and thus worth conducting (listed at over 300 bushels based on interviews conducted by Maxwell and Aldhouse); and the heavy reliance of the woods-run seed industry on squirrel presence and population sizes. The authors estimated that 95% of cones collected in Washington and Oregon in the 1960s were sourced from caches of cones cut and stored by the Douglas squirrel (*Tamiasciurus douglasii*), which remain a significant source of cones we procure from Washington, Oregon, and Idaho today.

The biological and logistical obstacles to cone collection we commonly encounter vary across California, Oregon, Washington, Montana, Idaho, New Mexico, Nevada, and Colorado. Biological obstacles that pose problems with cone health primarily include insect pests, poor pollination, and cone abortion, which can be associated. In 2022, coneworm (*Dioryctria* spp.) damage affected our collections of Douglas-fir (*Pseudotsuga menziesii*) in Montana, third party cone scouters reported abundant cone abortion among Jeffrey (*Pinus jeffreyi*) and ponderosa pine (*P. ponderosa*) stands in California, and we observed poor pollination of Douglas-fir east of the Continental Divide in central Montana. Cone abortion can be caused by failed pollination, which has been linked to elevated temperatures (Flores-Rentería et al. 2018). As an example of a partnership that could aid this challenge, local foresters or research collaborators may be persuaded by monetary or scholarly incentives to regularly check insect traps set out early in the season for monitoring insect accumulation and report on trap contents and cone cut tests intermittently through July and August.

Common logistical challenges we encounter across our collection range can include:

1. Ensuring adequate cone storage in remote locations across a large geographic area to protect cones from moisture and overheating;
2. Securing transportation services and truck-loading equipment in remote areas;
3. Matching the timing of cone collection to cone ripening phenology;
4. Managing operations to match the availability of cone collectors, many of whom collect cones as a secondary income; and
5. Forecasting cone crop sizes and the length of time necessary to collect cones, which is necessary for contracting collection laborers who are deployed to remote locations.

The first four logistical challenges can be solved through more and stronger relationships with, and improved incentives for, our partners involved in seed procurement and transportation. For instance, incentivizing timely and flexible transportation services, often in remote areas, will enhance successful cone collection operations by reducing the duration of bushel storage in stockpiles, which often cannot be kept sufficiently ventilated and cool to limit seed damage. Monitoring conifer cone crop ripeness, abundance, and health across large geographic areas would help alleviate the challenge of forecasting cone crop status. Each challenge noted here is extensive in geographic scope and importance for the quality of our future forests, and will be solved only through large-scale collaborative approaches.

In any given region we rely on local cone collectors who primarily collect woods-run seed via tree climbing and squirrel caches, similar to the collection strategies used in northwestern North America historically (Maxwell and Aldhous 1967). We facilitate the travel of contracted climbing crews to areas where knowledgeable collectors are not available. Ensuring that high quality seeds are collected across such a large range requires our collectors to know how to evaluate cone ripeness and seed count, identify cone pests to avoid collecting infested cones and cones with poor seed fill, and how to safely move and store cones to avoid seed damage due to mold, overheating, or rough handling. Sharing this technical knowledge and strengthening the network of professionals involved in the conifer seed supply chain were the objectives of the first annual Tree Seed Summit, which drew together applied scientists and practitioners in northern California in 2022. The second annual Tree Seed Summit will occur in 2023 in Washington State. There we will further address the biological and logistical challenges associated with cone scouting and collection and seek to develop approaches to strengthen the network of professionals we rely upon to procure high-quality woods-run seed.

With an increasing number of collection locations each year, we are invested in expanding the geographic range of our expertise and partnering with local experts for scouting and to assess cone crop status. Supporting rural communities who have traditionally conducted this work remains a core value for DroneSeed today. So, we wish to partner with local and regional individuals or organizations who can help us improve the efficiency of forecasting for cone crop status across our collection range. We have found, however, that in many locations there is a scarcity of individuals with sufficient specialized local or regional knowledge of cone production. In addition to hosting the Tree Seed Summit, we have taken additional steps to help improve awareness of opportunities in the tree seed and seedling industry, and to streamline and simplify cone scouting and collections.

For example, in 2022, we developed and tested the utility of a cone crop reporting form and cone scouting guide for internal use to encourage data gathering and sharing of cone crop information. We are refining these tools and working toward making them public to encourage widespread data collection. We also exchange cone crop information with and occasionally purchase bushels from several other private seed and nursery companies and forestry outfits. Considering the growing threat of large wildfires to loss of valuable forest genetic resources, this information exchange is vital to expanding the geographic scope of cone collections, and has increased our awareness of the importance of our existing partnerships and of expanding our professional network. Scouting for cone crops over multiple states is time consuming, and we actively provide financial incentives to knowledgeable individuals or organizations willing to scout for us. As we increase and improve cone scouting information, we can focus collection efforts on the species and seedlots with greatest demand, and in turn provide reforestation resources to areas that need it most.

In addition to the typical biological challenges noted above, research is now revealing that climate warming is reducing the availability of wild seed. Interestingly, this decreased availability can result from increased seed production and decreased synchronization of cone production among periods of interannual variability in reproductive output (i.e. masting; Bogdziewicz et al. 2020, Wion et al. 2020; Khoury et al. 2021). For example, a long-term study of European beech (*Fagus sylvatica*) fecundity revealed that warming temperatures coincided with increased seed production, but decreased the year-to-year variability of seed production both for populations and individual trees (Bogdziewicz et al. 2020, Bogdziewicz et al. 2021). Increased seed production coupled with reduced year-to-year variability in fruit production removed resource limitations that usually keep granivore populations in-check, and thus resulted in a net reduction in seed availability (Bogdziewicz et al. 2020). As masting is expected to respond to similar ecological mechanisms across masting species, the trend described by Bogdziewicz et al. (2020) likely indicates changes we can also expect across North America's ecologically and economically important conifers due to unmitigated population growth of both granivores and insect pests that affect seed cones.

Considering the dual challenge of diminishing seed availability alongside increased seed demand, we are fortunate that the orthodox seeds of North American gymnosperms can be stored safely for decades under sufficiently cold and dry conditions. This quality makes North American gymnosperms good candidates for ex situ conservation of genetic material in seed banks, unlike species with recalcitrant seeds which are less amenable to long-term storage (Bonner and Karrfalt. 2008). Orthodox

Figure 1. Historic photograph of cone quality assessment from Silvaseed Company records (left). Demonstrating cone quality assessment at Silvaseed to the next generation of tree seed advocates (right; photo credit: Katherine Wong-Velasco).

seeds can be banked during good seed production years for use in subsequent reforestation projects, though the long-term storage potential of orthodox seeds are affected by ripeness at time of harvest and post-harvest handling (Solberg et al. 2020).

DroneSeed is a seven-year-old tech venture company that in 2021 merged with Silvaseed, a 130-year-old seed and seedling company, to better achieve our organizational mission of strengthening and supporting the seed collection industry in service of improving and scaling the reforestation pipeline. As illustrated by Maxwell and Aldhouse (1967) and our reflections here on our two most recent seed collection years (2021 and 2022), challenges associated with seed production, the importance of cone status monitoring, and the need to promote seed collection are just as relevant today as they were 55 years ago.

A key takeaway from comparing our contemporary experiences to historic accounts of the seed supply pipeline is that new approaches are clearly required for tackling the challenges outlined above. We believe that effective new approaches are likely to arise through improved educational opportunities and knowledge sharing concerning seed procurement. We promote an understanding of our industry through presentations to K–12 (Figure 1) and college classes, and through knowledge sharing workshops such as our annual Tree Seed Summit, which brings together conifer seed researchers and practitioners to identify and tackle shared challenges. We recognize that in order to realize our company mission of making reforestation scalable, we must prioritize the development of a vibrant workforce and strong partnerships to support expansion of and improvements to our cone scouting, storage, transportation, and crop status monitoring efforts.

Please contact us at: contact@droneseed.co to share your thoughts or to explore collaborations with us regarding the contents of this article.

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Ehren Moler, PhD
Carson Herold, B.A.
Biological Science Research and Development,
DroneSeed Co.
Seattle, Washington, USA
Email: contact@droneseed.co

Nursery Seed Use Efficiency or Seeds per Seedling

Introduction

Seed use efficiency is becoming more of a concern with the increased use of genetically improved seed that is expensive to produce via a seed orchard and/or in limited supply. Wild stand seed for rare biogeoclimatic zones may also be in limited supply, thus increasing its value and need for conservation. A common descriptor for nursery seed use efficiency is "seeds per seedling", which depends on many things. While the seed's germination capacity is the primary determinant, seeds per seedling is influenced by species, seedlot, container size, planting season, seedling specifications, the number of seedlings requested, and each growers' experience.

It is important to consider that while no nursery aims to waste valuable seed needlessly, their primary goal is maximizing growing space, especially expensive greenhouse space. In situations where the seedling purchaser supplies the nursery with seed at no cost, there is little financial compensation for seed saving. Growers are the most optimistic people you will ever meet. Still, they are usually loath to take on additional risk, such as increasing the number of empty cavities in their crop by not using enough seed at sowing. However, understanding the risk considering all the factors makes it possible to make an informed decision regarding seed use.

If a nursery is trying to reduce its seed use during sowing, they've missed the boat. The most efficient place to reduce seed is in Excel before the amount of seed allotted for a specific request is taken out of storage and begun stratification or pelleting. That way, during sowing, the grower does not have to think about seed reduction but rather how to effectively distribute all the seed received for each specific crop. By calculating the desired seeds per cavity based on the amount of seed and number of cavities to sow, all the allotted seed can be used up through constant monitoring and adjustment of the seeding equipment. That is not to say that nurseries should not attempt to achieve the maximum number of seedlings out of the allotted seed for each order. There are various practices carried out in the nursery that can enable the grower to feel confident about lowering their seed requirements.

Determining Seed Requirements

Determining the amount of seed required to produce a requested number of seedlings may seem like a black box to those not intimately involved in the nursery industry, even those who produce and own the seed. Nurseries use sowing tables consisting of the seed's germination capacity, the desired seeds per cavity (SPC) or sowing factor, the oversow or sowing correction factor and sometimes a nursery handling factor. Probability equations based on the percentage of seed that will not germinate (Schwartz, 1993) have been used to estimate the potential empty cavities based on the germination capacity and seeds sown per cavity. Note: it is recognized that nursery sowing equipment currently in use does not result in 100% sowing accuracy and that the odds of physically achieving 2.25 seeds in one cavity are nil.

At first glance, it appears that a nursery should sow the number of SPC that results in 0% empties. However, as the probability of achieving 100% cavity fill increases, so does the amount of seed required. For example, sowing a seedlot with 90% germination capacity at 2.0 SPC would theoretically result in 1% empties (assuming sowing was perfect). That is 18% more seed required than sowing 1.7 SPC to end up with only 2% empty cavities. Not only does this increase the seed cost, but it also increases the nursery's thinning cost. Proper use of fractional sowing by strategically sealing drum holes with tape can create an optimum SPC for each request—minimal empties with enough "doubles" to transplant the empties if desired. Once the desired SPC has been determined, the nursery then determines the oversow, which is the percentage of additional containers required to produce the requested number of seedlings. The additional cavities are to account for empty cavities, disease, insect, abiotic damage, and seedlings not meeting the contract specifications or culls. Thus, reduced seedling specifications such as lifting to extractable plug increase seed use efficiency, as does planting all overruns (i.e., seedlings grown in excess of the requested amount). Placing a larger seedling request also increases seed use efficiency, as nurseries usually increase the oversow for small orders due to the higher risk when something goes wrong with a small number of containers.

Seed Handling

Various steps are taken in the nursery to get the maximum potential possible out of every seedlot (see Kolotelo et al., 2001 for practical guidelines). This begins by ensuring that the planned sow dates correspond to the nursery's actual sow dates so that the seed has received sufficient stratification prior to sowing. Alternatively, holding seed for an extended period after stratification may result in seeds germinating in the bag and/or excessive storage mould. To retain the vigour of seed stratified off-site, it should be properly transported via express courier in an insulated container with ice packs. Seed should be inspected upon arrival, the bags opened slightly for air exchange, placed into a cooler at 4°C with high/low-temperature alarms and rotated weekly.

Using clean seed results in greater cavity fill, which gives growers greater confidence in using less seed. Before stratification, heavy debris such as pitch and grit can be easily separated from dry seed via a water funnel. Poor germinating seedlots of certain species, such as *Abies* spp., can be upgraded through density separation (Kolotelo, 1993), resulting in less but more viable seeds being sown, which promotes better cavity fill. Light trash and debris can be separated from seed immediately prior to sowing via a vacuum separator, and pelleted seeds can be gently shaken in soil sieves to remove dust and flecks of the coating material. For the sowing equipment to operate at its full potential, the seed must be "surface dry" and flowable. In a pinch, talc can be introduced into a bag of seed and shaken to remove excess moisture, thus preventing seeds from clumping. Another cleaning method that may increase seed use efficiency is seed sanitation if the seedlot is known to be infected. For example, after stratification Douglas-fir (*Pseudotsuga menziesii*) seed is often disinfected via a hydrogen peroxide soak, to reduce seed-borne pathogens such as *Fusarium* spp.

Sowing Machinery

Numerous companies manufacture sowing equipment, although basic older equipment, upgraded with new electronic controls, is still in use. The challenge with forest tree seed is the countless variations in seed size, weight and shape among the various species sown and even among the same species. As well, operational logistics require that a large number of containers are sown within a relatively short time frame. A highly skilled sowing machine operator and mechanic go a long way in increasing the accuracy of any sowing machine. For larger seeded species, having staff drop seeds into empty cavities further increases the sowing accuracy. Vacuum drum seeders are desirable in that any possible combination of seeds per cavity (i.e., fractional

sowing) can be quickly configured with masking tape.

During sowing, tapered tampers or dibblers can create a depression in the growing medium to guide the seed toward the center of the cavity. Care must be taken not to add excess grit, which can impede seedling germination. After seed placement, the container may be misted before covering with grit or sawdust to prevent the seed from "bouncing" out of the cavity and keep the seed moist. While the containers may be sown with high precision, they can be upset on the way to the greenhouse. Ensuring the containers are not banged together when loading onto a bench or pallet and transporting the containers to the growing location with as little movement as possible helps ensure the seed stays where it is sown. Pelletized seed such as Western redcedar (*Thuja plicata*) tends to float to the surface of the grit and requires extra careful handling.

Germination

Germination capacity is the value growers most commonly use when describing seed quality. However, germination uniformity is the key to increasing the number of seedlings produced per container. Faster germination usually produces a more uniform crop by reducing initial size differences between young germinants. Peak Value is one metric describing germination rate or speed (see Figure 60 in Kolotelo et al. 2001), although it is not common nursery vernacular. Prior to sowing, extended stratification of some species is one of many steps nurseries can introduce to obtain more uniform seedling germination.

After sowing, providing a warm germination environment is another step the grower can take to promote crop uniformity. Warmer temperatures compress differences in germination speed within a seedlot. In a greenhouse, this is possible by setting a continuous high temperature (e.g., 25°C) day and night until germination is complete. As well, in a large greenhouse, waiting until the greenhouse is full before heating promotes uniformity. Quick even germination can also be promoted by thermal priming of the seeds before sowing.

To achieve maximum, even germination, it is essential that seeds remain moist and do not begin to dry out. This is done by saturating the growing media after sowing and misting as necessary. However, misting should depend on environmental conditions at the time of sowing, as too much of the typically cool water applied via misting will cool down the germinating seed and media it is resting on, slowing germination. Starting with the above, followed by many more favourable practices, a good grower can reduce the seed-to-seedling ratio by increasing the percentage of plantable seedlings grown or recovered per container.

Conclusion

At most nurseries, there is likely the potential for increasing seed use efficiency. This is best done through upfront planning, evaluating the SPC/probable empty cavity relationship and tightening up the oversow. How confident a grower feels in reducing their seed use depends on how well they can maximize each seed's potential from stratification to handling, sowing, germination and growing.

There is unlikely to be an optimum seed-to-seedling ratio for all nurseries, as it depends on many, often conflicting priorities. Most nurseries already practice one form of seed conservation or another, although there is an increased risk but often little reward for nurseries with the best seed use efficiency. Nursery seed conservation could be encouraged by calculating a nursery's seed per seedling ratio and using it as one of the parameters, such as quality and price, in awarding seedling contracts. In cases where there is a very limited seed supply, alternative payment models have also been used where nurseries are paid for the greenhouse space (i.e., by the container) rather than the seedling.

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Steven Kiiskila
Crop Manager, Arbutus Grove Nursery
North Saanich, British Columbia
Email: skiiskila@arbutusgrove.com

NTSC Supports Small-Scale Equipment Manufacturing Runs

The National Tree Seed Centre (NTSC) is helping to support a manufacturing run of small cone and seed extraction tumblers with a local collaborator in Fredericton, New Brunswick (Figure 1). We are also coordinating a limited run of cone cutting knives estimated at $350 CDN (Figure 2, terms FOB shipped from Ontario). This machete-style design is one depicted in Portlock (1996). Orders should be placed well in advance of when you need them.

While the tumbler is not efficient for large-volume collections, it has proven cost-effective for small and medium-sized enterprises handling a diversity of non-resinous species and smaller seedlots than typical industrial cone-processing services may handle. This tumbler can also be modified with different screens, and the manufacturer is open to certain modifications if discussed.

The tumbler can be previewed in action in the videos below:

- NTSC webinar "Equipment Solutions": https://youtu.be/mu0jTd5ahCc?t=1167
- Green Legacy Nursery (Wellington, Ontario) processing Norway Spruce: https://www.youtube.com/watch?v=addRc5y9aKU

Tumbler Specifications

- Exterior footprint: With lid closed, 74 cm wide × 75 cm tall × 88 cm deep (Figure 1a). With lid open, 110 cm tall (Figure 1b).
- Interior drawer size for seed catchment: 50 cm wide and long × 9 cm deep (Figure 1b).
- Interior drum volume: 45 cm wide × 22.5 cm radii, full = approximately 71 litres, but 10–40% filled is recommended for efficient extraction (varies by species).
- Primary screen size: 0.593 mm square mesh is currently standard. NTSC's experience is that *Thuja* cones can get caught in the screens, *Tsuga* generally do not.
- Motor: ¼ HP, 110V (standard Canadian plug). 1725 RPM reduced to 20 RPM.
- This tumbler is not heated, so extraction efficiency depends on having cones and fruits being well dried, scales reflexed or threshed before tumbling.
- For *Populus* and *Salix* extraction, wrap with additional screenings: 1.2 m × 2.1 m roll of window screening, openings ~1.18 mm. A hair dryer can be used to increase extraction efficiency (Daigle and Simpson 2009).
- Use a shop vac and/or air compressor to clean the machine; can also be wiped clean with a damp cloth. Do not add running water during operation.

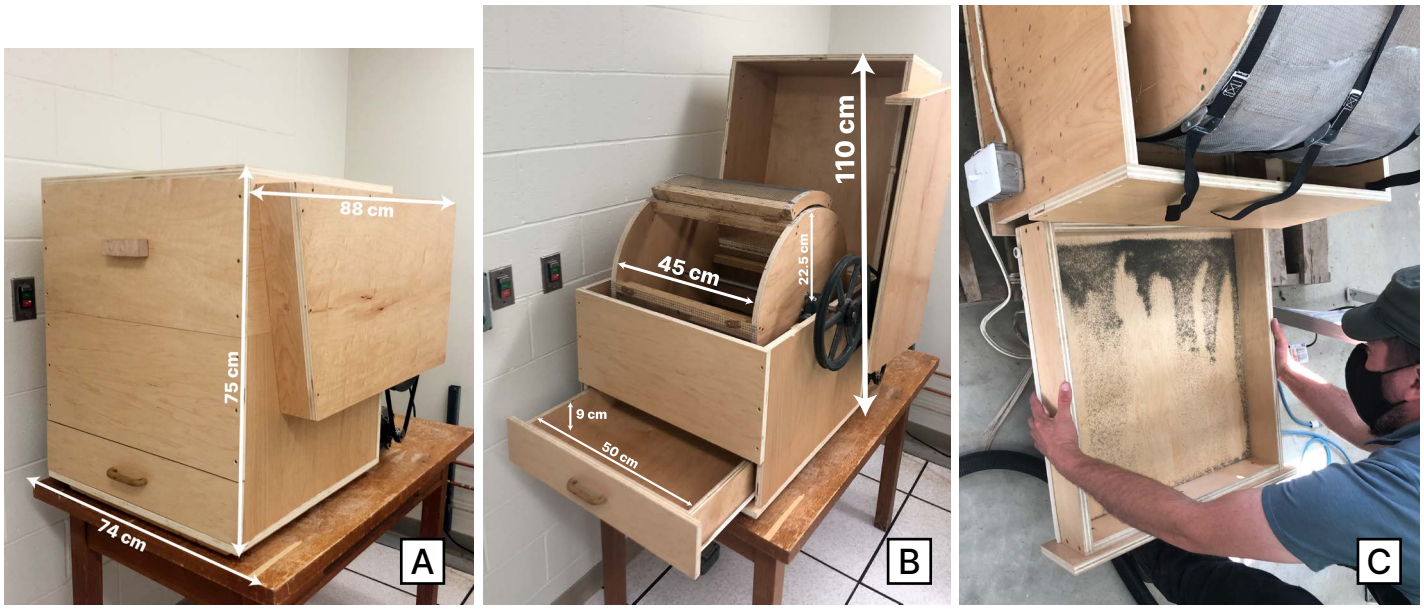

Figure 1. Cone, catkin and dry fruit tumbler and dimensions shown with lid closed (a), lid, drawers and tumbler loading door open (b), and in action at Verbinnens's Nursery extracting *Salix* spp. with the additional window screen wrapping.

Cost and Shipping

- FOB (Fredericton) estimated base price for 1 tumbler with 1 screen size = $2500 CDN.
- Typically ships on a standard 4' × 4' pallet. It is possible to strap 2 tumblers to one pallet.
- It is also recommended that more than 1 person is needed to lift the machine.

Caveats to Ordering

- Price for tumbler(s) will be quoted based on final FOB/pick-up price Fredericton. If you can arrange your own shipping to the final destination cheaper, that is helpful.
- The motor belt is partially exposed, so you may need to construct additional safety guards based on final installed set-up and local work safety rules.
- There are no guarantees on turn-around time from time of order to delivery based on ongoing supply chain issues for certain parts or substitutions. This unit is also out of typical production for the manufacturer.

Aspirator Designs

The NTSC also located full-sized AutoCAD engineering drawings in our archives, first described by Hergert et al. (1966) and a pamphlet annotated by Ben Wang in 1985 as being originally manufactured by Craftsman Machine Company, and later Mechanical Welding Company Limited, both in Winnipeg, Manitoba. These designs were intended for small research samples and seeds, with blower cups aspirating 20 or 200 grams at a time. With the addition of a variable rheostat motor on the fan box, the larger design has been a stalwart unit in our lab for almost 40 years.

Figure 2. Machete-style cone knife in use with a small eastern white pine (*Pinus strobus*) cone. Photo by Melissa Spearing.

We could not locate the complete engineering specifications series online in Agriculture Canada nor Library Archives (Canada Dept. of Agriculture 1971), but we can likely provide copies of the AutoCAD drawings made for us on request.

Any questions or needs to discuss with the tumbler manufacturer, please contact Simon Wilby below. Cone knife orders and all other NTSC questions should be directed to Jacob Billings below.

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Simon Wilby
Fredericton, New Brunswick
Email: wilbysimon@gmail.com
Phone: 506–440–0336

Jacob Billings
Natural Resources Canada, Canadian Forest Service
National Tree Seed Centre
Fredericton, New Brunswick
Email: jacob.billings@nrcan-rncan.gc.ca
Phone: 506–452–3289

Operation Hygrofoil

Introduction

The National Tree Seed Centre (NTSC) maintains more than 13,000 seed collections from over 200 tree and shrub species, the most diverse collection of its kind in Canada. Genebank management is critical to our long-term mandates for forest and seed research, biodiversity conservation and reporting on the state of Canada's forest genetic resources (Loo et al. 2022).

In 1998, the first seedlots were identified to be set aside from NTSC's Active Research (AR) collection to conserve valuable samples from being fully exhausted. The Gene Conservation (GC) collection and freezer was established "to assure that genetic material from rare, endangered and/or unique populations is preserved. Material stored in this category will be of good quality and testing will be carried out on sub-samples of the material." (Daigle and Simpson 2001). Today, the GC collection also includes a significant number of Canadian Forest Service breeding and provenance test seed reserves, long-term in-house NTSC experiments, donations from the former Indianhead Prairie Shelterbelt Program seed bank and now non-woody Species at Risk (i.e., *Pedicularis furbishae*, Williams 2021). Cryopreserved fractions and seedlots are not included at this time.

Moisture content can significantly impact seed longevity (Hay et al. 2022, FAO 2022). From 1996–2013 Annual Reports, the NTSC's operational target moisture content was 5–8%, which dropped to 7% as the upper limit thereafter. The NTSC stores the vast majority of orthodox seed samples in glass canning jars (Mason-style brands) at –20°C. However, canning jar lids may not be 100% moisture-proof. Humidity can infiltrate due to low quality of rubber seals or variability in tightening pressure (Smith et al. 2003, J. Adams pers. comm). So in addition to those originally sealed above 7%, random lids may be failing over time, thus potentially impacting seed longevity (Simpson et al. 2004). In truth, most GC collections have not been retested on NTSC's typical 10-year schedule due to a lack of capacity.

In Canada, Quebec's Berthier Tree Seed Centre, Alberta Tree Improvement & Seed Centre (ATISC) and province of British Columbia's Tree Seed Centre have adopted water activity (a_w) tools for rapid non-destructive seed and pollen testing (see TSWG News Bulletin No. 46, 48, 50–52, 54, 55, 58–63). Robb (2013) also tested various storage containers and concluded ATISC's research and conservation collections would be better stored in laminated foil bags.

In February 2022, the NTSC began "Operation Hygrofoil", an initiative intended to assess and extend the longevity of the Gene Conservation collection. This is to be accomplished by 1) retesting all GC seedlots, and 2) transferring high quality samples to a resealable foil bag seed storage system. This project is related to the materials handling theme of this issue, as a result of new equipment and operational procedures, and growing human resource capacity now available.

New Equipment and Moisture Targets

The NTSC has sourced all water activity equipment from Rotronic Canada (Stoney Creek, Ontario). Dale Simpson first acquired a HygroPalm 23–AW–A unit with two HC2–AW probes in 2015, and we added a single HC2–AW–USB probe in early 2019. To support Operation Hygrofoil and manage thousands of new seed samples collected or received in 2019–2020, we acquired a new 4-probe HygroLab unit in early 2021.

From 2015–2018, Dale took 209 a_w readings, 70% of which were paired with a germination and oven moisture content tests (Figure 1). This initial dataset indicated the NTSC was maintaining an average of 0.292 a_w over a range of species, to a minimum of 0.167. But without typical oil content of a species, or if any intra-specific variation occurs, we cannot utilize seed viability calculators used to predict moisture content or storage time in our collections (see https://ser-sid.org/viability/moisture-equilibrium).

After literature review and operational discussions, the NTSC set 0.25–0.30 a_w as our new target prior to hermetic frozen storage in 2020. This is equivalent to 25–30% equilibrium relative humidity (eRH) at 20–25°C. This is readily achievable under ambient conditions in the winter or in a dehumidified lab as necessary. For donated samples, this is a compromise between standards used by British Columbia (0.35 a_w), Alberta (0.15–0.25 a_w), Berthier Tree Seed Centre (0.33–0.38 a_w), and the USDA's Fort Collins genebank equilibrating seeds to 25–35% relative humidity. This was a useful demonstration video by the Centre for Plant Conservation (2020). Any samples sent to the NTSC already sealed in foil bags are stored as is, unless otherwise discussed.

Figure 1. Exploratory water activity data with same-time oven moisture content and germination tests done on the NTSC's Active Research collection from 2015-2018. The size of the point is relative to the seedlot age in 2021 (1–55 years), and red to dark green gradient represents the last high vigour germination value in 10% increments from 0–100%. The gray bands indicate average and minimum values across all species. The trend line is a 3rd degree polynomial and 95% confidence band, r^2 = 0.179, P<0.0001.

The Forest Gene Conservation Association in Ontario donated the initial shipment of foil bags (Baltimore Innovations B-Sure™, three sizes, two with zip-lock sides) and a foot-operated sealer (Pack Secure, AIE-302CH -12 Inch Constant Heat Foot Sealer) in 2019. The first collection foil-bagged was over 500 clonal seedlots from Southern Ontario's eastern white pine seed orchards. This project allowed staff to get familiar with the new equipment and adjust NTSC seed testing data collection sheets. In 2020, we also acquired a new S-25 digital seed counter (Data Technologies), which helped speed up counting once *Pinus strobus* was calibrated. Lastly, in February 2022, we received a new digital Kubtec Xpert® 80 Cabinet X-ray for quick, non-destructive assessments of filled, empty and insect-infested seeds (Figure 2).

Determining Priorities

Prior to the 2019 bumper seed registration year, there were 5,450 tree and shrub seedlots in the Gene Conservation freezer (Table 1). Beardmore et al. (2006) prioritized species through jurisdictional surveys and assigned rankings for 124 tree species ≥10 meters in height as follows:

- RV0 = The species is considered to be in good shape with no apparent cause for concern.
- RV1 = The species may need attention but current knowledge is inadequate due to a) insufficient data; b) direct evidence of a potential problem; or c) indirect evidence of a potential problem.
- RV2 = The species requires *in situ* conservation.
- RV3 = Specific gene conservation measures (*ex situ*) are required to ensure the integrity of the native gene pool.

These codes are part of the NTSC database for gap analysis and reporting, as well as fields for current federal and provincial Species at Risk designations. In the 2010 NTSC strategic plan, the goal was to update rankings, prioritize new collection efforts and research needs every five years with our collaborators, long before recovery programs required germplasm (Simpson and Daigle 2011). This approach remains urgent, since by the time legal protection and recovery strategies are enabled (if at all), effective population sizes (*Ne*) and allelic richness can be greatly reduced (Hoban et al. 2021, Williams et al. in prep). Any species or genetically distinct population with a current

Table 1. Summary of the 2018 National Tree Seed Centre Gene Conservation (GC) seedlots considered for Operation Hygrofoil. Yellow highlights indicate nationally-ranked RV3 species identified in the initial survey (Beardmore et al. 2006) or most recent update (Loo et al. 2022, Table 7.1). Blue highlights indicates a species with single jurisdictional high priority (RV3) ranking in the 2012 surveys[1].

Species	No. of GC Seedlots	Species	No. of GC Seedlots
Abies amabilis	3	*Magnolia acuminata*	1
Abies balsamea	8	*Nyssa sylvatica*	2
Abies lasiocarpa	3	*Pedicularis furbishiae*	18
Acer negundo (AB[1])	15	*Picea glauca*	1,647
Acer pensylvanicum	17	*Picea glauca* ssp. *porsildii*	15
Acer rubrum	111	*Picea glauca* var. *albertiana*	9
Acer saccharum	23	*Picea mariana*	435
Acer spicatum	49	*Picea rubens*	222
Alnus incana ssp. *rugosa*	3	*Pinus albicaulis*	60
Alnus incana ssp. *tenuifolia*	1	*Pinus banksiana* (NS[1])	95
Alnus rubra	2	*Pinus contorta* var. *contorta*	1
Alnus serrulata	2	*Pinus contorta* var. *latifolia*	14
Alnus viridis ssp. *crispa*	9	*Pinus flexilis*	102
Betula alleghaniensis	57	*Pinus pinceana*	181
Betula cordifolia	5	*Pinus ponderosa*	11
Betula lenta	8	*Pinus resinosa*	15
Betula minor	1	*Pinus rigida*	4
Betula papyrifera	10	*Pinus strobus*	72
Betula populifolia	20	*Pinus sylvestris*	12
Betula ssp.[2]	1	*Populus balsamifera*	20
Cephalanthus occidentalis	1	*Populus grandidentata* (MB[1])	13
Cornus drummondii	2	*Populus tremuloides*	17
Cornus florida	4	*Prunus pensylvanica*	61
Crataegus coccinea pringlei	1	*Prunus virginiana* var. *virginiana*	356
Crataegus rotundifolia	36	*Pseudotsuga menziesii* var. *glauca*	2
Fraxinus americana	349	*Ptelea trifoliata*	6
Fraxinus nigra	241	*Rosa acicularis*	10
Fraxinus pennsylvanica	368	*Rosa woodsii*	66
Fraxinus profunda	1	*Salix discolor*	16
Fraxinus quadrangulata	23	*Salix lanata* ssp. *richardsonii*	1
Gymnocladus dioicus	5	*Symphoricarpos occidentalis*	22
Hypericum kalmainum	1	*Thuja occidentalis*	89
Ilex verticillata	1	*Thuja plicata*	2
Larix laricina	268	*Tsuga canadensis*	186
Larix occidentalis	6	*Tsuga mertensiana*	1
Liriodendron tulipifera	1	*Ulmus rubra*	10
		Total Number of Seedlots	**5,450**

[1]National and jurisdictional survey responses are archived at https://pfc.cfsnet.nfis.org/CAFGRIS/survey_report_select.jsp

[2]Species will be identified or returned to Active Research Collection.

Figure 2. A poster made for National Tree Seed Centre tours to illustrate outputs from the new digital X-ray machine and Image Blender™ software on a diversity of tree and shrub seedlots.

Ne less than 500 mature individuals should automatically qualify as a high priority target for *ex situ* banking.

Operation Hygrofoil will prioritize RV3 species and any sample initially stored over 7% moisture content (Table 2), with one final set of oven moisture content tests to determine the proportion of canning jar lids leaking. It was also proposed to look at 1,400 seedlots with samples split between GC and AR collections. Will seed quality differ substantially since they were split? I.e. would the viability of the AR sample be impacted by repeated opening for retesting and seed orders in comparison to the unopened GC fraction, or vice versa? We present our approach below, but are far from a robust data analysis to answer these questions.

Hygrofoil Order of Operations

Jars are removed from the freezer and gradually warmed to room temperature over 48 hours (24 hours at 4°C, then 24 hours at room temperature). Within a few minutes of opening, each seedlot is thoroughly mixed, representative samples withdrawn, and divided between two HC2 probes. We use the AWQ "quick mode" (typically equilibrating within 10 minutes) most of the time, but the long AWE ("equilibrium mode") will be used to avoid grinding species with large seeds, impervious or thick seed coats. Initial a_w readings are averaged to two decimal places.

If seed quantities permit, an oven moisture content test is done (International Rules for Seed Testing (2022)) along with initial a_w measurements. Germination testing is set up on four samples of 50 seeds, with pretreatments and scored as per Spearing et al. (2021) or literature review for unusual species. Any seedlot >0.30 initial a_w is spread thinly in mesh trays to dry down in a 25–30% relative humidity lab.

Once seedlot's $a_w \times 100$ matches the relative humidity, thousand seed weight (TSW) and total remaining seed weight is calculated and recorded in grams. When there are less than 800 seeds, pure seed is counted by hand or by the S-25 machine. TSW is calculated with 8 × 100 pure seed reps (ISTA 2022) or by dividing the total weight of the seedlot by the total number of seed and multiplying the result by 1000. Two final a_w measurements are taken, averaged and recorded. Good quality GC collections are then transferred to an appropriately sized foil bag, heat sealed and labeled before frozen storage. AR collections are returned to an appropriately sized glass canning jar, with a 1 gram indicating silica packet near the lid before returning to the freezer.

Ongoing Work

Operation Hygrofoil began scheduling testing in February 2022, on top of existing new and COVID-delayed 10-year NTSC testing needs. This limited the number of Hygrofoil seedlots that could be initiated each week and month. While the digital X-ray is an efficient tool, the desire for quick viability assessments is now a new bottleneck in our lab for deeply dormant species. We also had to expand and reorganize our processing labs to make a designated work-safe X-ray room.

To December 1, 2022, 321 seedlots have been withdrawn for Operation Hygrofoil, including 59 seedlots with samples in both the Active Research and Gene Conservation collections (Table 2). While some paired germination tests are done, many with longer pretreatments (i.e. *Fraxinus* spp.) will be going into the germinators this winter. Scheduling tests to end as the AFC greenhouse warms up enables the potential for transplanting germinants if needed.

At the current rate, Operation Hygrofoil could take up to five years to test, assess and foil seal the best Gene Conservation seedlots accumulated prior to 2019. The speed of testing could be doubled with the assignment of one other skilled technician on the project on at least a part-time basis. We also need to train our staff on new statistical programs suitable to analyzing our data, or partner with researchers interested in exploring other questions.

As we progress, Operation Hygrofoil is a unique opportunity to generate significant new imagery and longevity data for rare and uncommon Canadian tree and shrub species. Retaining only high quality Gene Conservation collections will also support gap analysis with our partners and report progress in the next "State of Canada's Forest Genetic Resources" report.

Any questions about Hygrofoil data to date, please contact Roger Graves. For questions related to conservation priorities and potential germinants, please contact Donnie McPhee.

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Table 2. Average initial water activity and previous moisture content from Active Research (AR) and Gene Conservation (GC) seedlots measured as part of Operation Hygrofoil, as of December 2022.

Species	Average Initial Water Activity	Average Previous Moisture Content (%)	Number of Paired AR-GC Seedlots	Total Number of Seedlots
Abies amabilis	0.34	6.6	3	6
Abies lasiocarpa	0.39	6.1	3	6
Acer negundo	0.49	8.7	0	15
Acer pensylvanicum	0.29	7.4	12	29
Acer rubrum	0.26	8.6	12	43
Alnus incana ssp. *rugosa*	0.38	6.9	2	4
Alnus incana ssp. *tenuifolia*	0.34	7.6	1	2
Alnus serrulata	0.27	6.0	2	4
Betula lenta	0.35	6.3	0	4
Betula papyrifera	0.32	7.4	0	1
Fraxinus americana	0.35	7.1	4	10
Fraxinus nigra	0.33	7.1	11	42
Picea mariana	0.37	8.1	3	7
Picea rubens	0.55	8.1	0	132
Pinus banksiana	0.54	---[1]	1	6
Tsuga canadensis	0.46	7.2	5	10
	0.37	**7.3**	**59**	**321**

[1]Insufficient seed to conduct a gravimetric oven moisture content test.

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Roger Graves
Technician, National Tree Seed Centre
Atlantic Forestry Centre, Fredericton, New Brunswick
Email: roger.graves@nrcan-rncan.gc.ca

Donnie McPhee
Coordinator, National Tree Seed Centre
Atlantic Forestry Centre, Fredericton, New Brunswick
Email: donnie.mcphee@nrcan-rncan.gc.ca

Melissa Spearing
Biologist, National Tree Seed Centre
Atlantic Forestry Centre, Fredericton, New Brunswick
Email: melissa.spearing@nrcan-rncan.gc.ca

TSWG Membership Needs: A Review and 2021 Summary

Every so often, the Tree Seed Working Group (TSWG) Chair, Editor or champion researcher canvas our membership for input on current seed research and operational needs. This article reviews these past efforts for those interested and summarizes the last membership survey that closed in June 2021. The final results are intended to spur further discussion and direct TSWG workshops and News Bulletin (No. #) themes.

TSWG Research Needs since 1983

At a Canadian Tree Improvement Association (CTIA) workshop in Toronto, August 1983, Dr. Robert Farmer (Lakehead University, who later published *Seed Ecophysiology of Temperate and Forest Trees* (1997)) led the first TSWG research scoping exercise. These were, in no particular order:

- Variation in genetic control of seed germination
- Seed population biology and ecology
- Seed and cone yield analysis
- Seed maturity related to reproductive processes and conditions
- Maturation and ripeness indices
- Seed crop management: production, procurement and protection
- Efficient utilization of seeds

The CTIA motioned to endorse the TSWG's first set of priorities and encourage research to be done by appropriate organizations. Besides TSWG Chairs and Editors, tree seed champions like Dr. Guy Caron, Dr. George Edwards, Frank Bonner, Dr. Carole Leadem, Dr. Peter de Groot and Ron Smith continually pushed for input and support inside and outside the TSWG over the next three decades. A scan of the top priorities is highlighted in Table 1.

2021 Membership Survey Results

The 2019 survey started with two specific objectives, 1) to rank important needs to discuss at the August 2019 TSWG workshop in Lac-Delage, Quebec, and 2) to assess other TSWG knowledge exchange opportunities in light of travel limitations for many members. The survey was first distributed to 276 subscribers in March 2019, and preliminary results from 43 members were noted in TSWG No. 69. The last call went out during a virtual TSWG breakout session during the May 2021 student and post-doc CFGA-WFGA symposium, which helped to capture a few underrepresented jurisdictions.

In total, we received 53 responses, with representation from Canada (35, including Dave Kolotelo and myself), the United States (14), China (1), Norway (1), Sweden (1) and New Zealand (1). The majority of responses (49) were received from March to August 2019, so the response rate was approximately 17.8%, compared to 58% Hugh Schooley captured in 1992. Thanks to the Forest Gene Conservation Association for hosting the survey for us.

Figure 1 finalizes 25 new priorities, with "high priority" choices weighted ×2 to emphasize potential operational bottlenecks forthcoming. Figure 2 maps the average rankings of the top four priorities within Canadian and US jurisdictions, with federal employees included at their reported primary office location. While it would be nice to have a larger sample size in many regions, I present this data "as-is" as a measure of engagement mostly before the COVID-19 pandemic and a basis for improvement.

Still, the top initial priority from 2019 came out stronger in the final analysis: the shortages, efficiency, training and succession of cone and seed collectors. Given discussions at Lac-Delage and the international June 2022 "Challenges to our Future Tree Seed Supply" event, this appears to be a worldwide concern, but as Figure 2 shows for North America, it varies by region.

Figures 3 and 4 present counts of self-reported tree seed biology and applied technology skills. I grouped the status of active members in Fall 2022 by email correspondence, government and company directories, and LinkedIn profiles. Accounting for retirees and those I couldn't find, in the span of just three years, we have about 14% fewer seed biologists and 23% fewer seed technologists still actively working. Going back to the founding membership drive TSWG (No. 3), Table 2 compares 1985 and 2021 representation by jurisdiction. The decline and engagement over this period is likely reflective of the true number of people working in tree improvement, following similar trends to Wheeler et al. (2015)'s regional tree improvement membership numbers from 1957–2013.

Table 1. Summary of Tree Seed Working Group research priorities from 1984–2021.

Year	Survey Group	Top Priorities		Reference[1]
		Research & Development (R&D)	Operational & Training (O&T)	
1984	Joint BC-Canadian Forest Service (CFS) Cone and Seed Committee	Seed testing and preparation for sowing (includes seed pretreatment; monitoring seed performance in the field; vigor testing; quick viability tests; viability separation)	Cone and seed processing (includes kilning; extraction; precision seeding; sowing factors)	Edwards TSWG No. 2
1984	BC Coastal Tree Improvement Council	Research needs were also operational for orchard management, Top 3 were: Cone enhancement, pollen management, cone and seed pests		Edwards TSWG No. 2
1987	TSWG / IUFRO	Requested input from TSWG members to update the 1977 Tree Seed Equipment List, including those in research labs. No update was completed.		Bonner TSWG No. 7
1990	BC Cone and Seed Committee	Top priority in both R&D and O&T: Seed testing and preparation (including pretreatment and dormancy, viability sorting, monitoring seed performance, vigour testing and quick tests) with expected high impact and medium-high feasibility.		Leadem TSWG No. 14
1991	Integrated Pest Management in Seed Orchards	Funded CFS project #1: Development of pheromone-based management tools for integrated pest management of cone beetles		De Groot, TSWG No. 19
1998	TSWG Members	"Tree Seed Research: Is anyone doing any?" a scan of CFS programs indicated seed research was hidden amongst Biodiversity, Biotechnology and Advanced Genetics, Forest Health and Pest Management programs. Smith indicated "the National Tree Seed Centre is the only CFS centre with seed research remaining as one of its core priorities". Smith acknowledged that BC Ministry of Forests seed research programs were going strong.		Smith TSWG No. 29
2001	Literature	Editorial review on types of research problems and how to motivate new tree seed researchers, communication and investment.		Kolotelo TSWG No. 34
2004	TSWG review	Competition for tree seed research funding with molecular studies	Retirements of former tree seed leaders; lack of newcomers interested in advancing tree seed technology	Kolotelo TSWG No. 40
	Quebec	Electrostatic pollination to improve seed orchard production	Improve extraction methods to increase seed lot quality	Colas and Bettez TSWG No. 40
	Saskatchewan	Seed volume planning by species	Current education and short courses for inexperienced; regional perspectives	Weedon TSWG No. 40
	Academic review, operational users	Seed biology: oxidative stress, antioxidants and seed senescence	Antioxidant protectant field studies	Blake and Smith TSWG No. 40
2021	TSWG Members	25 priorities ranked, no distinction between R&D or O&T. Top 4 globally: 1. Cone and seed collectors/contractors: efficiencies, shortages, training, succession, etc 2. Effects of climate change on seed crops 3. Seed use efficiency and seed and cone yield analysis 4. Seed orchard management: efficiencies, establishment, economics, etc.		Spearing TSWG No. 73

[1]Past Tree Seed Working Group News Bulletins can be found here: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/tree-seed-centre/cone-seed-improvement-program/tree-seed-working-group

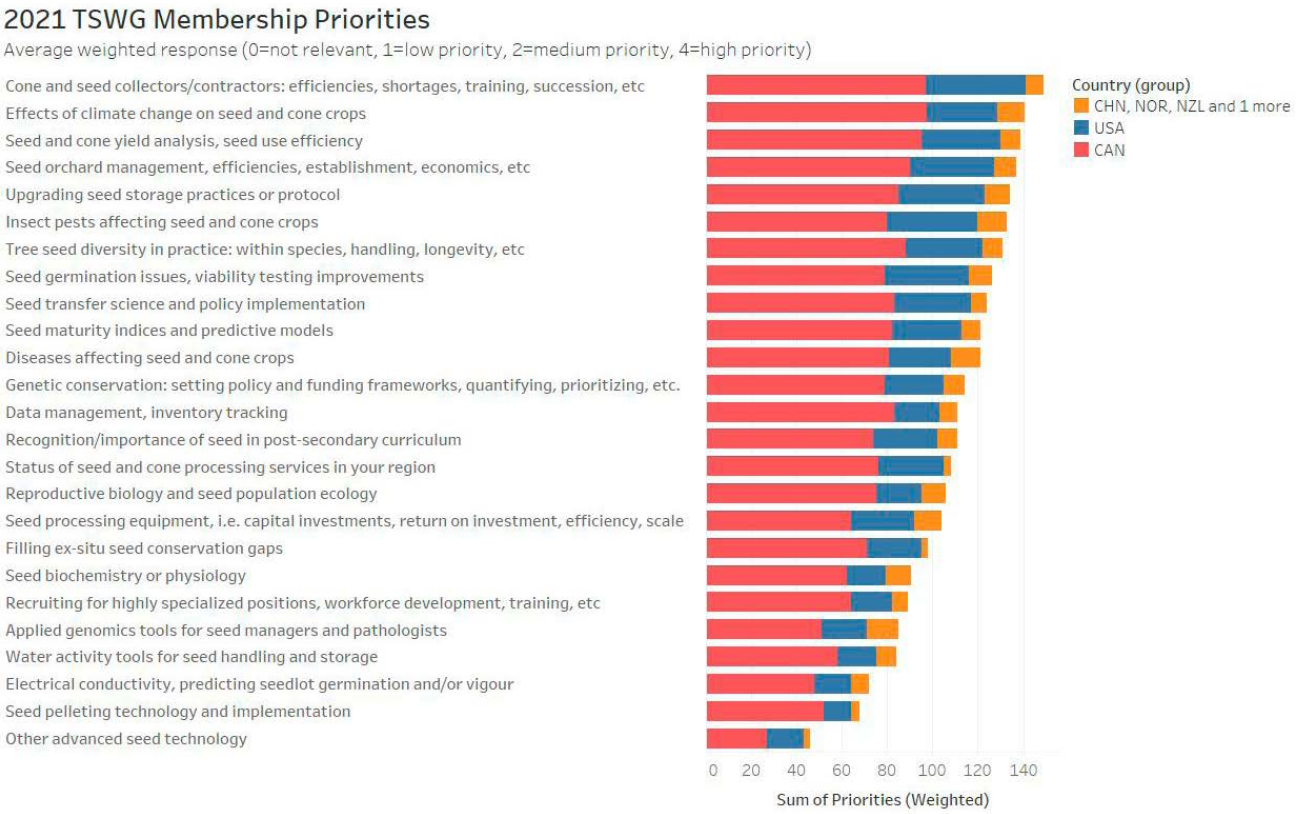
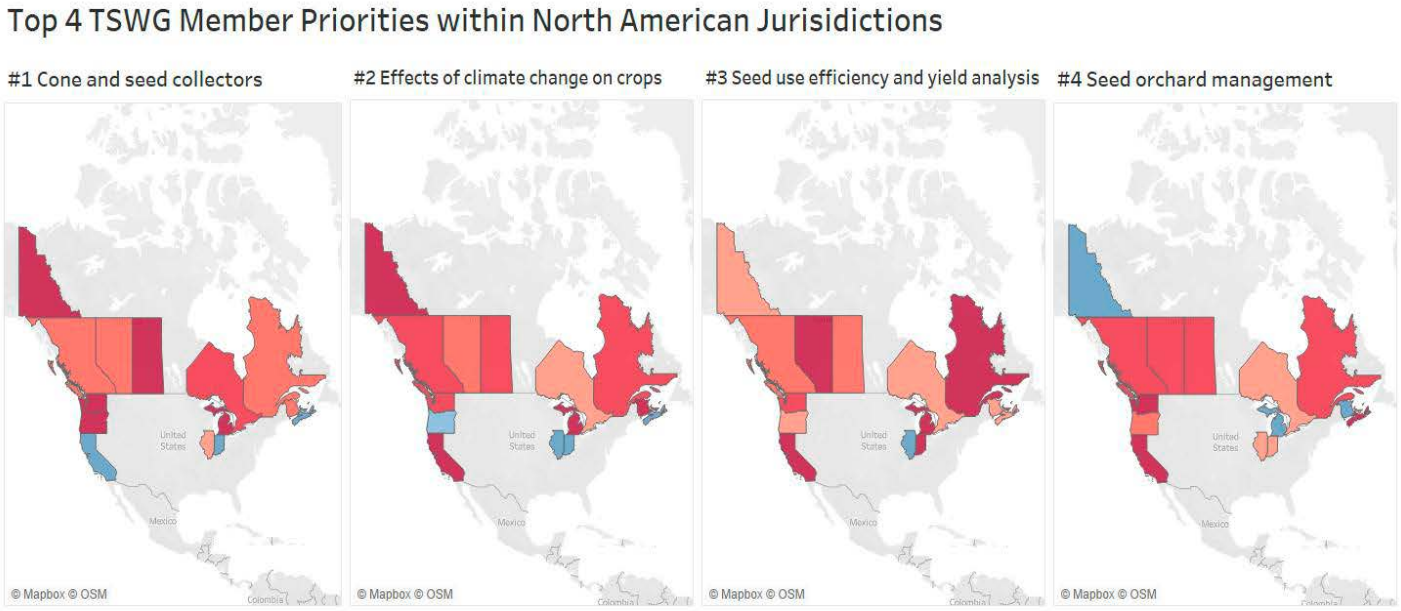


Figure 1. 25 ranked priorities from 53 Tree Seed Working Group members, summed by Canadian (red), United States (blue) and all other country (orange) responses. "High priority" responses were weighted to emphasize critical operational needs.



Canada									United States of America						Grand Total
BC	ON	QC	AB	NB	SK	NS	PEI	YK	OR	WA	CA	IL	IN	MI	
10	7	5	4	4	2	1	1	1	8	2	1	1	1	1	49

Figure 2. Average priority (blue = low, red = high) rankings within each North American jurisdiction for the top four overall choices from Figure 1.

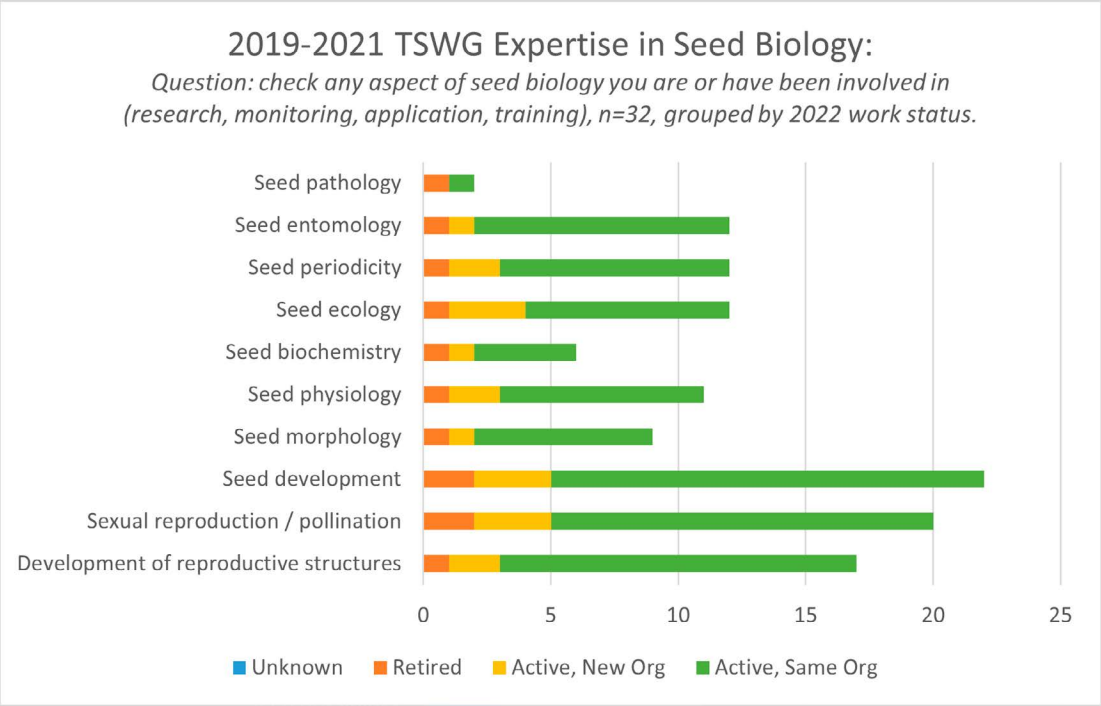


Figure 3. Count of self-reported TSWG members' expertise in various seed biology topics, similar to the initial Membership directory reported by Wang (TSWG No. 3). Respondents' organization (org) were checked if the same or new since 2019.

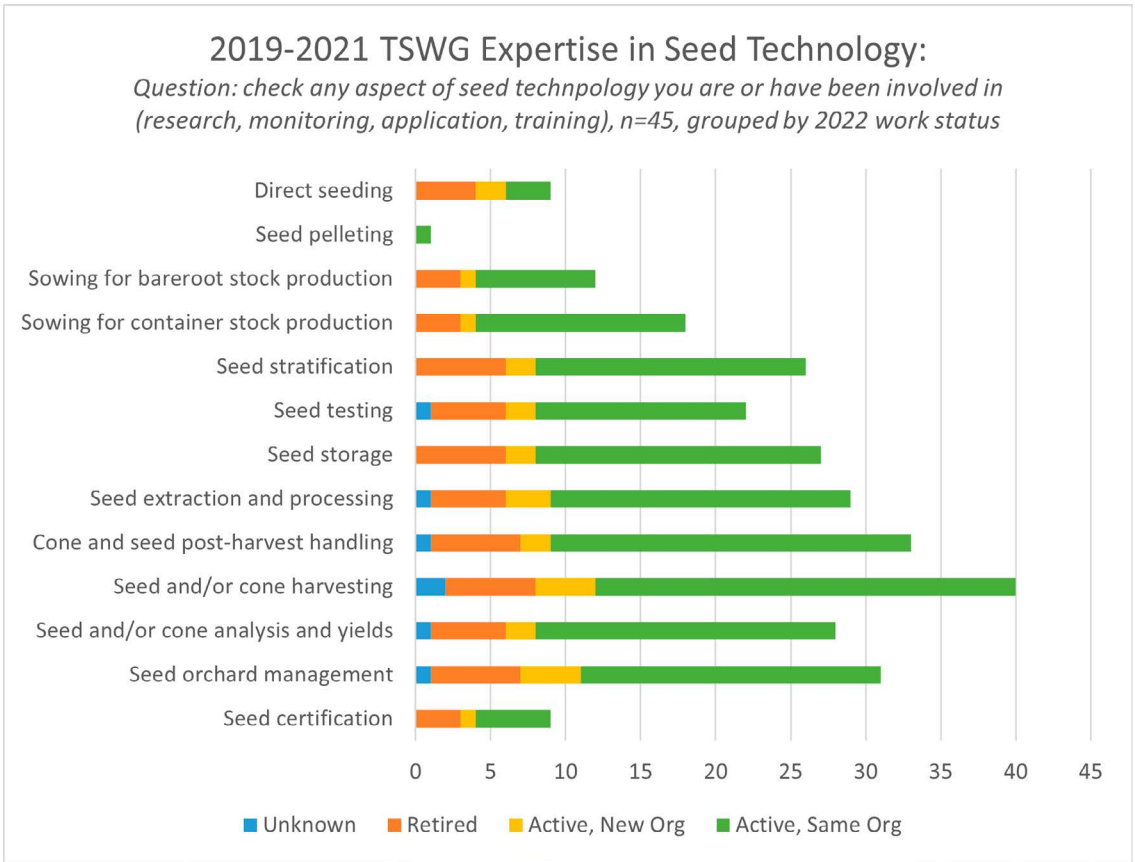


Figure 4. Count of self-reported TSWG member's expertise in various seed technology and handling topics, similar to but with additional categories relative to the initial Membership directory reported by Wang (TSWG No. 3, 198). Each respondents' organization (org) were checked if the same or new since 2019.

Table 2. 1985 and 2021 TSWG Membership Directory responses by jurisdiction.

Jurisdiction	1985	2021
British Columbia	25	10
Ontario	28[1]	7
Quebec	9	5
Alberta	8	4
New Brunswick	14	4[1]
Saskatchewan	2	2
Nova Scotia	3	1
Prince Edward Island	1	1
Yukon	0	1
Newfoundland	4	0
USA	7	14
International	5	4
Total	**106**	**53**
Professors and Grads[2]	**13**	**4**

[1]Location of the Petawawa National Research Institute (6 respondents in 1985) and National Tree Seed Centre (1 respondent in 2021).

[2]Includes those who identified as post-doc, PhD or graduate students.

TSWG Knowledge Exchange

Where else would be best to share our information, beyond the biennial TSWG workshop? While 78% of respondents said "yes" or "maybe" to a live stream option, we were not able to support this for the 2019 workshop. Over 90% of respondents said they would benefit from tree seed-focused webinars (i.e. hosted by the Canadian Institute of Forestry, or Forestry Adaptation Community of Practice). The pandemic has certainly made online conferences, webinars and meetings easier to set-up, manage and participate in, though it does not replace training best learned in the field.

In terms of contributions to the New Bulletin, a third of respondents had contributed articles, while 20% would like to. There were generally high levels of satisfaction with the diversity of topics covered in the Bulletin, the frequency, length and practical application. However, there may be some room for improvement with diversity of geographic areas, upcoming events, recent publications and building a strong sense of community. 35 members and organizations agreed (at the time) to be printed in a new TSWG Membership Directory, but this may be outdated (see Conclusions).

Discussion

There are few avenues to outline our collective needs at a level that can draw attention from decision-makers. Case in point: I stumbled upon a recently digitized report aptly titled *Seeds of Renewal: Biotechnology and Canada's Resource Industries* (Science Council of Canada 1985). The biotechnology investment agenda for forestry at the time was geared towards innovating pulp and paper processing techniques, based on industry workshops at the time (fair enough). But surprisingly, except for recommendations to properly staff and fund long-term germplasm collections for tree improvement, seed science and technology was only considered necessary to advance Canada's agricultural and horticultural sectors. This seems odd considering the timing of Farmer and company's first research agenda. Did our message not filter up to the right people? Or it assumed the Canadian Forest Service and provincial programs had seed improvement well under control? It seems we did.

Thanks to our TSWG champions, top priorities from the early years have largely been addressed for important genera, and many minor ones. Others will know more (since I was a toddler!) but whomever or whatever spawned Canada's Forest Resource Development Agreements (FRDA) in the mid-1980s to mid-1990s resulted in significant reforestation research investment, including reports on seed and cone reproduction biology and incubation-drying-separation technology prospects (see CFS Publications). In parallel, tombs of applied tree seed science were generated around the world, now referenced in every-day operational manuals we may take for granted. Certainly others do now.

When FRDA II ended, what happened? Ron Smith's 1998 review suggests CFS moved onto new biotechnologies, conservation and forest health threats, and regional cooperative programs appeared capable of turning over their last few stones. By the late 1990s, reforestation seed supply appeared plentiful, even in poor seed years (Morgenstern and Wang 2001). Industry and nurseries had all the information they needed to be sustainable and profitable, right? So what should we really have to complain about now?

Bear with me as I'm not an expert, but long been interested in demographic cycles which Foot and Stoffman (1997) argued are responsible for "two-thirds of everything". What I see in Table 1 is a slow torch-bearing come to pass; the baby-boomer cohort solving so many technical

problems, down to fewer technicians able to carry the load. So where have all the seed workers gone?

I think the first indicator that reinforces Dave's concise hypothesis of "***no funding, no research, no people, no teaching, no progress***" lies in the subset of professors and graduate students in Table 2. Many TSWG experts and graduates are well aware that post-secondary programs provide little exposure to current tree seed science, yet it ranked only 14th on the recent priority list. Looking to allied fields, many claim applied botanical education is near extinction and responsible for reinforcing plant blindness in society at large (Kramer et al. 2010, Stroud et al. 2021).

Then, to the cities, where about 74% of Canadians live, surrounded by less urban greenery than 20 years ago (Census of Environment). The proportion of Canadians actively employed in forestry, agriculture, hunting and fishing has steadily declined from 5.5% in 1985 to 3% in 1998 and 1.4% in 2020, according to the World Bank. In good news, direct and indirect employment in forestry has been on the rise since 2014 (Natural Resources Canada), and programs like Free to Grow in Forestry are repositioning the sector to welcome a diversity of new participants.

Still, obvious factors to attract and retain new workers are good wages and a rewarding career ladder. A quick review of Canada's National Occupation Classification (NOC) statistics revealed that out of 51 NOCs from 2011–2021, technical positions in natural and applied sciences ranked 8th slowest in average annual wage growth (1.8% per year), and higher professionals in the hierarchy 14th slowest (2.03% per year). Scientists and their technicians were rewarded slightly less than those in operations; production supervisors gained 2.04% per year and harvesting, landscaping and natural resource labourers 2.08% per year. The latter could be argued as a virtue relative to their output. But in terms of current dollars, harvesters (counting anyone over the age of 15 on a payroll) made only $4.03 more per hour in 2021 than they averaged in 2011 ($17.13). Meanwhile, middle managers in retail and wholesale trades topped the NOC chart with 3.68% average annual wage growth ending 2021 at $39.28 per hour. In my cohort (1980s-born), I can attest that most of my farm or woods-raised friends with any hands-on proficiency were lured to Red Seal trades, heavy equipment, extractive industries or emergency response. Cannabis legalization recently stole a lot of nursery talent too. Yes, everyone has to start somewhere, but this ladder seems opposed to progress if R&D technicians get left behind another decade. And with recent inflation, picking seed for even part of a living is not getting easier either.

Our working population has also never been older (Census of Population). The Canadian labour market tipped towards high job vacancy rates starting in 2017 and is expected to persist for most of this decade (Employment and Social Development Canada (ESDC) 2020, EcoCanada 2020). By OECD comparisons, many Canadians lack access to job skills training, while gig work and the pace of digitization have accelerated. Though the gap has narrowed since 2006, Canadian firms spent only 81 cents for every dollar US firms spent on training in 2018 (ESDC 2021). All this supports Dave's frequent ***"Grand Canyon"*** analogy of the gap that exists in knowledge-extension. It may also explain the chronic difficulty of encouraging problem-solving on the job, and inadvertent "cowboy science" employed instead (Sprague and Sprague 1976, Haase 2014).

With these considerations in mind, it makes sense (to me) that we may have predicted the loss of tree seed expertise through retirement, transition, and sadly, of late, many obituaries. As a result, remaining staff have to overcompensate until new positions are made or filled (if at all), or a new technology alleviates the time crunch. I also see this in broader economic datasets, i.e. labour productivity in forestry, fishing and farming spiked at 17.6% in 2020, compared to only 7.5% for the entire Canadian economy (NAICS). Most training is happening on the job, in a rush or perhaps just in time. This seems neither sustainable nor effective if trainers or trainees burn out wearing too many hats.

Maybe we also have a marketing problem? We are a specialized group providing seed and services sometimes to several sectors (reforestation, afforestation, reclamation, horticulture, retail/eCommerce and international trade), but only lately has the media shed light on what's involved (2021, 2022). We rely on very few active, sometimes elusive, seed pathologists, morphologists, biochemists, pelletizers, seed testing, direct seeding and seed certification specialists. Behind the scenes, we feel the loss and transition of even half a dozen seed testing, orchardists or seed stratification experts in a region. The ripple effect is far worse when entire programs close. Ensuring experts' know-how is captured for successors is paramount, even if a particular technique

wanes, i.e., while bareroot seedling production has declined in Canada, it is still important for hardwoods in the United States (McNabb and Pike 2019). The viability of every producer targeted through an assisted migration lens is crucial to what material we may handle in the future (O'Neill and Gómez-Pineda 2021). We need you; hang on.

Lastly, younger cohorts are concerned about climate change, what it means for their future and what those in charge are doing about it. The first mentions of climate change in the News Bulletin are from a 1993 CTIA conference workshop themed "The Future Forests–Options and Economics". The second was as rationale for changes to the genetic resource management delivery model in British Columbia in 2002 (McAuley and Yanchuk). Given the steadfastness of forestry policies and existing planning processes, it is not surprising the evidence for changing course has taken so long to filter down. Seed banks are also time machines capable of solving most of our spatial and temporal problems. But now, concerns about the effects of climate change on seed crops are #1 for Canadian respondents and #2 overall. Those wanting to ease their eco-anxiety should look to the great work of Wang and Morgenstern (2009), Potter et al. (2017, 2019) and Wang et al. (2020), to name a few. Then call Greta Thunberg to rally her troops!

Conclusions

The 2021 Tree Seed Working Group Membership survey identified new research and operational priorities required to sustain high-quality tree seed supply. A lack of cone and seed collectors, tracking and understanding the effects of climate change on seed crops, seed use efficiency, and seed orchard management are top of mind from experts in the field. Yet, it appears there are less people to shoulder the work than ever before. Particularly in Canada, the attractiveness of this field may be due to a lack of post-secondary education and exposure, low average wages and limited career growth prospects with high productivity expected. Those truly concerned with nature-based solutions should consider the efficacy of Canada's Red Seal apprenticeship programs in the last 20 years. Recent retirees who want to stay engaged have the know-how to infuse a new cohort with seed management skills. All told, this is and will continue to be a challenging decade for any manager expected to sustain or grow production. But I also suspect there is a tidal wave of opportunity coming. Seed is always a good news story.

It is also clear TSWG readers are no longer as enthusiastic about surveys as in the past. To respect your time and techno-fatigue, I won't be initiating another anytime soon, as it is usually the same people answering. I'd much rather have your autobiography, an article for the Bulletin, or feedback in workshops or live meetings.

For those of us still planning on working past 2025, I'd like to circle back to Ben Wang's wise words in TSWG No. 1 (1983): ***"Because our human resources are limited, it is absolutely essential that seed workers cooperate and communicate with each other."*** If you are involved in this field or want to be, I suggest you create or update your LinkedIn profile or website(s) to be easily found. Since so few of our readers responded to the call for an updated Directory, I set up a TSWG LinkedIn group to keep us connected, inspired by the Young@ISTA initiative: https://www.linkedin.com/groups/14113630/

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Melissa Spearing
TSWG Editor
Email: melissa.spearing@nrcan-rncan.gc.ca

A Reminder to Tag Every Bag

Email to the Editorial call for content, October 2022.

Hi Melissa, regarding your topic "material handling", I have a quick comment:

After collecting cones, they are often measured, and put into burlap sacks, then stacked on pallets and (plastic) wrapped for delivery to a Seed Processing facility.

Typically, each pallet load would only need to be tagged once (showing cone collection info: location, species, dates, etc), as all the sacks on the pallet are identical.

However, while rare, occasionally the plastic-wrap will fail and sacks will become loose (see photo attached, Figure 1) during transit to the processing facility. So we've learned to tag every single sack, for situations like this.

Figure 1. Photo of shrink-wrapped pallets of cone sack that have fallen apart, requiring every sack to be labeled in transit.

Newton Phillis
Silviculture Forester, Government of Manitoba
Winnipeg Manitoba
Email: Newton.Philis@gov.mb.ca

Going "Seedy" in the BC Woods

Editor's Note: this article was written for the Forest History Association of British Columbia Newsletter, but reprinted with permission from both authors. Minor edits have been made for readability and BC notation.

Introduction

The first attempt by foresters in British Columbia to generate seed crops, rather than merely collect them, began in 1957 when Bruce Devitt and Mike Meagher of the BC Forest Service (BCFS) Reforestation Division. They had just graduated from UBC and were directed by Alf Bamford, second-in-charge of the Division, to join with Dave Wallinger, the Division's "Man in the Interior", down to the Coast from Cranbrook. This team was to select 2nd-growth Douglas-fir stands at middle elevations (1,500+ feet) on Vancouver Island and assess their potential as a site for thinning to remove weak or poorly-shaped stems and then fertilize the ground to induce cone buds on the selected, better-formed trees.

"Simple" concept. Certain to succeed?

This initiative was suggested by Dr. Alan Orr-Ewing, Geneticist in the BCFS Research Division, who felt that such simple actions could increase the growth potential and stem quality in planted stock derived from the seeds collected after the removal of less-desirable trees that could be pollinators.

Aided by BCFS inventory maps and after several weeks and miles of 100% cruises we selected a stand—to be called a "Seed Production Area" [SPA] on the southwestern side of Mt. Prevost above Duncan, due to its easy access, visible record of "coning" recently and sufficient indication of past cone crops by the plentiful ground cover of decaying cones.

The thinning ended in the early spring of 1958, followed at the start of the growing season by a scattering of fertilizer to give a boost to that year's potential supply of regeneration buds for the 1959 cone crop. 1958 was a really hot year, resulting in early closure of industrial operations, but in the initiation of a heavy crop of reproductive buds for the next year in the SPA, as hoped. Fertilizer treatments were recommended by Dr. Lorne Ebell, Research Scientist, in the Forest Research Branch of the Department of Northern Affairs and Natural Resources, based on field trials in the nearby Robertson valley. Applications were made early in May just as vegetative buds were opening. We applied two fertilizer treatments: one of ammonium nitrate and one of forest-grade urea, and also the unfertilized control treatment to provide data regarding the natural "repro" buds. From memory, two to three hard hats full of fertilizer per tree were applied, depending on crown-width at the drip line (approximately 200 pounds/acre).

SPA Success

1959's weather was the opposite of 1958: cool with plenty of rain feeding the "repro" buds that were pollinated well, resulting in a heavy cone and seed crop—the best since 1945 on Vancouver Island. Unfortunately, the crop-yield records for this bountiful crop of cones and seed have been lost. The winner was ammonium nitrate at 200 pounds/acre. In 1961, this rate was checked i-n two Douglas-fir SPAs in the Chilliwack River valley resulting in an 8-fold increase in bushels and a 10-fold increase in seed collected[1].

That 1959 Mt. Prevost bounty sparked some industrial foresters to duplicate the program on their private lands, but also us to select and treat stands in other locations. Our next target was a higher-elevation stand on Mt. Benson above Nanaimo. It was also successful but was dropped from our program because multiple embryos showed up in standard seed testing.

The SPA program expanded to other sites, including several inspired by Dave Wallinger and others throughout the Interior Districts, but none were as dramatically successful as the Mt. Prevost site. It persisted in being a reliable site for some years—until its target areas for planting were reforested.

At the end of 1974, it is estimated there were at least 30 BCFS SPAs totaling 200 acres, and 24 which were coastal industry sites totaling 134 acres. The coastal SPAs were mostly in Douglas-fir stands, while the interior sites were mainly in spruce. SPA development and management dropped off after this; 1959, 1966 and subsequent collections took the pressure off at mid-elevations for the Vancouver Forest District and include some interior Forest Districts[2]. Also, the interior SPA fertilizer results, especially for spruce, were disappointing and seed-orchard programs were accelerated. Furthermore, the geneticists were not recommending SPAs

[1]BC Forest Service Annual Reports, 1957 to 1974.
[2]1970 collected seed inventories totaled 16,100 kilograms: BCFS 12,300 kilograms; Industry 3,800 kilograms

because of their narrow genetic base and small areas.

Mt. Prevost was also the site of the first application of pollen from some of Dr. Orr-Ewing's prize trees, generating the first crop of "B Class" seed (Improved Seed Registration System introduced 1957). The "prescriber" was Mike Crown, BCFS South Coastal Seed Orchard Management Forester, who felt it a waste of time to ignore Alan's work to improve Douglas-fir seed quality when the chance to capitalize on it was so clear. So much seed of that initiative was collected that Dr. Francis Yeh—Alan's successor—applied testing a seed sample for marker enzymes not in the native population and proved the effect of the pollen "boosting" on the genetic composition of that seed crop. More pollen boosting occurred during later years in the Puckle Road Seed Orchards in Saanich, north of Victoria, when pollen was sprayed on the trees' newly-emerged seed conelets via a backpack mist sprayer to spread the pollen as widely and well as possible to yield a heavier seed crop than otherwise likely.

Background information of interest

First recorded shipment of container-grown seedlings sent out in 1971 for operational planting and survival trials. 7.1 million grown at Duncan and 4 million were shipped out, of which 1 million went to the interior.

Average annual planting seedling numbers.

- 1948–1955: 7.8 million, 2.6% to the interior
- 1956–1960: 6 million, 8% to the interior
- 1961–1965: 13 million, 8% to the interior
- 1966–1969: 21 million, 13% to the interior
- 1970–1974: 47 million, 41% to the interior

In summary

- Coniferous trees CAN be manipulated to increase seed yield
- "From such small efforts mighty seedlings grow."
- Keep faith with the past!

Please visit the Forest History Association of British Columbia website to become a member: https://fhabc.org/

Bruce Devitt, RPF (Retired)
Mike Meagher, Ph.D., RPF (Retired)

Reflections on 2022

2022 was a humbling, momentous year, as it has been since I took up Dale's red pen duties in 2016. I started this month-by-month recap as a personal gratitude list over the holidays but thought it may be a good thread to weave into the Bulletin.

First of all, like Dave, I am grateful for the resurgence of and opportunity to participate in so many in-person events last year. I owe great thanks to Natural Resources Canada for supporting my participation in key relationship-building moments with the CFGA and TSWG. I always value the mountain of knowledge shared at those events, and connection to the big picture. While I'm a big fan of emissions reductions in our new hybrid reality, the real FaceTime connections made do last much longer.

So in chronological order, here is a short list of my professional and personal "Wins of 2022":

1. Repeating the success of and reporting initial results of magnolia (*Magnolia acuminata* and *M. tripetala*) *in vitro* embryo recovery techniques to the Global Magnolia Conservation Consortium. This work was only possible by single-tree collections from the University of Guelph Arboretum (see Sean Fox's article in TSWG No. 65). At one point, there were more cucumber magnolias in the AFC greenhouse than the entire last COSEWIC report. We still owe *Applications in Plant Sciences* a protocol note but prioritized getting seedlings back into the hands of capable recovery partners in Southern Ontario. Matt Brophy, John LeTourneau and Ted Spearing are owed great thanks for growing them on in the last two years. The Centre for Plant Conservation's forum is helpful for anyone seeking unpublished or practical experience with exceptional species.

2. Participating in Seed Functional Ecology School 2022, This affordable virtual short course featured lectures and workshops by Fiona Hay (Aarhus University, editor of *Seed Science and Technology*), Borja Jiménez-Alfaro (University of Oviedo), Sergey Rosbakh (University of Regensburg), Angelino Carta (University of Pisa), Andrea Mondoni and Alma Balestrazzi (University of Pavia), and Simone Pedrini (Curtin University). There were also virtual tours and lectures by the seed breeding and technology staff of ISI Sementi (Italy). The focus was on theory and practices related to seed functional

traits important to wild species dispersal, persistence and recruitment. The germination studies component was applied and useful. In open discussion periods and in the chat, I clustered with several attendees studying trees and shrubs. If it continues to run, I highly recommend it for graduate, PhD and post-docs, or seed technologists wanting to up their R skills with seed testing data.

3. Thanks to the Pavia course, having great follow-up conversations with Mikolaj Wawrzyniak at the Laboratory of Reproduction Biology and Population Genetics (Poland) and learning about their mandate expansion into the conservation of understory plants in the Bialowieza Forest. In preparing for such international meetings and discussions, I find it helpful to look up the FAO State of Forest Genetic Resources reports for each country (i.e., Poland 2011).

4. Helping the NTSC team run our "Scaling Up Seed Supply" webinars in support of the 2 Billion Trees Program's capacity-building efforts. We had over 600 attendees and have shared resources and 1-on-1 follow-ups with many more beyond this. We are working on the 2023 series based on the most requested topics and will include more invited and industry panelists to balance our expertise. Those interested in simply attending can be alerted about new dates through the NTSC MailChimp Newsletter subscriptions.

5. Helping to support the Indigenous Seed Collection Program (ISCP) launch in March. Though the NTSC has always tried to engage Indigenous communities in collections planning, a truly Indigenous-led program is a milestone towards growing seed conservation economies for cultural restoration and reconciliation. I'm not responsible for any of the ISCP conception, just grateful to be a part of something I've always thought important.

6. Getting to interview a number of long-time TSWG experts, reclamation specialists, nursery growers and collectors about seed supply issues and how to sustain the sector. While the public opinion surveys NTSC ran last spring received more responses than the 2021 TSWG survey, I learned way more through the interviews and follow-up in-person visits. Two reports will be available soon, one posted to the NTSC website in English and French.

7. Supporting the "Challenges to our Future Tree Seed Supply" event in June. It was a big win for everyone in-person and online that the technology worked (thanks to Michael Postma!), all the way down to Brazil. I'm glad we have the recordings for others to learn from long into the future. I thoroughly enjoyed the BCSOA and CFGA tours, which concluded at one of Greg O'Neill's assisted migration (AMAT) trial sites. Bucket list check!

8. While in Victoria, I toured the Pacific Forestry Centre's former Seed Lab in search of records related to the OECD Forest Seed and Plant Scheme. Thank you to Gwylim Blackburn for touring Dave, Shelagh McCarten and myself that day. Don Pigott put me in touch with Percy Ruth, Peter Hellenius, Paulus Vrijmoed, and long-retired OECD inspector Frank Portlock. Frank and I had a lovely dinner in Sidney and shared many stories.

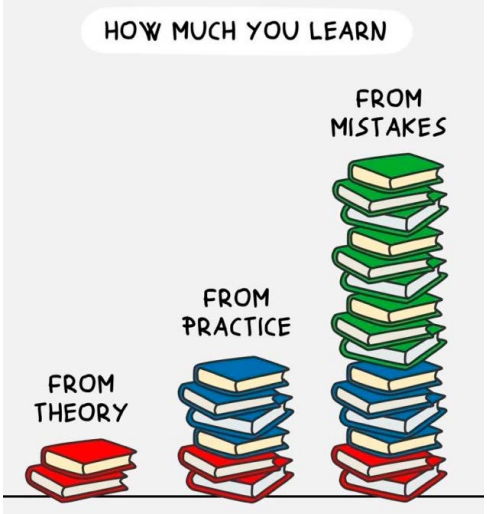
9. Supporting Donnie's cross-Canada RV road trip from August to November in support of the Indigenous Seed Collection Program. As interest grew and his calendar booked up, I stayed working remotely in Southern Ontario until mid-October. I had the chance to meet with six Indigenous communities interested in seed conservation and propagation. Every ISCP meeting was and continues to be eye-opening and emotional. Listen to Donnie's November 24, 2022 CBC interview.

10. Being asked to help organize the virtual component of an industry workshop towards spruce seed problems. Mark Montville (JD Irving, NB) was initially inspired by my sharing of the Iowa Seed Technology course last summer. We will provide a summary in the next issue, and Mark hopes to organize a field tour later in the year if crops develop. I'm encouraged to think that industry-requested, genera-focused problem solving workshops like this can focus our knowledge exchange and hone new nursery and seed centre staff skills. It may also inspire some post-secondary programs to take up the reigns on focused labs and lectures too.

11. On a personal note, I'm pleased that Patrick von Aderkas and I have been nerding out over our shared love of fern propagation in the last year or so, thanks to a single fiddlehead photo in his 2021 CFGA virtual keynote presentation. As a bonus, I have learned about Patrick's early connection to AFC and more about Dr. Yill Sung Park and Dr. Jan Bonga's work in the process.

12. Last but certainly not least is an ongoing relationship with Dr. Steve Jones, past president of the International Seed Testing Association. Steve, Donnie and I initially connected to seek advice from the Canadian Food Inspection Agency in modernizing our internal OECD Seed Scheme process. Steve is enthused by the resurgence of tree seed activity in Canada. He said yes to being on my MScF committee, participated virtually in our BC Tree Seed Supply and Spruce Seed Problems meetings, and hosted Donnie, Loretta and the RV when they were passing through Saskatoon. Steve recognized the NTSC in the 50th anniversary issue of *Seed Science and Technology* (see Recent Publications). That article, and his ways of simplifying seed science and exuding calm in every discussion, helped break my paralyzing writer's block and insomnia last fall. I'm extremely grateful for that. We are all doing our best, so be kind.

Reflecting on my first TSWG editorial, my goal was to bring greater awareness to the issues afflicting our group. I can sum this year up as becoming wiser about *how to do that* and *when to shut up*. I'll end with a meme I saw circulating this fall; the stacks could alternatively be labeled what impact you can have with information, knowledge and wisdom, building up from a great network of people around you. I'll shut up till I have something more useful to show you.



A meme circulating on LinkedIn and Reddit, November 2022 (author / creator unknown).

Melissa Spearing
Biologist, National Tree Seed Centre
Atlantic Forestry Centre, Fredericton, New Brunswick
Email: melissa.spearing@nrcan-rncan.gc.ca

Tribute to Dr. Will Hintz

Editor's note: reproduced with permission from: https://www.uvic.ca/news/topics/notices/2022+notice-memoriam-will-hintz+notice

Professor Will Hintz passed away November 27, 2022 after a brief illness. We are shocked by this sad and sudden news. Will was in the midst of planning his teaching for next spring and had just submitted a proposal for an NSERC Discovery grant. He was very much looking forward to many more years of activity.

Will came to the UVic as an assistant professor in 1993 after a PhD and postdoc at the University of Toronto, and a research position with Allelix Biopharmaceuticals. Will joined the Department of Biology and a few years later became part of the Graduate Centre for Forest Biology. He served as department chair for six years, from 2004 to 2010.

Will was a productive and inventive researcher. His special expertise was Dutch elm disease but he was interested in the molecular genetics of all fungal diseases. He worked on pathogens of tree seed, fish and amphibians, including the planet's great frog die-off, which resulted in a paper in Science. Will published widely with collaborators from many countries. Locally, he developed and patented a fungal biocontrol treatment for weedy deciduous trees. Will loved teaching students how to undertake scientific experiments, and trained many undergraduate and graduate students over the years.

Will was a quiet man, dedicated to his family. He was an artistic and sophisticated photographer. Sadly, Will suffered a freak accident in 2016 that left him almost fully paralyzed and confined to institutions for the rest of his life. Will was heroic in his determination to continue as a loving husband and father, and as a creative scientist and teacher. He fought to return to his working life. For Will, COVID was an extraordinary opportunity that provided him the chance to teach online–and he loved it! He also stayed involved with his lab and continued to plan new research projects.

Will was a remarkable man who met the most challenging circumstances with grace, courage and fortitude. We extend our heartfelt condolences to his family.

Barbara Hawkins and Patrick von Aderkas
Department of Biology, University of Victoria
Victoria, British Columbia

Passing of Dr. Michael Black

Editor's note: reproduced with additional context from: https://seedscisoc.org/mike-black/, see also https://www.researchgate.net/scientific-contributions/Michael-Black-2083235386

It is with great sadness that [the International Seed Science Society is] relaying to you that Mike Black passed away on January 5th, having lived with cancer for five years, well controlled by immunotherapy until his very last weeks. He was a vital force in the founding of our Society and the successful launching of our journal, Seed Science Research. An obituary highlighting his many achievements will follow.

Comment by Dr. Sanjay Kumar: Saddened to learn about the sad demise of Prof. Mike Black. An outstanding seed physiologist and a wonderful human being, Prof. Black's book co-authored with Prof. Derek Bewley will remain reliable sources for seed scientists for years to come.....A great loss to seed fraternity. May Almighty rest the departed soul in peace.

International Seed Science Society blog post, dated January 8, 2023

2022 Forest Nursery Association of British Columbia Annual Conference

On September 27–29, 2022, the Forest Nursery Association of British Columbia (FNABC) held its 40th Annual Conference in Prince George, BC. Over 90 attendees from forest nurseries across BC, some representatives from Alberta, suppliers and agency representatives gathered in person after a three-year hiatus. The meeting focused on three major themes:

- Current status, forecasts, policies and aligned programs for seedling requests given the effects of substantial forest fire seasons and severe heat/drought events on seedling performance;
- Labour concerns and solutions in silviculture and workplace safety; and
- Operational nursery management topics from seed, to recycling and seedling management for climate change.

The conference rounded out with pre- and post-conference tours of four local forest nurseries. The full agenda is archived here: https://www.fnabc.com/_files/ugd/2d5091_ded469bbd8834b1ebb6a81e142d48324.pdf

This conference would not have been possible without the generous support from our industry and agency sponsors, the organizing committee, and several volunteers. The FNABC would like to thank all for their dedication and contributions. Thank you, especially to all the speakers for their submitted presentations. Information on the location of the next FNABC Conference and AGM will be forthcoming in the Spring.

David Trotter
FNABC Secretary
Email: fnabc@fnabc.com
Website: https://www.fnabc.com/

2022 Atlantic Forest Nursery Association Annual Meeting

The Atlantic Forest Nurseries Association (AFNA) took shape in 1970 as a nurseryman's annual meeting. Since that time, it has served as a regional network for nursery managers and workers. The membership consists of provincial, federal, and private nurseries from Nova Scotia, New Brunswick, and Prince Edward Island. Representatives from the nursery and tree improvement end of seedling production as well as some vendors meet annually to discuss the forest industry, spark research collaborations, solve common problems, and foster informal mentorships.

On October 25th and 26th, 2022, the AFNA met in person for the first time in three years. This year's meeting was held at the Crowne Plaza in Fredericton and was hosted by Natural Resources Canada's Atlantic Forestry Centre. As hosts we offered a guided tour of the National Tree Seed Centre and AFC's greenhouse and nursery complex (Figure 1). The afternoon of the 26th provided an opportunity for presentations of some of AFC's research and programs. Presentations included: preliminary climate change research on seed and seedlings by Rob Vaughn, Biologist at AFC; an overview of the 2 Billion Trees program by Christy Arseneau, Research Director at AFC; and the Indigenous Seed Collection Program by Mary Knockwood, Indigenous Program Coordinator at AFC.

Figure 1. Some AFNA members on tour at the Atlantic Forestry Centre nursery and greenhouse complex, October 25, 2022.

John Letourneau
Technical Services Supervisor, Atlantic Forestry Centre
Natural Resources Canada
Email: john.letourneau@nrcan-rncan.gc.ca

Training & Meetings

Recorded: Web-based resources for seed scientists
A joint webinar of the International Seed Testing Association (ISTA), the International Society for Seed Science (ISSS), and the International Network for Seed-Based Restoration (INSR). The webinar was held on December 14, 2022.
https://www.youtube.com/watch?v=FWRcv3JXp9s

Terraformation Academy Training Series
Free, self-directed online courses (English):
- Seed Collection
- Foundations of Seed Banking
- Nursery Management

https://academy.terraformation.com/

Global Seed Conservation Challenge Learning Modules
Free, self-directed online courses and resources (available in English, Español, Français and Chinese):
- Planning a seed collection
- Prioritisation and Pre-collection Assessment
- Seed Collection
- Post Collection - Cleaning, Drying & Storage
- Germination and Dormancy
- Data Management

https://www.bgci.org/resources/bgci-tools-and-resources/global-seed-conservation-challenge-learning-modules/

Florabank - Australian Native Seed Sector Training
Self-paced online training towards Florabank Guidelines (English)
- Module 1: Collection - Introduction, Seed Sourcing, and Seed Collection
- Module 2: Cleaning - Seed Cleaning and Seed Drying and Storage
- Module 3: Storage - Seed Drying and Storage, Seed Quality and Seed Germination Testing
- Module 4: Production - Seed Production Areas, Seed Enhancement Technologies, Nursery Propagation and Direct Seeding

https://www.florabank.org.au/training

SUPERB & IUFRO Forest Restoration Talks
Monthly online webinars, February–June 2023
https://forest-restoration.eu/superb-iufro-forest-restoration-talks-upcoming-webinars/

Forests Ontario Annual Conference 2023 – Growing a Healthy Tomorrow
February 16–17, 2023, hybrid
Alliston, Ontario, Canada
https://forestsontario.ca/en/event/annual-conference

ISTA Workshop on Tetrazolium Testing and Equilibrium Relative Humidity (eRH) Determination for Native Species
May 26–27, 2023, in-person
Peri, Italy
Registration deadline: April 20, 2023
https://www.seedtest.org/en/workshops-and-webinars/ista-workshop-on-tetrazolium-testing-and-equilibrium-relative-humidity-erh-deter-product-10030.html

IX World Magnolia Symposium and Conservation Workshop
May 29–June 3, 2023, in-person
Siguatepeque, Comayagua, Honduras
Abstract submission deadline: February 15, 2023
https://www.bgci.org/news-events/ix-world-magnolia-symposium/

R3 Conference 2023: Reclaim, Restore, Rewild
June 10–15, 2023, in-person
Québec City, Québec, Canada
Abstract submission deadline: February 6, 2023
https://re3-quebec.org/en

2023 American Official Seed Analysts / Seed Certifying Society of Technologists Annual Meeting
June 9–15, 2023, in-person
Saskatoon, Saskatchewan, Canada
https://analyzeseeds.com/2023-aosa-scst-annual-meeting-info/

14th International Seed Science Society Conference – Challenges of Seed Science in a Changing World
July 3–7, 2023, in-person
Sorbonne Université, Paris, France
Abstract submission deadline: April 30, 2023
https://isss2023.sciencesconf.org/

Forest Genetics 2023 – Discovery & Innovation in Changing Climates
July 10–13, 2023, in-person
Vernon, British Columbia, Canada
Abstracts and poster topics to be considered:
- Collection and analysis of progeny test data
- Genetic conservation
- Seed orchard design and management
- Seed transfer and provenance test analyses
- Interdisciplinary research
- Forest health
- Seed research and propagation of seedlings
- Genomic tools
- Population and quantitative genomics
- Other forest genetics related topics

Abstract submissions deadline: April 5, 2023
https://forestgenetics2023.ca/

Cryo2023: 60th Annual Meeting for the Society of Cryobiology
July 25–27, 2023, hybrid
Minneapolis, Minnesota, United States of America
Abstract submissions close: February 20, 2023
https://cryo2023.com/

10th World Conference on Ecological Restoration
September 26–30, 2023, in-person
Darwin, Australia
Abstract submissions close: February 5, 2023
https://ser2023.org/

5th International Congress on Planted Forests
November 7–10, 2023, in-person
Nairobi, Kenya
https://www.iefc.net/icpf-2023/

Recent Publications

Books

Antler, Susan. The Tree Seed Plant: The Unfinished Story of the Ontario Tree Seed Plant. 2022.

The Tree Seed Plant tells the story of the near 100-year-old Ontario Tree Seed Plant, a provincial property. It shares the efforts of the community, environmental groups and forest industry stakeholders to save this valuable community asset.

Located in Simcoe County, Ontario, the Ontario Tree Seed Plant has been long recognized as a world leader in:

- tree seed collection, processing and distribution;
- biodiversity preservation; and
- reforestation.

The property is ideal as a viable centre for ecotourism, featuring both state-of-the-art as well as heritage infrastructure. It can serve as a showcase for many local natural resources, such as the Minesing Wetlands and Nottawasaga River. But the Ontario Tree Seed Plant's purpose and history can tell us so much more. The site has been responsible for billions of tree seeds which have grown into Ontario's current tree population – both rural and urban.

The beautifully illustrated story builds on the actions taken by the community to stop the sale of the property. And, it shares the local dream of turning it into a centre for ecotourism, community development and local job creation.

Copies are $10. Contact **Stephanie McCann** (705–737–9821) or **Susan Antler** (416–670–0510).

Newsletters, Reports and Proceedings

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Call for Manuscripts

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Preprint

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