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News Bulletin
Canadian Forest Genetics Association
l'Association canadienne de génétique forestière
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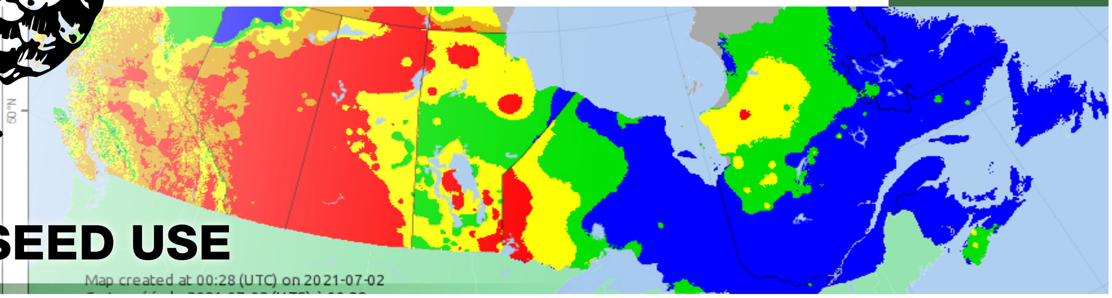

MAXIMIZING SEED USE

Featured in this Issue:

Armchair Report No. 71

Hello, I started writing this from the midst of a BC heat wave. We now have the honour of the highest recorded temperature in Canada: 49.5°C in Lytton, BC, on June 29th. Even in Vancouver's relatively mild maritime climate, we hit 31.1°C–breaking the 27.2°C record from 1935–and White Rock hit 36.9°C. Several other areas of the world are also experiencing their highest recorded temperatures. Fortunately, we are in an off-year in seed production for most of our seed orchards in BC. Global warming is certainly something to fear, but these extreme events will likely impact our planet and its organisms more.

In terms of the Canadian Forest Genetics Association (CFGA), under which the Tree Seed Working Group resides, this organization has finally been registered as a not-for-profit corporation in Canada. Thank you to Brian Barber (President) and Shona Millican (Treasurer) for doing the heavy lifting with that process. It's a bit of a transition for the CFGA as we look at some bigger picture items and provide some attention to the organization between the revolving executive and biennial meeting that has been their primary focus. The CFGA and the Western Forest Genetics Association (WFGA) hosted a virtual student and Post-Doc Symposium, which turned out to be a smashing success, and I hope some of you were able to attend. This symposium allowed students and post-docs to present their research findings despite us having to cancel our live biennial meeting in 2021. The plan is to post the oral presentations on the CFGA website. Brian also summarizes all attendance and student award winners later in this issue. We are optimistic and hope to offer a live (possibly hybrid) meeting in the summer of 2022 in the Okanagan. I have some tree seed meeting ideas I'll discuss further below.

In 2020 we had a bumper crop for many species, with our facility processing 6,123 hectolitres of cones resulting in 4,416 kilograms of

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Banner image: Fire Weather Map from the Canadian Wildfire Information System, Natural Resources Canada. Retrieved July 2, 2021 from https://cwfis.cfs.nrcan.gc.ca/maps/fw

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Deadline for Issue No. 72: February 15, 2022

We welcome any comments, suggestions and article submissions and will solicit active, subscribing members for content. Submissions may be edited for length. 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). All issues of the News Bulletin are freely available here.

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

1. Seed research from bud initiation to seed utilization
2. Identification of seed problems relating to tree improvement and forest management
3. The exchange of information on seed-related problems
4. Advising on implementation practices

seed. This equates to over 363 million potential seedlings; 86% of the seed is from BC seed orchard seedlots; 2% from BC wild stand seedlots; 5% from Alberta seed orchards and 6% from Alberta wild stand collections. This past season saw 286 million seedlings being ordered in BC, with 69% of the seed originating from seed orchards. Some seed orchard production gaps for interior lodgepole pine and interior Douglas-fir reduce that percentage from our 80% target. Other species like coastal Douglas-fir, interior spruce, Sitka spruce, western larch, western white pine and red alder have 90% or more seedlings produced with seed orchard seed. We expect very small crops for the upcoming season due to periodicity and/or a significant increase in pest populations after last year's bumper crop.

In BC, we continue to transition to our Climate Based Seed Transfer (CBST) system from our geographically based system. It has a greater ecological connection and incorporates assisted migration of seed sources. We have been transitioning to this new system and will now fully implement it as the way all seed transfer is done starting in August 2022. A general overview of CBST can be found here. Moving to CBST has resulted in some complications to seed and future orchard planning as we move away from the relatively simple fixed zone seed transfer concept. Many orchards have areas of overlap for seed deployment, and the actual demand from any orchard is hard to predict. Many in BC have been hard at work improving the seed planning tools available. The production side has been easier to gain confidence around, and reviews conducted on improving orchard seed production estimates and seed to seedling conversion factors. It's an exciting time in tree improvement in BC with a new suite of tree breeders, some new species programs initiated (Ponderosa pine, interior western redcedar), CBST and new planning tools, new second-generation lodgepole pine seed orchards going in the ground and development of a *Comandra* rust-resistant lodgepole pine orchard.

Tree planting promises and their role in helping to capture carbon have garnered a great deal of attention and are generally politically safe unless you are cutting down old-growth forests to do it. It certainly is more generally acceptable to considerations of "reduction" that may impact our economic growth, which somehow seems to have become inseparable from the quality of life. For whom is for others to answer, but I wonder where all those trees will go, who or what they may displace and more relevant to this forum, where are the seeds and the seed services infrastructure going to come from? Some of you may have seen this WIRED article "Reforestation is Great But We're Running out of Seeds". I heard about one News Bulletin subscriber hitting their head against the wall with the message of the end-is-near as squirrel cache pirates are becoming extinct and the description of seed orchards as a contingency plan for wild collections. Still, I do appreciate that the tree seed component is receiving some attention. I also think it's a fair point that many involved in collection and processing are past standard retirement age, and the amount of investment in processing infrastructure is minimal. It seems to be a hard sell, but it really shouldn't be–these aspects of reforestation programs have just been taken for granted, and we'll eventually have to pay the piper.

Planning is in place to host the CFGA/WFGA and BC Seed Orchard Association meetings the week of June 27, 2022 in the BC Interior. I am organizing a tree seed-related meeting to precede this from June 23–26 on Vancouver Island which will include a wide variety of related venues (seed orchards, nurseries, the Cowichan Lake Research Station, Yellow Point Propagation extractory) and various beautiful BC sites. The regular Tree Seed Workshop would then take place at the BC Tree Seed Centre in the lower mainland on June 27th and include presentations and round table discussions. Transportation would then be available to connect to the meetings in the BC Interior. The goal of this meeting is to try and draw a wider international audience and in addition to discussing tree seed science and technology, we will continue with our theme from Lac Delage to **"Reaffirm the Importance of Cone and Seed Services and Identify Knowledge Gaps."** Hopefully, this will enlarge the circle and make an international impact on increasing awareness and addressing the bottlenecks in education, research funding, and infrastructure investment. The draft 2022 theme **"How to Change the World of Tree Seed"** indicates that the intent is to go beyond the exchange of technical details and deal with some larger-scale global issues regarding tree seed and try to do something about it.

I have wanted to do it for a while and didn't really get much uptake, but I can be stubborn and think the timing is right to try again. In addition to the Tree Seed Working Group, the International Seed Testing Associations Forest Tree Seed and Shrub Committee; IUFRO 2.09 Seed Physiology and Technology; International Seed Federation – are invited to attend given common interests. We are part of a highly specialized part of forestry, and I strongly think there is strength in numbers and many learnings to be gained from increased collaboration. Please feel free to forward your thoughts, ideas and interest to me for such a meeting.

All the best to everyone.

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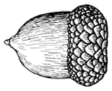
Editor's Notes

Happy fall to you all; I sincerely hope you, your seeds and trees are happy, well-watered and have recovered from any smoke inhalation (unless of course, they need that to germinate). I hope you attended some of the great virtual seed events organized this year and that fieldwork returned to relative normal as vaccination rates rose. For those transitioning out, I hope retirement parties were allowed. One in particular I know of is Mr. Dave Flight from Manitoba's Forest Health and Renewal Branch. Dave only wrote one article at his time at Pineland Nursery (No. 42, 2005) but was first noted as a TSWG member in 1995. All the best Dave! If you know of others that happened or are pending, please send me a nice photo and story or two.

The impact of wild weather and skilled labour ready to pick when needed is top of mind for everyone I talk to. Every seed counts when minimum wages are $11.75–$16.00 CDN/hour vs global assessments that level collection labour at $1 USD/hour. Seed is not a minimal investment, and to quote Jack Woods in 2018, **"The cost of no seed often exceeds the cost of too much seed"**. It's why this issue covers everything from seed transfer to new cooperatives to maximizing seed use. In more mainstream coverage, Maclean's covered Chris McGee's challenges ("How humans and squirrels team up to collect tree seeds—and save the planet") and WIRED added some techno-realism ("Drones may help replant forests - if enough seeds take root"). It has been good to see global financiers begin to explicitly support afforestation and reforestation; congratulations to PRT Growing Services and INSTAR on their new green loan financing this year. Again, very few headlines note orchards as a solution.

Decade-by-decade, TSWG members have made incredible progress. In the 2001 assessment by Morgenstern and Wang, 3.9 billion Canadian seeds were sown to regenerate ~460,000 ha and multiple jurisdictions had >50% improved orchard seed in use. The 2012 State of Canada's Forest Genetic Resources reported 332,073 kg of seed housed in just eight Canadian seed centers. How many years are in your portfolio? The NTSC will soon relaunch a National Native Seed Supply Assessment (on hold for election period) to assess wild and improved seed stored, capacity needed, and capture growing expertise in the restoration and reclamation sectors. We hope for your support and a snowy day to answer.



On purely Editorial matters, I have a number of aspirations for TSWG evolution and a newly minted login as the CFGA Webmaster. I welcome your input on:

1. How to make over 1,300 pages of our knowledge easier to search? I'd like to list past articles and authors similar to the RNGR.net resource library. Search engines do not search within PDF text unlike our computers do.
2. Would you like the ability to manage your own Membership profile and expertise on the new CFGA website? I still love Ben's original vision but its a new day and opt-in age. Said it before but I really like BGCI's Directory of Seed Expertise tool and filterable map.
3. I encourage anyone who has not yet realized the complimentary advantages of the separately maintained CFGA Google Groups mailing list; please sign up. It's particularly useful for short-notice events and job postings this Bulletin can't always keep up with.
4. I would like to make an annual winter photo collage like No. 70's COVID/Dr. Suess Poem to sum up the joys of the previous year. I'll make it easier and even accept submissions with a quick text to 416–909–9755!

Lastly, I'd like to ask for extra TSWG help as I'm not the publishing rock star I want to be (yet…). Dave is a stellar Chair but **I'd love a tech-savvy Editorial buddy if anyone has the time?!?** Compilation got bogged down this summer as I tried to adjust work-life-health priorities to start my MScF program. I take knowledge extension seriously and have great support from CFS/NTSC, but also need to be more realistic with part-time studies and 10+ manuscripts I have been wanting to write. Hence the adjusted winter 2022 deadline. In the meantime, I'm practicing "No" and delegating to our growing NTSC team. Please let me know if you're interested and I can outline specifics. Immense thanks to all the contributing authors for your patience and support.

Errata in No. 70

- Dr. Richard Sniezko's last name incorrectly spelled throughout. Corrected in the final PDF online.
- Standard deviation intervals on Fig. 3 (page 22) chart were not accurate. Corrected in the final PDF online.

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New Analysis of Critical Seed Transfer Distances

Climate change is expected to have significant impacts on forest growth and mortality. A key driver of these impacts is the disparity between the velocity of climate change, which is projected to shift tree climate envelopes hundreds of kilometers northward by the end of the current century, and tree migration, which typically occurs at rates less than 50 km per century. As a result, tree populations are expected to become increasingly maladapted to local climate conditions as the century progresses.

In anticipation of these impacts, many jurisdictions are reviewing and revising their seed transfer systems, which provide guidance regarding movements of seeds and seedlings for forest regeneration. Many seed transfer systems are based on a series of contiguous fixed zones, with seed movements constrained such that seeds are deployed within the zone from which they originate. This constraint reflects one of the basic tenets of forest genetics—that sites should be planted using local seed sources, thus ensuring a match between the climate at the planting site and the climate to which the seed sources are adapted. However, as climates rapidly shift under climate change, local deployment of seed sources no longer ensures this match.

Forest planting events present key opportunities to enhance forest adaptation and growth through the selection of appropriate growing materials. Critical to such efforts is knowledge of the climatic distance that seed sources can be moved before significant growth forfeitures are incurred. These limits, referred to hereafter as critical seed transfer distances ((CSTD); Ukrainetz et al. 2011, O'Neill et al. 2014), can be used to identify a potential seed collection area for any given planting site and can readily incorporate climate change projections. Provenance studies—which measure growth and mortality through time of various seed sources (provenances) planted at various test sites (common gardens)—provide data to help elucidate these climate-growth relationships. In a recently published article in the Journal of Ecology (Pedlar et al. 2021), we assembled and analyzed a significant amount of provenance data to derive CSTDs for five tree species in eastern North America: black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), white pine (*Pinus strobus*), and yellow birch (*Betula alleghaniensis*).

Table 1. Summary of transfer function regression analyses and associated critical seed transfer distances (CSTD) for five North American tree species.

				CSTD for Growth >90% of local		CSTD for Growth >95% of local	
Species	N Test Sites	N Significant	Mean R^2	Cooler Transfer (°C)	Warmer Transfer (°C)	Cooler Transfer (°C)	Warmer Transfer (°C)
Betula alleghaniensis	7	3	0.14	–7.8	3.4	–6.7	2.2
Picea glauca	40	15	0.22	–5.7	2.8	–4.9	1.9
Picea mariana	19	13	0.17	–6.1	3.9	–4.9	2.7
Pinus banksiana	30	12	0.23	–6.6	4	–5.5	2.9
Pinus strobus	28	13	0.32	–9	3.8	–7.7	2.5

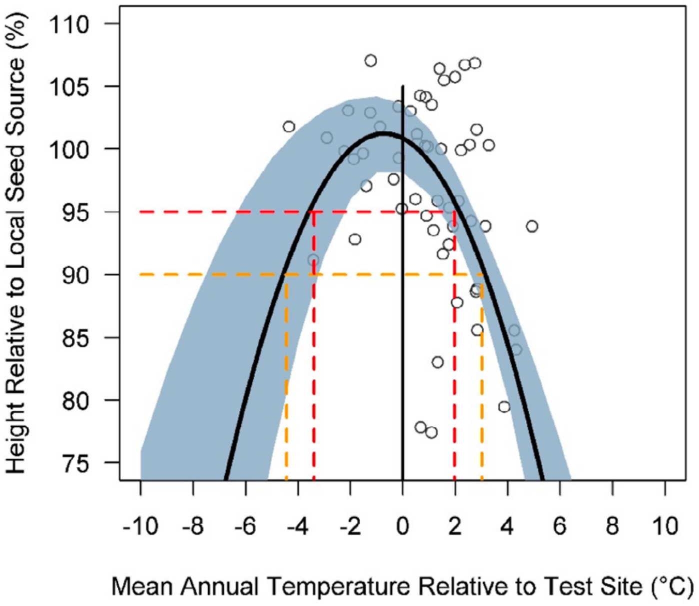

Figure 1. Sample transfer function for black spruce *(Picea mariana)* at a test site in Petawawa, Ontario. Plot shows the relationship between height and mean annual temperature transfer distance (calculated as test site climate minus seed source climate). Orange and red dashed lines indicate critical seed transfer distances that would maintain growth rates equal to or greater than 90 and 95% of expected height of a local population, respectively. Blue shading around the regression line indicates the 95th confidence interval.

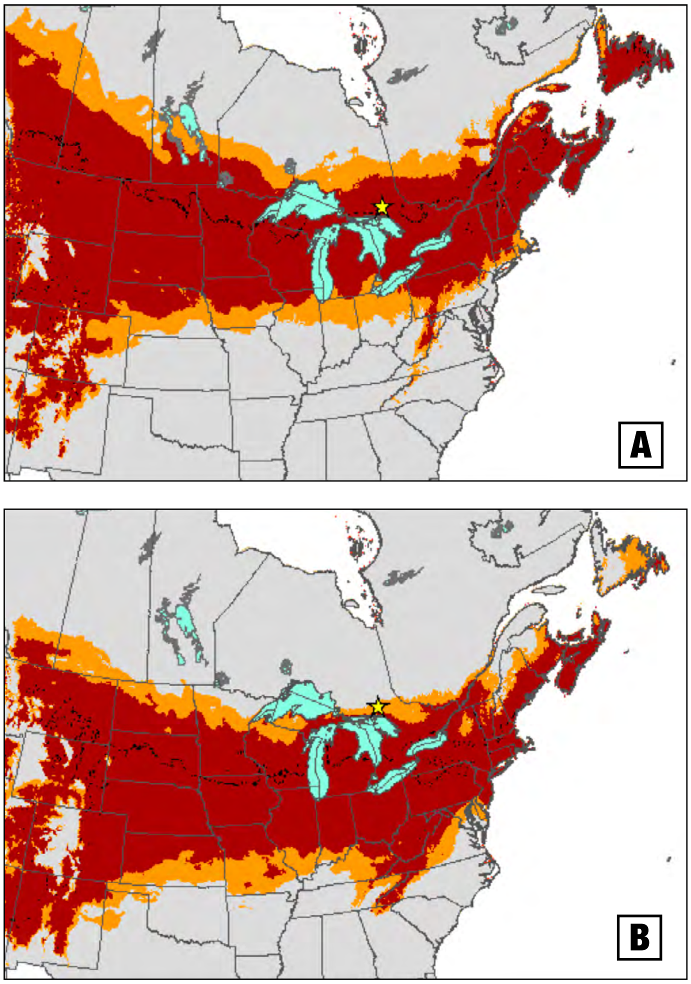

Figure 2. Black spruce *(Picea mariana)* seed collected from the red (or orange) procurement area and planted at a hypothetical site near Sudbury, Ontario (yellow star) is expected to yield trees with average height greater than 95 (or 90) percent relative to the local seed source. Results are shown for mean annual temperature under (a) current climate (i.e., with no assisted migration) and (b) future climate (i.e., with assisted migration).

We employed transfer functions, which are quadratic regression models, to quantify the relationship between tree height growth and the climatic distance that seed sources were moved. Climate variables of interest included mean annual temperature (MAT, °C), annual precipitation (ANNP, mm), climate moisture index (CMI, cm/year), growing season length (GSL, Julian days), and extreme minimum temperature (XMIN, °C). Figure 1 depicts a sample transfer function for black spruce (*Picea mariana*) at a test site in Petawawa, Ontario. Note that values on the x-axis are MAT transfer distances, with negative values representing warm-to-cold (i.e., northward) transfers and positive values for cold-to-warm transfers (i.e., southward). The dashed lines in Figure 1 illustrate critical seed transfer distances, with the red lines showing how far seed sources can be moved before 5% growth forfeitures (relative to local) occur and the orange lines showing transfer distances associated with 10% growth forfeitures. Critical seed transfer distances can be mapped both with and without climate change as shown in Figure 2 for a hypothetical planting site near Sudbury, Ontario.

Critical seed transfer distances and associated regression metrics are provided in relation to MAT (°C) for the five species in our study (Table 1; please see Pedlar et al. 2021 for full results). There were a number of noteworthy findings associated with these regression models. First, calculated CSTDs were large for all species, with northward transfers of about 6°C or more required before growth forfeitures >10% were incurred. In the relatively flat terrain of eastern Canada, MAT declines by approximately 1°C for every 100 km of northward movement, so these CSTDs indicate that seed sources could be moved hundreds of kilometers before incurring significant growth losses. Further, the regression relationships were generally weak as indicated by the low R-squared values and the low proportion of test sites with statistically significant regression outcomes (Table 1; Fig. 1). This finding underlines that there is a great deal of variation in tree response along climatic gradients, which may be related to factors such as extreme climate events (e.g., drought, flooding, and blowdowns), microsite conditions at planting sites, forest insect and disease outbreaks, genetic variation, and even epigenetic factors. It is important to keep in mind that selecting a suitable seed source does not guarantee a successful plantation.

The relatively large CSTD values reported in our paper would allow considerable flexibility in resulting seed transfer systems, such that seeds may not need to be tracked at high spatial resolution. For example, ecological units—such as the ecoregions employed in Ontario's recent seed transfer system update (OMNRF 2020)—would appear to be adequate for seed tracking efforts in eastern Canada. Although our study suggests that relatively long distance seed transfers could be undertaken with only modest growth forfeitures, the significant uncertainty surrounding climate change—particularly in the location and timing of extreme weather events—means that prudent application of seed transfer limits may be appropriate. Finally, the weak regression results presented here raise legitimate concerns as to whether seed movements that are constrained within existing species' range limits are an effective response to climate change. Forest managers may need to consider more aggressive forms of assisted migration—such as assisted range expansion (Ste. Marie et al., 2011)—wherein species are moved beyond current range limits to address potential climate change impacts on forest health and productivity.

Open access supplementary data can be downloaded here (jec13605-sup-0001-Supinfo.docx). Data is also available to download from the Dryad Digital Repository https://doi.org/10.5061/dryad.dv41ns1x2.

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Adapting Seed Transfer Guidelines in Northeastern Ontario: Lessons from Lodgepole Pine Climatypes

Editorial Note: this text is an excerpt from a 2018 report so section and figure numbering is retained for context. Please contact the author for the full report or more information.

1.4 Transfer functions

Long-term field performance provenance tests (common garden studies of multiple seed sources) provide data on growth performance, pest resistance, and survival; typically at multiple-year intervals. When provenance test series include evaluation of growth performance and survival in an array of environments, they are effectively empirical climate-change experiments (Carter 1996, Matyas 1994, Schmidtling 1994). Relative growth rates of individual populations regressed on the climatic transfer distance (the difference between the climate of a seed source and the climate of the hosting test sites) has become the standard for evaluating provenance test data from a climate change perspective (e.g., Rehfeldt et al. 2003). The term 'response function' pertains to growth performance of individual populations in a test series as a function of climatic transfer distance. General transfer functions, which reflect growth performance of climatypes, are more relevant to seed transfer guidelines.

Quadratic transfer functions quantify climatic conditions suitable for optimum growth and expected deterioration in growth performance and survival associated with movement across climatic gradients (Rehfeldt et al. 1999, 2001, Leites et al. 2012a, b, Thomson and Parker 2008, Thomson et al. 2009, Wang et al. 2006). While quadratic transfer functions are consistent with results of numerous ecological genetic studies in many species, the symmetrical nature of the quadratic function and the lack of test sites severe enough to document zero survival lead to ecologically simplistic response curves. The predictive quality of quadratic transfer functions is further constrained by the limited statistical power associated with the limited number of provenances and test sites included in typical provenance test series (Leites et al. 2012a). As such, quadratic transfer functions are indicative, rather than predictive, of growth performance.

A recent study based on twelve common gardens and 266 provenances of lodgepole pine (Rehfeldt et al. 2018) has improved the predictive quality of transfer functions by addressing the limitations of earlier quadratic transfer functions. Ten climatype classes were defined by subdividing populations according to the winter temperature of their provenance. Climatype-specific transfer functions were then developed for each class with a regression model suited to describing skewed normal distributions, which are more ecologically realistic. And, U.S. Forest Service forest inventory plots in the geographic region of the study that lacked lodgepole pine provided an estimate of climatic conditions associated with null survival.

While winter temperature was the best predictor of deterioration in growth performance of lodgepole pine populations, IPCC projections of climate change are largely focused on changes in mean annual temperature, or MAT (IPCC 2013, 2014a). To facilitate examination of ecological impacts due to climate change, the lodgepole pine transfer functions were reworked as a function of MAT in degrees Celsius (Rehfeldt unpublished).

Figure 2 provides graphical support for understanding general principles associated with climatype-specific transfer functions:

- The optimum growth (an assay of growth potential) is greatest for the climatype associated with the highest MAT of provenance origin (curve A). That is, climatypes adapted to the mildest climate have the greatest growth potential. Optimal growth of each subsequent climatype declines in association with provenance MAT.
- The temperature associated with optimum growth varies by climatype. That is, northern climatypes (e.g., curves C and D) realize optimum growth at colder temperatures than southern climatypes (curve A).

- Optimal growth is expressed in environments warmer than the provenance origin. The disparity in temperatures between the provenance origin and optimal environments is small for populations adapted to warmer climates (curve A), but increases in relation to severity of provenance origin (curves B, C, and D).
- The steepness of transfer functions varies among climatypes. In relatively mild environments (Figure 2, curve A), selection for high growth potential is dominant. As a result, southern climatypes have superior growth potential with an associated reduced tolerance of environmental heterogeneity that results in steep transfer functions. Toward the northern limits (Figure 2, curve D), selection for cold hardiness is preeminent. Tolerance to adverse weather is enhanced, transfer functions flatten, but growth potential is low. In the climatically central regions of the climatic niche (e.g., Figure 2, curves B and C), the intermediate steepness of the transfer functions mirror the shifting severity of the climate.

1.5 Phenotypic stability

In plants, phenotypic plasticity is a broadly used term that describes the limits of plant tolerance to environmental variability. In the forest management venue, the capacity of climatypes to maintain growth performance reflective of growth potential under a range of climatic conditions is regarded as phenotypic plasticity, or more accurately – phenotypic stability. The steeper the adaptive cline, the narrower the breadth of phenotypic stability.

Figure 3 illustrates the trade-off between growth potential and phenotypic stability. The optimal growth of climatype 'A' is roughly three times greater than climatype 'C'. Yet, the inverse is true when considering the breadth of phenotypic stability. In the long term, a warming climate will have a negative effect on the growth of all populations, but inter-climatype differences in phenotypic stability portend differential response times. These transfer functions indicate that southern climatypes are the least tolerant of escalating climatic stresses.

1.6 Rotation length

Maladaptation accrues as the limits of phenotypic stability are exceeded. Under a stable climate paradigm, maladaptation is strictly a spatial attribute. In principle, seed zones are

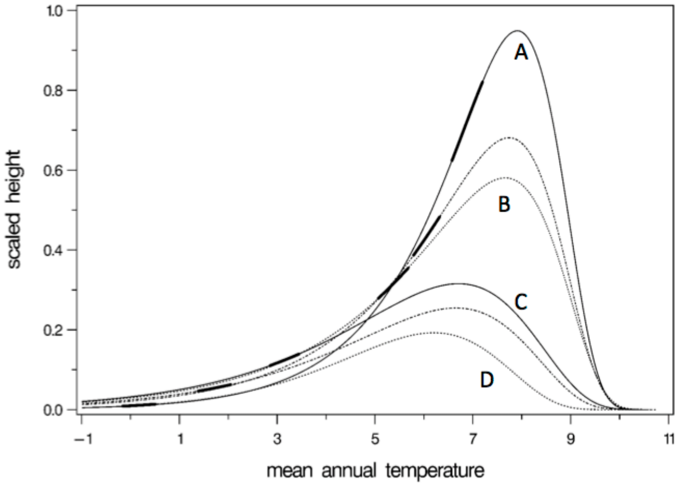

Figure 2. Predicted growth performance for six selected lodgepole pine climatypes plotted according to the mean annual temperature (°C, 1961–1990) of the planting site. Thickened portions of each curve represent range of provenances included in each climatype.

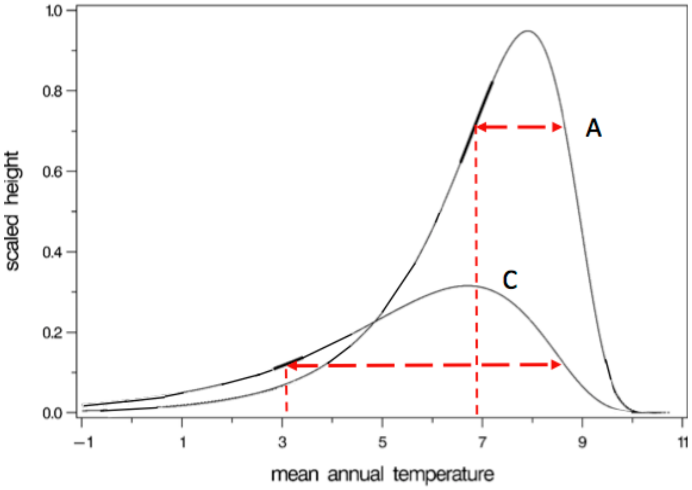

Figure 3. Predicted growth performance for two contrasting lodgepole pine climatype classes (A and C from Figure 2) plotted according to the mean annual temperature (°C, 1961–1990) of the planting site. Thickened portions of each curve represent range of provenances included in each climatype class. The vertical lines represent the mean of the climatypes included in the class. The horizontal double-headed arrows represent the breadth of phenotypic stability for each climatype.

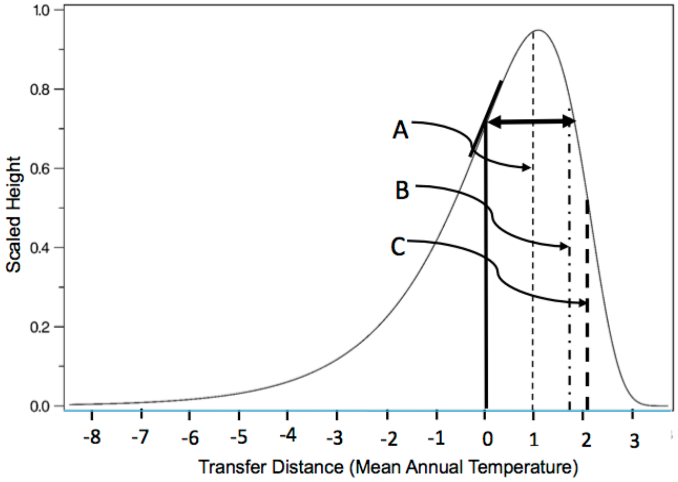

Figure 4. A transfer function representative of a southern 'trailing edge' climatypes (from Figure 2, curve A). Transfer distance refers to the difference between a climatype class average mean annual temperature (°C, MAT), and the MAT of the transfer environment. The solid vertical line represents the mean MAT, which represents the zero transfer distance. The horizontal double-headed arrow represents the range of MAT associated with phenotypically stable growth performance. Vertical line 'A' depicts a 1°C shift in MAT, representing current level of global warming. More than 30,000 ground plots documented to contain black spruce provided estimates of the contemporary mean MAT, as well as projected increases in MAT (RCP6.0) for the decades centered on 2030 (1.7°C, labeled 'B') and 2060 (2.1°C, labeled 'C').

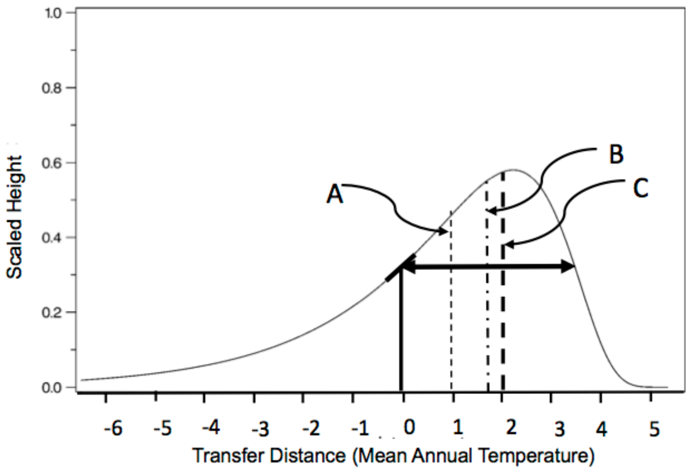

Figure 5. A transfer function representative of a climatype class adapted to the central portion of the species' climatic niche (from Figure 2, curve C). Transfer distance refers to the difference between a climatype class average mean annual temperature (°C, MAT), and the MAT of the transfer environment. The solid vertical line represents the mean MAT, which represents the zero transfer distance. The horizontal double-headed arrow represents the range of MAT associated with phenotypically stable growth performance. Vertical line 'A' represents a 1°C shift in MAT, depicting the current level of global warming. More than 30,000 ground plots documented to contain black spruce provided estimates of the contemporary mean MAT, as well as projected increases in MAT (RCP6.0) for the decades centered on 2030 (1.7°C, labeled 'B') and 2060 (2.1°C, labeled 'C').

designed to ensure phenotypic stability. Under a shifting climate paradigm, a temporal element to maladaptation must also be considered. Life expectancy of a stand, and thus rotation lengths, are inherently limited by the finite capacity of phenotypic stability to buffer climatic stresses.

Figure 4 illustrates the connection between projected phenotypic stability of a southern 'trailing edge' climatype (Figure 2, curve A) and rotation length of existing stands. The shift of 1°C (A), reflective of contemporary warming, on the transfer function suggests boreal species at their southern limits are likely approaching optimal growth rates. The MAT projected for 2030 (B) is roughly at the warmer limits of phenotypic stability. The interval between 2030 and 2060 is characterized by rapid decline in growth (and by implication, survival). Stands in declining vigor are increasingly vulnerable to insects and diseases. For existing stands, extreme weather events (heat and/or drought) would likely truncate this time line. Realistically, even planting programs based on the best adapted seed sources of boreal species must include consideration of mid-century rotation lengths.

In contrast, preferred seed sources for introducing northern hardwood forest species into northeastern Ontario will undoubtedly represent more central climatypes. Figure 5 illustrates the effects of a flatter transfer function of projected rotation lengths. Under the projected increases in MAT, well-adapted climatypes of northern hardwood forest tree species would likely approach optimal growth at mid-century (C). Because habitat suitability is improving, and phenotypic stability is broader, longer rotations are more realistic.

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Artificial Reforestation Programs in the Boreal Forest under a Changing Climate

Ecology is founded on the observation that the limits of species distributions are defined by ambient climatic conditions (i.e., climate niche). Thus, the warming climate portends sustained deterioration in habitat suitability leading to range recession of the boreal forest (IPCC 20007). More explicitly, a study has concluded that by mid-century the entire managed boreal forest land base in Ontario is expected to be climatically best suited for northern deciduous forest tree species (Rehfeldt et al. 2012).

In the face of these conclusions, formulating a reasoned response to where and when to plant long-lived tree species appears to be an intractable concern. Ontario's seed zoning retains the procurement function, but deployment is subject to the vagaries of shifting climatic conditions. Description of individual species climatic niche and projecting shifts into the future has become the standard for formulating species management plans (IPCC 2014). Seed transfer principles can then be applied to promote the deployment of well-adapted seed. The operational seed transfer recommendations summarized here are based directly on two range-wide studies describing the climate niche and patterns of adaptive variation for eastern white pine and black spruce (see Joyce and Rehfeldt 2013, 2017) and projecting geographic shifts at different time steps into the future. These results are then generalized to include both boreal and northern deciduous Forest tree species.

Black Spruce

Two attributes of black spruce convey high vulnerability to extirpation forces. Close adaptation to local climatic conditions portends minimal capacity for buffering against escalating climatic stress. And, the southern limits in distribution are essentially the same as the boreal forest, which precludes availability of climatically sensible seed sources from further south.

Figure 1 presents the geographic distribution of the climatic niche of black spruce (A), as well as projections for range recession for the decade centered on 2030 (B). Widespread early deterioration in suitable habitat is evident along the southern edge. These sobering projections infer that intensifying chronic abiotic stresses will result in declining vigor, elevated mortality, and reproductive failure ultimately leading to range recession.

Maintaining black spruce through mid-century seems problematic. But, range recession may be delayed by adopting these recommended seed transfer guidelines. Contemporary seed zones derived from disparate seed source trails (Fig. 1C) document the complex spatial pattern of adaptive variation. Projected shifts on seed zones (Fig. 1D) indicate that the southernmost seed zone represents the optimum seed procurement zone for deployment into all suitable habitat in Ontario. Given the temporal proximity of project ecological stresses testing recommended transfers takes on some urgency.

Eastern White Pine

The expansive distribution of eastern white pine in the northern deciduous hardwood forest leads to the expectation that it would be a viable option for reforestation programs in northern Ontario. However, the pairing of models describing the climatic niche and patterns of adaptive variation elucidate a complex pattern of range recession and expansion.

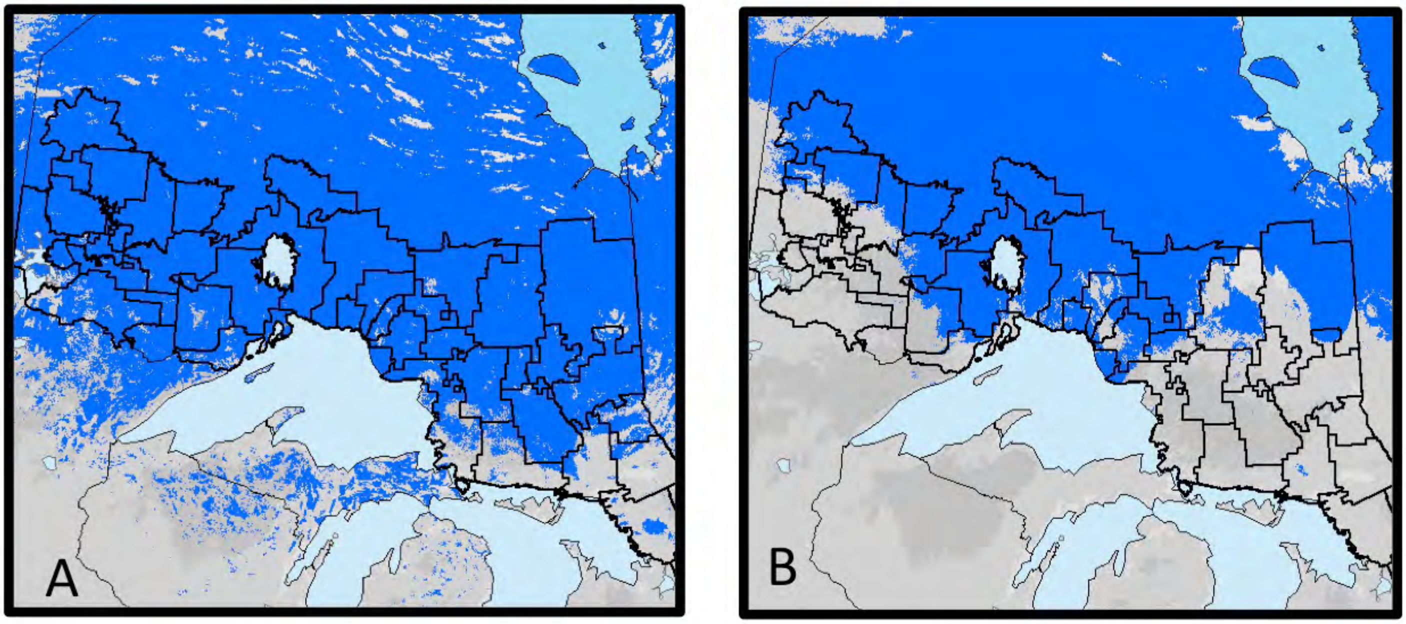
Figure 2 presents the contemporary climatic distribution of eastern white pine (A) as well as the redistribution of the climate niche projected for 2060 (B). Projected range recession is evident in northwest Ontario and the Temagami district. But, these losses are more than compensated by emergent suitable habitat east of Lake Superior. A range-wide model describing adaptive variation in eastern white pine resulted in six seed zones that function as procurement zones (Fig. 2C). The procurement zone along the north shore of Lake Superior (blue) is projected to be a match for small areas in the managed boreal forest land base (Fig. 2D). But, the seed sources originating from central Wisconsin, the lower peninsula of Michigan, southern Ontario, New York, and New England (green) are expected to optimize adaptation for most of northeast Ontario.

Other Species

Studies that assess patterns of adaptive variation are only available for a small number of boreal and northern deciduous forest species. In the absence of such studies, seed transfer guidelines based on climate variables of known predictive value must serve. The variable 'degrees days above 5°C' (DD5) has proven to be the best predictor of adaptive variation for both black spruce and eastern white pine and will be used to illustrate the approach. However, because no genetic information is available, delineation of seed zones is not possible. Alternatively, the term 'profile' is used to refer to graphic representation of climate gradients.

Red pine is used to illustrate seed transfer supported by a climate niche model but without information on adaptive variation (Fig. 3). The climate niche models provides an enhancement of Little's range map (Little 1971) because distribution is based on a robust presence and absence data base (A). Projections for 2060 include range recession in Minnesota and Wisconsin with expansion of suitable habitat in northeast Ontario (B). While no significance

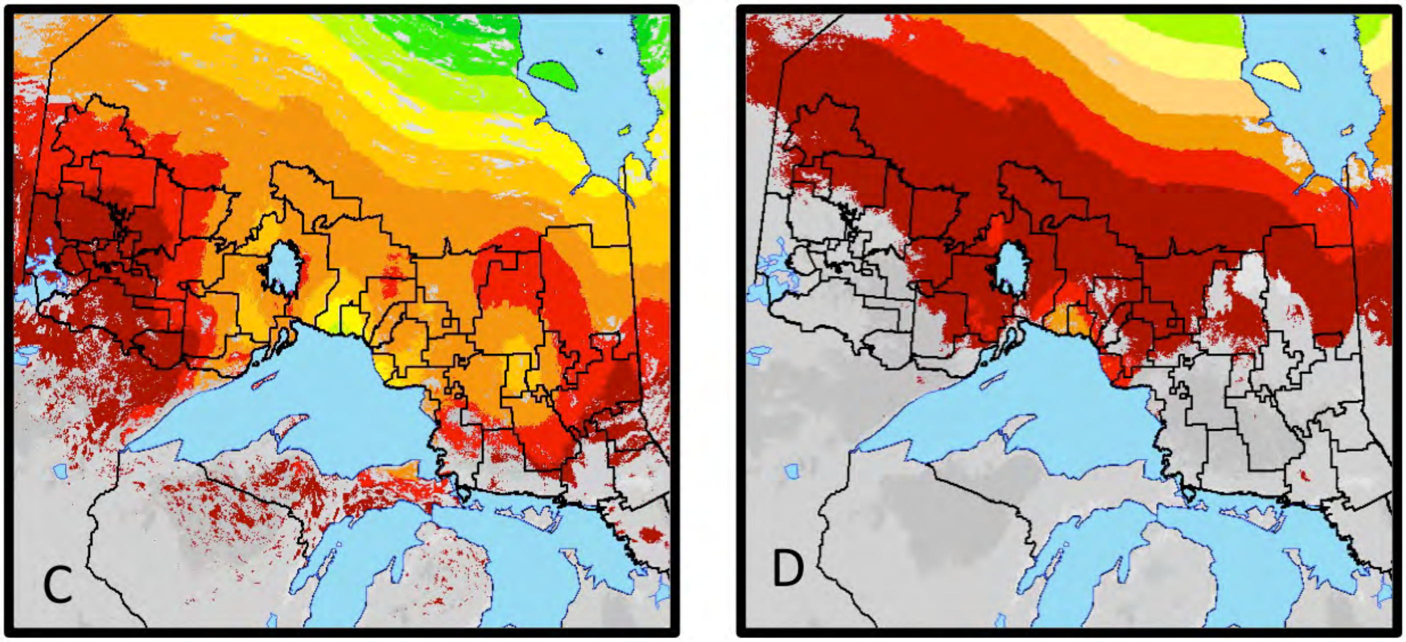
Climatic Niche Black Spruce



Base Climate (1961-90)

RCP6.0 2030

Black Spruce Seed Zones



Base Climate (1961-90)

RCP6.0 2030

Figure 1. (A) Contemporary climate niche; (B) Projected shift in suitable habitat for the decade centered on 2030; (C) Contemporary seed zones assume the function of seed procurement zones; and (D) Projected shift in seed zones for 2030 seed deployment.

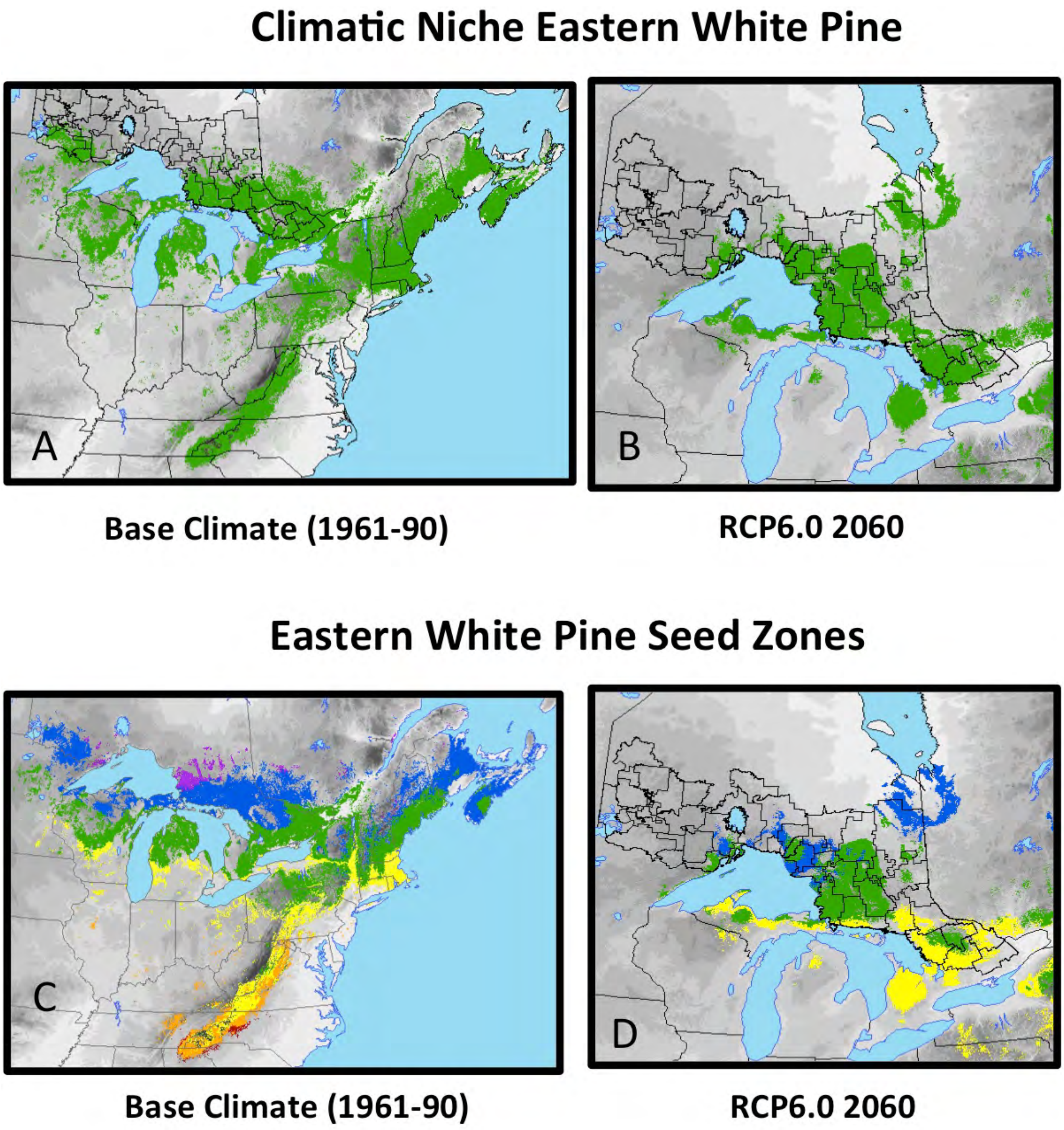
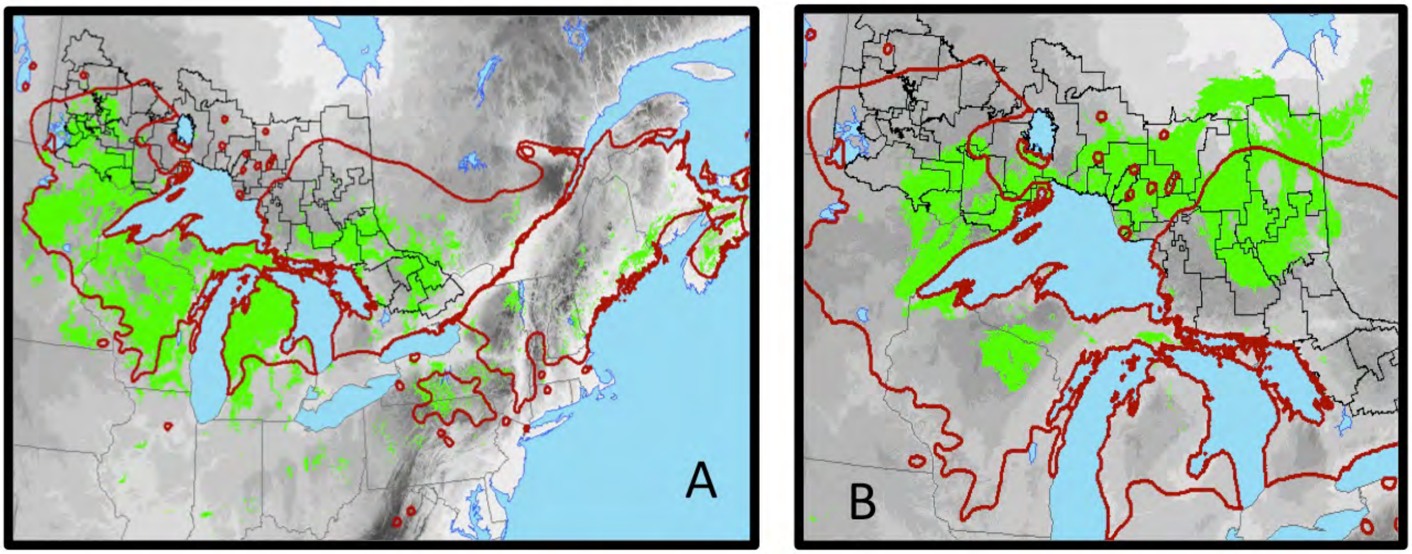


Figure 2. (A) Contemporary climate niche; (B) Projected geographic shift in suitable habitat for the decade centered on 2060; (C) Contemporary seed zones function assume the function of seed procurement zones; (D) Projected shift in seed zones for 2060 seed deployment.

Climatic Niche Red Pine



Base Climate (1961-90)

RCP6.0 2060

Red Pine Seed Transfer Profile

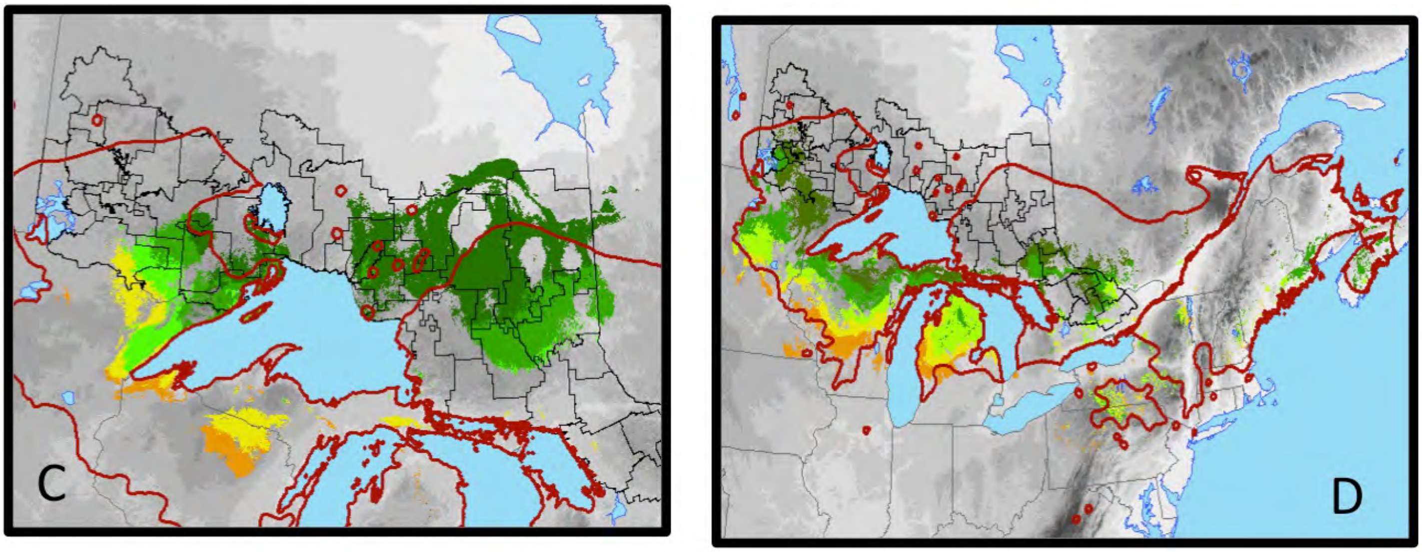


Figure 3. (A) Climatic niche of red pine; (B) Projected suitable habitat for 2060 RCP6.0; (C) Seed deployment and (D) Seed procurement profiles based on degree days above 5°C (DD5).

Seed Deployment & Procurement Profiles for Jack Pine

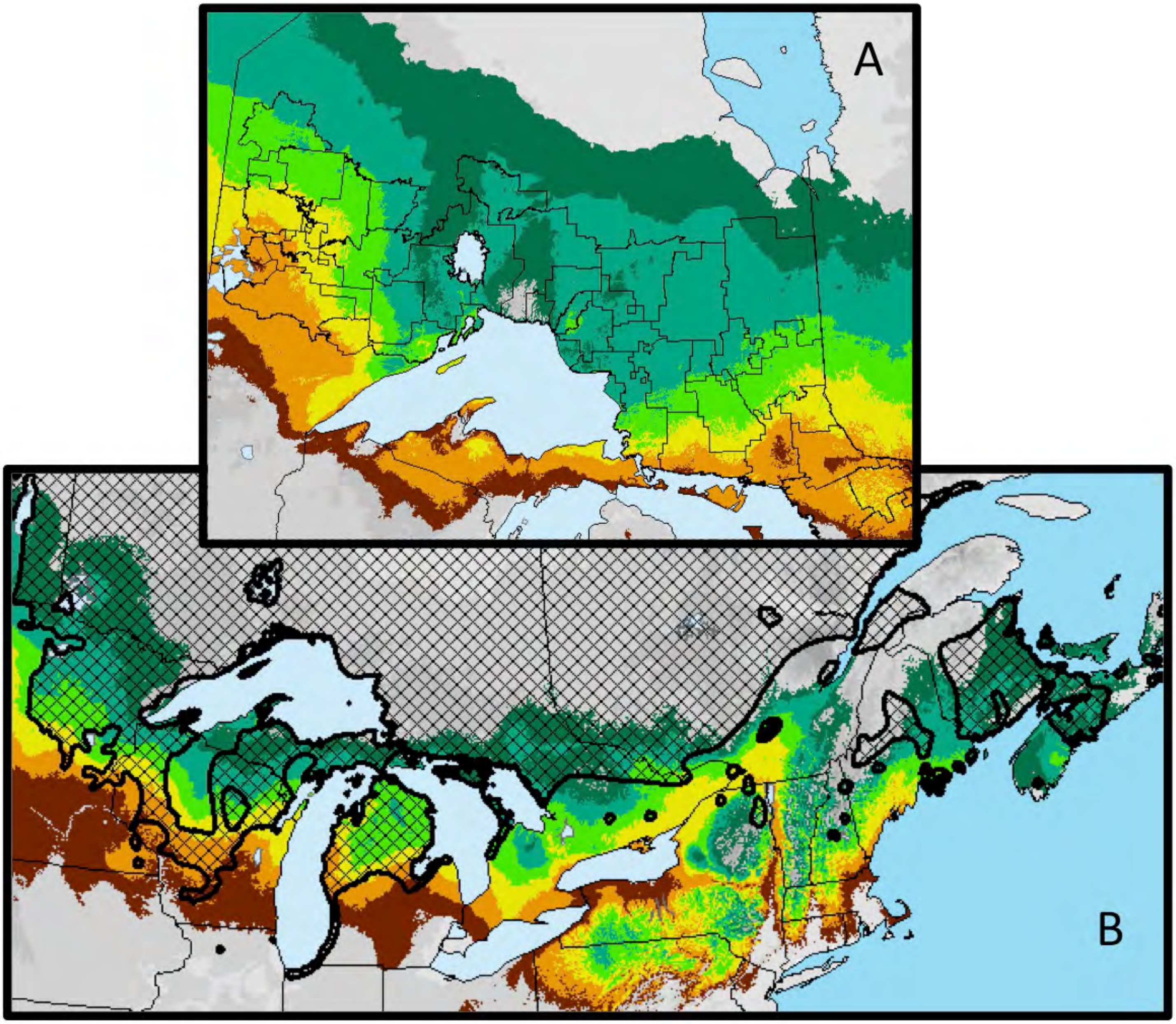


Figure 4. (A) Generic seed deployment profile based on projected 2060 RCP6.0 degree days above 5C (DD5); (B) Seed procurement profile with Little's (1971) jack pine range map overlaid (hatched area).

is associated with the profile intervals, matching of DD5 bands of the seed deployment (C) and procurement profiles (D), promote the use of well adapted seed.

When information on both the climatic niche and patterns of adaptive variation is absent, shifts in the climate profile provide a generic basis for seed transfer. Figure 4 illustrates the climatic profile for jack pine (A) and the suitable habitat projected for northern Ontario by mid-century (B). Matching seed to planting site based on similarity of DD5 in both the deployment and procurement profile (C and D) represents the best approach to operational reforestation.

Conclusion

Climate change sufficient to cause severe ecological impacts to the boreal forest are inevitable. Modeling results indicate that these impacts are likely to be evident by mid-century. Even an informal risk analysis quickly concludes that action is required. The work described here provides a template for implementing reforestation programs to mitigate these impacts. Yet, the climate and ecological models involved are imperfect representations of real ecological dynamics. As such, these recommendations should be viewed as testable hypotheses.

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Local *was* Best: Sourcing Tree Seed for Future Climates

Continued climate change demands that foresters must look to ever-warmer climates for seed sources adapted to their cutblocks. In a recent article (O'Neill and Gómez-Pineda. 2021. Canadian Journal of Forest Research. doi: 10.1139/cjfr-2020-0408) we explored the implications of continued climate change and increased adoption of assisted migration on future seed procurement. Using BC as an example, we asked two questions:

1. Where in BC might there arise a lack of well-adapted domestic seed in the future?
2. Where in our neighbouring states might we find seed capable of filling those gaps?

Using a straightforward, climate envelope approach, we found that 21% of BC's ecosystems (seed zones)—all from southern BC—will be at moderate or high risk of lacking adapted domestic provenances for plantation establishment by 2040. However, we also found large areas in the Pacific Northwest that should contain seed sources climatically suited to fill most of BC's future domestic seed supply gaps (Fig. 1, example map generated for the PPxh1, Ponderosa Pine Zone, very dry, hot). Other provinces may expect similar findings, given the generally warmer climate of neighbouring states.

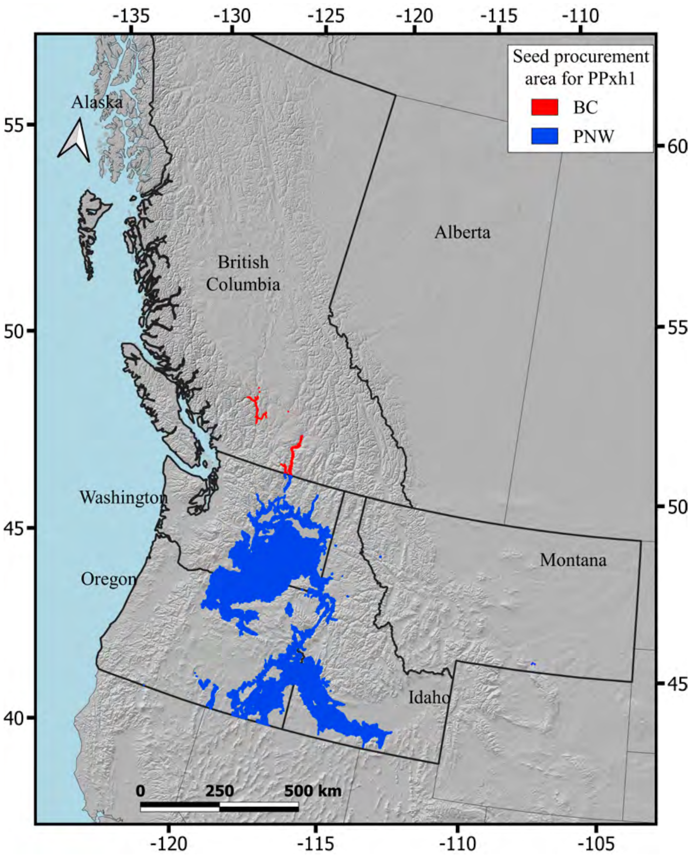

Figure 1. Map of the locations within BC and the Pacific Northwest where seed suitable for planting in the PPxh1 ecosystem in 2040 can be expected to be found.

Several options may exist to address these expected deficits in adapted seed supply for Canadian provinces:

- For existing Canadian breeding programs, establish progeny tests of domestic genotypes across a wider and warmer range of climates (possibly including locations in the USA) to identify individuals adapted to future climates in southern Canada.
- Infuse warmer American genotypes into Canadian testing and breeding programs.
- Initiate new breeding programs for gap areas in Canada using either domestic or imported American genotypes from warmer climates.
- Import suitable orchard or natural stand seed sources from the USA. The suitability of each option will depend on the size the gap, the presence of existing breeding programs, human and financial resources, and the availability of US genotypes and seed sources.

A climate envelope model or several web-based programs (seedlotselectiontool.org/sst/; https://pnw-focal-zones.shinyapps.io/match_zones_1/; and https://public.tableau.com/app/profile/larlo/viz/SeedSourceOntario/Intro can help provinces identify the size and location of future gaps and the locations of test site, genotype and seedlot climates for these options. However, as several years may be required to vet all options and implement response strategies, now is not too early to begin.

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New EUFORGEN Report Highlights Genetic Aspects in FRM Production

In tree breeding programs and during seed orchard establishment, much effort is put into ensuring that the best trees are chosen to reproduce. Focus is also put in calculating that the genetic diversity of the future crops is sufficient. Similar efforts take place in vegetative propagation programs. The reality of managing seed stands and orchards is, however, complex and a multitude of biotic and practical factors may affect how well the hypothetic and sought-after genetic diversity is realized. While high genetic diversity of forest trees is an insurance policy against pest, diseases and abiotic threats such as drought, climate change will exacerbate the risk to such diversity.

The European Forest Genetic Resources Programme (EUFORGEN) has released a report on the genetic aspects linked to production and use of forest reproductive material (FRM), which aims to cover the steps of producing FRM and choosing it for forest regeneration. The goal is to introduce the reader to various practices in European countries in FRM production and to point out possible steps in which genetic diversity may be uncontrollably or unintentionally decreased. Potential reductions in genetic diversity could occur during seed fractioning or size-based culling in seedling production. On the other hand, genetic diversity may be protected for instance in seed orchards with flowering inducing treatments or with pest control.

The choice between natural and artificial regeneration and the choice of FRM are key factors influencing the genetic diversity of forests. Their role as well as the concept of assisted migration and enrichment plantings are discussed. Examples of decision support tools for FRM transfer available and in practice in Europe are presented. These include the new Swedish web tool Planter's Guide (https://www.skogforsk.se/plantersguide). In the extension for *Pinus sylvestris* the tool allows a user to choose the location of the intended planting site, current or future climate (+2.5°C average global mean temperature, SRES-A1B) and expected average growth or survival as a percentage relative to the local orchard sources. The tool offers a list of seed orchards most suitable for the site including all Swedish and Finnish seed orchards. Thus, the optimal solution for the site might not include only domestic options.

The report ends with 38 recommendations targeted to policy makers, research organizations or FRM producers. The report is a collaborative effort of tree breeders and forest researchers from 28 European countries and it was prepared over five years. The report is available online free of charge: http://www.euforgen.org/publications/publication/genetic-aspects-linked-to-production-and-use-of-forest-reproductive-material-frm/


EUROPEAN FOREST GENETIC RESOURCES PROGRAMME

EUFORGEN

Genetic aspects linked to production and use of forest reproductive material (FRM)

Collecting scientific evidence for developing guidelines and decision support tools for effective FRM management

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Introducing the Atlantic Tree Improvement Council

AtlanTIC
Tree Improvement Council
Conseil d'amélioration des arbres

I would like to introduce myself and the Atlantic Tree Improvement Council (AtlanTIC) to the Tree Seed Working Group (TSWG) of the Canadian Forest Genetics Association (CFGA). In February of 2021, I started in my new role as the Executive Director of AtlanTIC. Having been involved and working in the agricultural and forestry biorational products industry over the past 20 years, I am familiar and experienced with the forestry sector; however, I am new to forest genetics and the tree improvement world. I look forward to working with and learning from members of the TSWG and the CFGA.

AtlanTIC was recently established as a member-based, not-for-profit organization that promotes and supports tree improvement activities across Atlantic Canada. It is modelled on successful tree improvement cooperatives that have been in operation for many years in other areas of North America. AtlanTIC's mission is to realize the economic and environmental benefits of tree improvement in the Atlantic region through collaborative breeding, field testing, resource sharing, and research. The launch of the organization was in direct response to the need for addressing climate change adaptiveness of our forest, better use of genetic and technical resources including big-data and integrating new advanced genomics applications across tree improvement efforts. These challenges require greater resources than the capacity of any individual partner or member.

Members of AtlanTIC include organizations from the private sector, all four provincial governments, and the scientific community. AtlanTIC's members collectively plant approximately 50 million trees over 25,000 hectares of land per year across the four Atlantic provinces. These plantations are critical for the future success of the forest industry in Atlantic Canada. Given this, and the challenges associated with a changing climate, increased global competition and pest pressures, it is imperative that the best trees available be selected for planting. To this end, AtlanTIC's overall focus is on improving the efficiency and shortening the time required for the region's tree improvement processes. This will be achieved by making AtlanTIC the nucleus for integrating genomic selection into the region's tree breeding programs while coordinating Pan-Atlantic tree improvement activities.

AtlanTIC's role is to provide regional coordination of tree breeding strategies, programs, research and development, and germplasm collections. The organization also fosters international collaborative partnerships for tree improvement efforts and provides educational and technical transfer services for its members and others. For example, on November 4th and 5th, AtlanTIC will be hosting a virtual workshop on white pine weevil management and tree improvement, in conjunction with the Canadian Woodlands Forum and the Canadian Wood Fibre Centre. You can register online here: https://pheedloop.com/EVETBDGFERQOF/site/home

Over the next year and beyond, AtlanTIC is working towards becoming a sustainable, supportive hub for tree improvement efforts across AtlanTIC Canada and is positioning itself to becoming a leading organization in the tree improvement space. As AtlanTIC grows and succeeds, I look forward to working with new partners, new collaborators and encourage participation from future members.

For more information on AtlanTIC please visit www.atlantictrees.ca or contact me directly below.

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Boreal Forest Plant and Seed Technology Access Center (TAC)

Introduction

The Boreal Forest Plant and Seed TAC is located within the Northern Alberta Institute of Technology's Centre for Boreal Research in Peace River, Alberta. Its mandate is to provide scientific findings, methods, technologies, and services to advance the capacity of industry to use native plants to lessen the environmental footprint in the boreal forest. The business sector served by the TAC includes forest industry, nurseries, First Nations' economic development organizations, oil and gas industry, utility companies, and consulting firms that are involved in the land reclamation and reforestation using native boreal seed and other propagules. As reclamation of severely disturbed sites becomes important in Alberta and British Columbia, the TAC focuses primarily on forest understory species.

Objectives

The TAC objectives include:

- Provide scientific guidance, develop methods and protocols for native seed harvesting, handling, enhancement, treatment, storage, germination, and propagation.
- Develop systems to deploy and improve seed delivery at a large scale.
- Develop plant and seed delivery businesses within Indigenous and Métis communities to reduce barriers to reforestation and reclamation by training highly qualified personnel (HQP) from these communities.
- Provide new or modified equipment to facilitate harvest, handling, and deployment of seeds and other propagules on disturbed sites to increase SME productivity.
- Strengthen the industry-business supply chain within the region through a Seed Consortium and promote the growth of SMEs.

Applied Research Projects

Significant knowledge gaps remain concerning the proper methods and techniques to harvest, handle, pre-treat, grow seedlings, and deploy native understory species onto disturbed sites. The TAC primarily focuses on several tall shrubs that can fix nitrogen and grow in nitrogen-poor soils such as green alder (*Alnus viridis*), river alder (*Alnus incana*) or buffaloberry (*Shepherdia canadensis*), or have the ability to persist and flourish in adverse soil condition or environmental stress that affect plant growth such as dogwood (*Cornus sericea*) and willow (*Salix* spp). Several challenges need to be addressed to reclaim or reforest industrially disturbed sites with these plants.

Efficient Seed Collection and Extraction

There is currently a lack of knowledge surrounding seed collection and handling many of the species used in disturbed sites. The questions to address include the best time of the year to harvest seed from each species. What is the best method for harvesting seeds from each species? How should the seeds from each species be extracted?

The TAC has developed technical guides or notes for harvesting and extracting fleshy shrub seeds, seed from catkins such as aspen, balsam poplar, and herbaceous species fireweed, showy aster and Canada goldenrod used as a cover crop in land reclamation. More resources can be found here: https://www.nait.ca/industry/applied-research/centre-for-boreal-research/resources/technical-notes

Furthermore, the current approach of harvesting seed directly from the boreal forest is costly and complicated by physical constraints, including remoteness, scattered distribution of species populations, and seasonality of seed production and maturation. To alleviate these challenges, the TAC has established two experimental orchards for five native shrub species. The purpose is to demonstrate the effectiveness of seed orchards for forest understory species, conduct genetic improvement of shrubs and herbaceous species through plant selection, and facilitate seed supply.

Seed Pretreatment and Viability Testing

There is currently limited information on seed viability, dormancy, and germination for boreal native species. Our main questions are:

1. What is the germination potential for each species under 'normal' germination conditions?
2. What are the effects of dormancy, stratification, scarification, and other pre-treatment methods on the germination potential and rate?

The seeds from each species are tested to determine germination potential and dormancy type. The effect of various treatments are tested to improve germination. TAC's germination testing allows for rapid evaluation and testing of all collected seedlots. It assesses seed viability and germination response of freshly collected species to different stratification lengths (from 0 to 12 weeks). A couple of articles produced by the TAC can be found here: https://www.nait.ca/industry/applied-research/centre-for-boreal-research/resources/publications

Efficient Container Production of Native Species

Procedures and optimal conditions to grow seedlings for native species are not widely available. Other important questions to address are:

1. What seeding rate is required to achieve uniform emergence in styroblocks?
2. What are the required growth conditions to achieve adequate plant growth?
3. Do outdoor conditions produce healthier, superior seedlings?

A novel plant propagation and deployment that is being developed at the TAC is Hitchhiker seedling stock. Incorporating or 'hitchhiking' native forbs into the same nursery container as a shrub or tree is a means of efficiently establishing native forbs on a disturbed site. TAC research has evaluated the types of species and timing of planting for optimal hitchhiker stock types. The protocols for the inclusion of herbaceous plant species with nursery woody stock and strategies for successful deployment will be made available soon.

Field Establishment, Mixtures & Pretreatments

Field establishment practices vary widely by species, and specific information for understory species is less available. The questions to address include what is the appropriate time to plant? Do site preparation techniques assist in field establishment? Can species mixtures and higher densities improve establishment success?

While planting seedlings is reliable, nursery stock and labor make this a high-cost endeavor. We are testing a number of parallel methods:

Direct broadcast seeding: Knowing that this alternative approach is rarely practiced as part of re-vegetation programs due to uncertainty resulting from failures in previous trials. The TAC is testing direct seeding of pelleted seeds in the field as recent greenhouse trials of some pelleted native species have shown promising results. A technical video has been produced to show the process of native seed pelleting below:

Native Boreal Seed Enhancement: Seed Pelleting

1,106 views • Apr 24, 2019

Seed coating with nanoparticles: Studies have demonstrated the benefits of using nanoparticles in improving the growth and development of plant species (primarily agronomic). TAC is evaluating the potential of this technology on boreal native species by studying the effects of carbon nanotubes in improving seed germination (including seedling vigor, and growth) and the response to multiple abiotic stressors (e.g., salinity, limited nutrients, high osmotic pressure-drought tolerance). See early results that have been published (https://www.mdpi.com/2079-4991/10/1/176 and https://www.mdpi.com/2079-4991/10/9/1852).

Seed exposure to magnetic field: Treating seeds with a magnetic field is a potential physical technique used to improve seed germination. The purpose of testing this technology is to determine the optimum magnetic field strength and exposure time to treat selected native plant seeds and improve their germination.

TAC Services

The two primary services provided by the TAC include the creation of business synergy among companies (the Northwest Plant and Seed Consortium), and enabling the development of plant and seed delivery businesses within Indigenous and Métis communities.

Northwest Plant and Seed Consortium

A regional alliance of industry, SMEs and communities called the Northwest Plant and Seed Consortium is being developed for the purpose of harvesting and banking boreal native seeds, disseminating research findings, and promoting awareness and adoption of plant and seed technologies in Alberta and British Columbia. The Consortium facilitates regional collaboration, driving SME business growth and diversification. The Consortium helps member companies to share seed resources to achieve reforestation and reclamation business goals.

While the Consortium relies on the wild harvest of seed during the first years, the TAC has established two shrub seed orchards and is encouraging the establishment of industry-owned ones in the provinces. The privately-owned orchards will benefit from ongoing TAC's shrub seed orchard research. This could lead to the provision of a reliable supply of improved seed. In addition to being the incubator of the Consortium and the liaison to industry, the TAC provides scientific guidance for seed harvest, handling, and storage for clients.

Supporting Indigenous Plant and Seed Businesses

Indigenous communities are interested in developing seed and reforestation and reclamation businesses on traditional lands and applying traditional ecological knowledge to reclamation and revegetation practices. The market research into commercial nurseries indicated an absence of native plant material in Alberta and British Columbia. There is also a great opportunity for local indigenous groups to develop successful plant and seed businesses to address this gap. The TAC is assisting communities in establishing successful reforestation businesses and building capacity through hands-on training and mentoring. Indigenous students, mentored in plant and seed business operations and greenhouse management, have access to the TAC facility and equipment for training courses and skill development and upgrading. The TAC currently works with six Indigenous and Métis communities in northern Alberta and two in northeast British Columbia.

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Is There a Future for Western Ash Species?

Editor's Note: this article is combined, edited for length and URLs updated for the TSWG readership from two regional news bulletins in 2020 and 2021. Contact Dr. Richard Sniezko or follow the "Proactive Conservation Efforts with Oregon Ash" project on ResearchGate for more direct updates.

In summer 2019, Dr. Richard Sniezko started an informal, ad hoc ash working group and outreach mailing list, originally centered on Oregon ash (*Fraxinus latifolia*, Fig. 1). Here we expand on that to mention some of the interest or projects going on with other western species.

2019 Seed Collection Efforts

Now (before arrival of EAB) is the time to be proactive and consider strategies to protect our native ash species of the West. Gene conservation and knowledge of potential genetic resistance to EAB are several actions to contemplate. Most species have at least some level of genetic resistance to diseases or pests. If this is the case for Oregon ash, then it may be possible to develop populations of ash for future restoration efforts. The USDA Forest Service's Dorena Genetic Resource Center is a world leader in the development of populations of trees with resistance to non-native pathogens such as white pine blister rust, Port-Orford-cedar root disease, and koa wilt (Sniezko and Koch 2017). A similar effort could potentially be launched with Oregon ash and EAB resistance.

Updated in 2021, the state of Oregon published an Emerald Ash Borer – Readiness and Response Plan, available here.

The callout box on page 53 states ***"While discussing lessons learned with states already dealing with EAB, Michigan shared that they regret not collecting seeds from their native ash and they have now lost native seed diversity as a result."***

Below is a list of native ash species we are concerned with in the West, of the 16 US species (Fig. 2).

- *Fraxinus anomala* (single-leaf ash) in CA, NV, AZ, UT, NM, CO, WY
- *Fraxinus cuspidata* (fragrant ash) in NV, AZ, NM, (UT)
- *Fraxinus dipetala* (California ash) in CA, NV, AZ, UT
- *Fraxinus gooddingii* (fresnillo) in AZ
- *Fraxinus greggii* (Gregg's ash) in (AZ)
- *Fraxinus latifolia* (Oregon ash) in WA, OR, CA
- *Fraxinus lowellii* (singleleaf ash) in AZ, NV, UT, NM (*F. anomala* by most, rare case where I am a splitter)
- *Fraxinus papillosa* (Chihuahuan ash) in AZ, NM, TX
- *Fraxinus velutina* (velvet ash) in CA, NV, AZ, UT, NM, TX

In 2019, the first major known individual tree seed collections of Oregon ash were undertaken: (1) a formal gene conservation (from natural Oregon stands) collection headed up by Oregon Department of Forestry (ODF) with funding from USFS FHP-WO, and (2) a second collection organized by USFS Dorena Genetic Resource Center (DGRC) relying on partners and citizen scientists in OR, WA, CA.

107 seed collections from 12 populations were made in 2019 by ODF (Fig. 3); in addition, 47 seed collections were made for DGRC by various cooperators/citizen scientists (Fig. 4). A subset of the seedlots have been X-rayed, and the

Figure 1. A collection of Oregon ash (*Fraxinus latifolia*) stands, seed and leaf characteristics. Provided by Richard A. Sniekzo, Dorena Genetic Resource Centre, WA, USA.

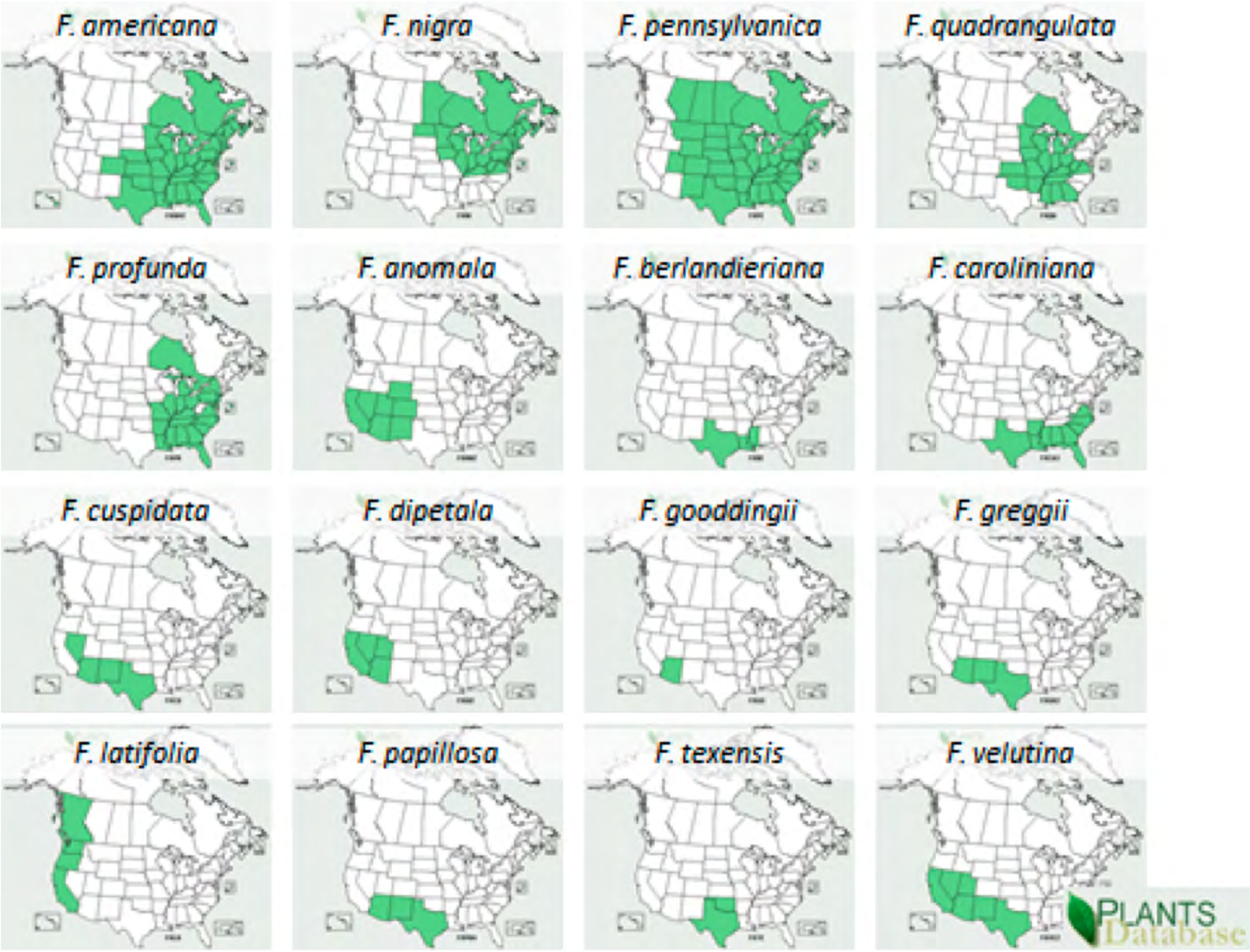

Figure 2. A distribution map of the 16 species of ash that occur in the U.S. Provided by Kathleen Knight.

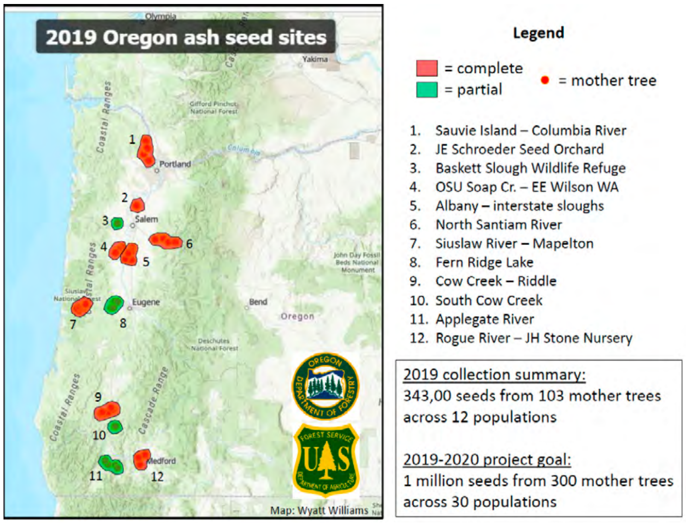

Figure 3. Gene conservation collections of Fraxinus latifolia made by ODF in Oregon in Fall 2019 (map courtesy of ODF). Note: actual number of seed collections was 107.

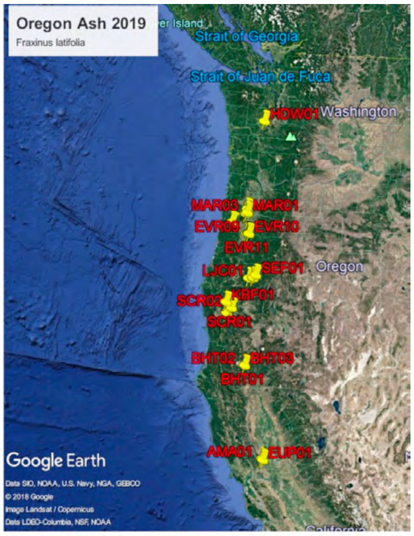

Figure 4. Locations of Fraxinus latifolia seed collections made by Dorena GRC and cooperators (map courtesy of M. Lewien).

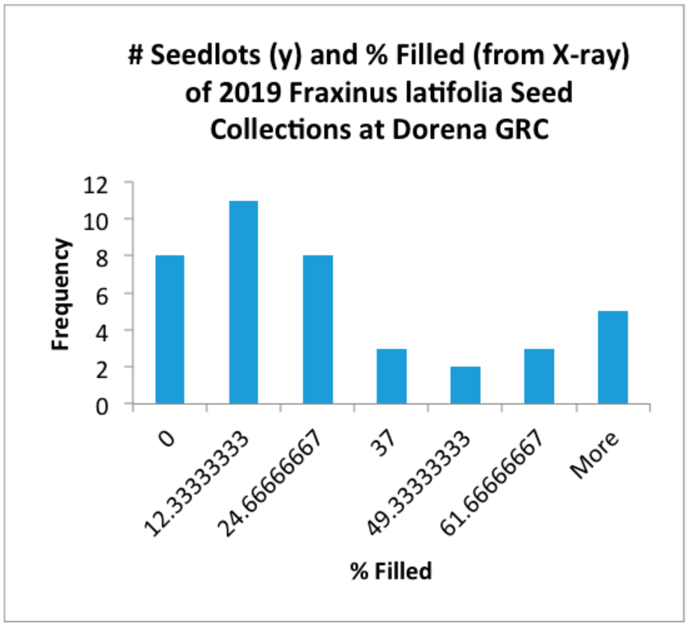

Figure 5. Percent filled seed for Oregon ash seedlots x-rayed at DGRC, November 2019.

Figure 6. Oregon ash (F. latifolia) seedlings in the DGRC greenhouse in July 2020.

level of viable seed was assessed to be generally low (Fig. 5) for DGRC collections. In addition, the first ODF lots sent to the USDA Forest Service's National Seed Lab showed 0–47% filled seed (information provided by Victor Vankus). Insect damage and possibly other events are responsible for the low fill seed percentage in 2019. Some of the potential interested collectors noted that they did not collect in 2019 either due to little seed in their area or heavy insect damage. Note that the each seedlot from the ODF collection is split into three groups for storage at Dorena GRC and two ARS facilities. Working collections are available at two of these facilities for genetic studies. Interestingly, on some trees samara had two or even three seed within them. Some of the tree locations have been entered into the TreeSnap app.

A subset of the collections (from 30 trees) were put into stratification in Fall 2019, and the seed sown in Spring of 2020. The number of seed to sow was adjusted based on its X-ray result, and this allowed for us to obtained sufficient seedling for the trials , so collection of a large number of seed even when the percentage filled is relatively low can be useful. Seedlings were grown in the Dorena GRC greenhouse and are doing well, and have recently been moved outside (Fig. 6). Some seed stratification trials by DGRC nursery group will provide good information for those wishing to grow Oregon ash in the future

2021 Project Updates

By May 2021, the emerald ash borer (EAB, USDA APHIS | Emerald Ash Borer) has already made it as far west as Colorado; when will it arrive on the West Coast? Can we do anything to save Oregon ash, or others? That is unknown, but the forestry and public gardens communities recognize the value of genetics and tree improvement (Showalter et al. 2018; Sniezko and Koch 2017). If we work together, we can examine the genetic variation within Oregon ash and its potential for the future. The initial work would be to gather seed from a large array of ash parent trees, both for gene conservation, and a working collection to learn more about genetic variation in this species and information on possible genetic resistance to EAB.

Objectives

Begin proactive measures to address community concerns on the West Coast about the future fate of the important riparian species *Fraxinus latifolia* (Oregon ash) by:

1. Initiating the first well documented resistance testing of this species to EAB,
2. Establishing two genetic conservation plantings that will also serve to examine adaptive genetic variation and be a sentinel planting for the species. We believe that this will be the first investigation of genetic variation

Figure 7. (a) Oregon ash (*Fraxinus latifolia*) common garden trial at Dorena Genetic Resource Center. (b) Seedlings were planted in the fall of 2020. Photo credits. E. Boes (a), R. Sniezko (b).

in this wide-ranging species, which occurs in CA, OR, WA and BC, and

3. Preserve the genetic diversity of *F. latifolia* by depositing seed collections and storing them for long-term use and preservation prior to the very high mortality expected from EAB–these collections will also be a source for future genetic studies.

Progress to Date

1. A few additional Oregon ash seed collections were made in WA in 2020. Collections were made by both agency staff and citizen scientists. Additional collections in OR will likely be planned by ODF in Fall 2022.
2. A common garden field trial of 27 seedling families was planted at Dorena GRC in Fall 2020 (Fig. 7a and 7b), and additional seedlings of the same families were transported to WSU's Puyallup Research & Extension Center for planting in Fall 2021 (Dr. Gary Chastagner is the contact there).
3. Seedlings of 17 ash families were sent to Dr. Jennifer Koch, USFS Northern Research Station, in early March 2021, for future EAB resistance testing (likely in 2022 when seedlings are larger).
4. Gene Conservation of all western ash species is now planned: worked with Tim Thibault and Brian Dorsey, at The Huntington (Gardens | The Huntington) to write proposals for funding to collect ash seed from all the western species in 2021 and 2022. The USFS FHP-WO funded the proposals and collections will be made in fall 2021 and 2022, including collections of *F. latifolia* in WA and CA. Tim and Brian will organize collections. Once this collection is completed there will be a more substantial range-wide collection of F. latifolia available to use for future genetic studies. Several groups in WA have been contacted to provide Tim with locations of ash stands for potential collection in fall 2021. Seed for F. latifolia will be stored at Dorena GRC, and also at the ARS facility in Ft. Collins, and at The Huntington.

Other Western Ash Conservation Activities

Tim Thibault at The Huntington was awarded a USDA Plant Exploration Grant for seven populations of fragrant ash (*Fraxinus cuspidata*) in northern Arizona earlier this year. Sadly, COVID has forced a deferment again to 2022. Tim gave a presentation on his plans in June at the 2020 APGA 'virtual' meeting. He is pursuing other funding opportunities for additional species.

Jeffrey Carstens (jeffrey.carstens@usda.gov) and Andrew Sherwood (andrew.sherwood@usda.gov) are initiating plans to acquire seeds of the western species of *Fraxinus*.

Seeds would be deposited into the U.S. National Plant Germplasm System and the U.S. National Laboratory for Genetic Resources Preservation seed vaults for preservation, research, etc. Any help from local contacts–botanists, foresters, ecologists–would be extremely helpful. Local expertise is key to gathering insight on species abundance, specific localities –"hot spots/concentrations", levels of seed production, and also timing of seed maturity. Herbarium specimens are just a small piece of the pie and often the best knowledge comes from locals. Often this sort of real-time information can be gathered during regularly scheduled activities. Proposed target areas include:

- Coconino National Forest, AZ
- Gila National Forest, NM
- Lincoln National Forest, NM

Ash Yellows 'disease'

Michael Chamberland and Jiahuai (Alex) Hu have corresponded with me about ash yellows 'disease'. Alex runs a lab at the University of Arizona with facilities for examining phytoplasma infestation responsible for ash yellows. The disease has not been much studied since the technology has not been widely available.

They are interested in looking at ash yellows among cultivated ash, but also the disease has been observed in wild ash populations (Zion Canyon). Michael mentioned that Jeff Schalau has the longer-term observation of ash performance, in Yavapai County, Arizona.

Ash Anthracnose

Beth Willhite and Laura Lowrey (USFS) have both notice ash anthracnose (Ash foliage discoloration) in their respective areas in Oregon. I'm guessing that is what I'm also seeing in the Eugene area along the Willamette River. For more information, see https://pnwhandbooks.org/plantdisease/host-disease/ash-fraxinus-spp-anthracnose. Keep an eye out for severely infected areas.

This is just a start on gathering information on genetic variation in ash. It is a project that will require inputs from many people, and an opportunity to enlist citizen scientist inputs and assistance. Folks interested in being on a mailing list can send an email to richard.sniezko@usda.gov. Anyone (or group) willing to help keep the ash 'working group' active or provide funding to assist can also contact us.

Acknowledgments

Thank you to the many professionals and citizen scientists who have assisted with seed collections, and advice on ash. The USFS Forest Health Protection (WO) and Tualatin Soil and Water Conservation District (Tualatin SWCD) have provided some funding for collections, common garden field trials and future EAB resistance trial in 2021/2022; and the FHP (WO) for the new seed collections scheduled for fall 2021. Thanks also to USFS NRS (Jennifer Koch) and WSU (Gary Chastagner) for hosting ash trials, ODF (Wyatt Williams) for many ash seed collections in OR, and The Huntington for their seed collections slated for WA and CA in 2021. The technicians and staff at Dorena GRC are thanked for all their assistance.

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Pinus strobus Orchard at the Berthier Nursery: Small Insect, Big Damage

During summer 2020, while monitoring for blister rust in our eastern white pine seed orchard, we observed resin nodules on some trunks, some being quite big (Fig. 1, 2). Larvae of Zimmerman pine moth (*Dioryctria zimmermani* [Grote]) were found in these nodules. Considering the large amount of nodules, we considered that the infestation's importance justified a treatment of the trees with dimethoate the next spring (2021).

Also during summer 2020, following a storm with strong winds, a lot of atypical branch or top breaks were observed (Figs. 3, 4). Larvae of pitch mass borer (*Vespamima pini* or *Synanthedon pini*) were then observed. This insect also produces resin nodules on the trunk, especially at branch junctions (Fig. 5).

After a lot of contacts made during last winter, and thanks to a famous Québec entomologist, M. Bruno Boulet, we can now affirm that the major infestation is not caused by the pine moth, but by the pitch mass borer. To our knowledge, little information on this insect is available. The larvae need 2–3 years to mature, and there is only one generation every 2–3 years. Adults deposit eggs on branches especially on wounded sites (Nursery & Landscape Pests). Regarding to the insect life cycle, it looks like this infestation began many years before we finally detected it. M. Boulet thinks that the population has been able to grow rapidly thanks to climate change, more particularly thanks to warmer winters.

In order to limit the insect spread, M. Boulet suggested trimming the trees during autumn. That will be done in the next few months. We are still facing a very big problem since the only way to get rid of the pitch mass borer seems to eliminate manually the nodules. This is a big challenge considering that the infestation is almost in the whole orchard and the tree height is around five meters.

Figure 1. Pitch exudate on the stem of a grafted eastern white pine (*Pinus strobus*) at Berthier Nursery in Québec.

Figure 2. Pitch exudate at the base of the trunk of a grafted eastern white pine (*Pinus strobus*) at Berthier Nursery.

While 2021 is a good seed year for eastern white pine in South Québec, there are almost no flowers in the orchard, leading us to fear the worst for its health. Our orchard survival seems highly jeopardized.

Now, if any reader of this short text has advices to share, do not hesitate to contact me. I will certainly share this information in the next bulletin.

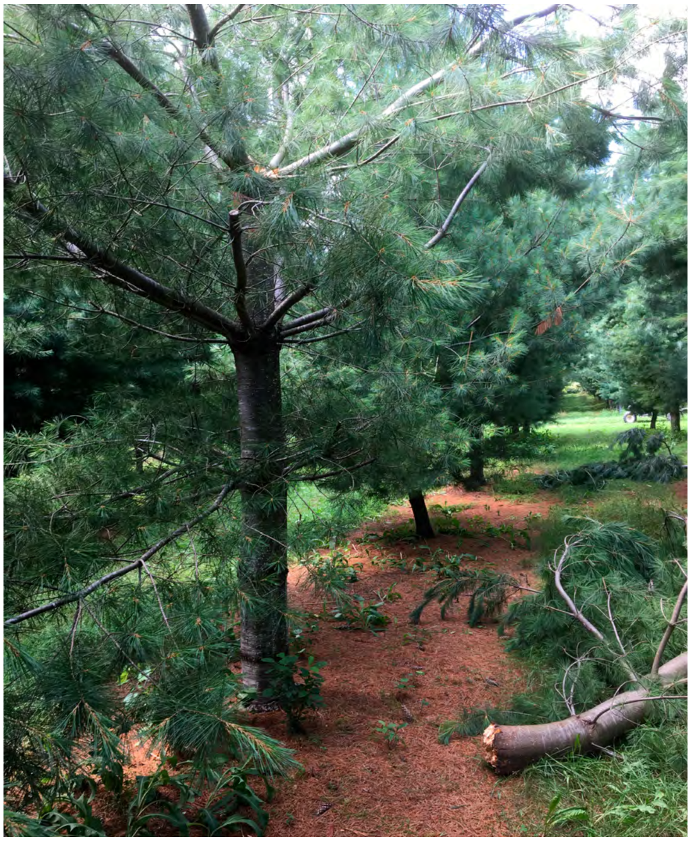

Figure 3. Branch breakage after a storm to a grafted eastern white pine (*Pinus strobus*) at Berthier Nursery.

Figure 4. Closer view of atypical breakage to a grafted eastern white pine (*Pinus strobus*) at Berthier Nursery.

Figure 5. Pitch mass borer larval damage to a grafted eastern white pine (*Pinus strobus*) at Berthier Nursery.

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Dewinging Yellow Birch Seeds with Plastic Particles

Yellow birch (*Betula alleghaniensis* Britton, YB), is Québec's emblematic tree. YB seedlings are produced in containers by the Berthier public forest nursery. Approximately 200,000 seedlings are produced annually. As for other species used for reforestation in Québec, and in order to ensure that seedlings produced for Québec's public and private forests come from top quality seeds, the Québec government mandates the Berthier Tree Seed Centre (BTSC) to process and store the seeds required for this production.

In 2019, the YB seed harvest was exceptional. Over nine hectolitres of strobili from 10 different sources were harvested and shipped for processing to BTSC. After extraction, YB seed must be dewinged to facilitate seedlot cleaning and subsequent seeding. Unlike spruce, they are not easily dewinged. It is not possible to use the Hilleshög wet dewinger due to the small volumes to be processed and the low YB seed weight. Seeds are dewinged by stirring in a cement mixer (Fig. 1) in which we add a 2:1 volume ratio of jack pine (JP) cone scales to YB seeds (Fig. 2). The treatment lasts two hours (Fig. 3).

During stirring, the cone scales break, introducing additional impurities into the seedlot, and making them less effective. Therefore, they need to be often renewed. Due to the large volume of the 2019 crop, our supply of JP cone scales would have been limiting for the completion of YB dewinging.

Guided by the idea of finding a new type of particle that would be strong and reusable, the use of plastic particles was considered. Initially, Mr. Éric Leclair, Director of Plastics Operations at Coalia (Thetford Mines, QC), a bioplastics research center, suggested regrind polypropylene pellets (irregular pieces of plastic to imitate JP cone scales, Fig. 4). But these particles were too heavy and altered the seed coat. Two other types of smaller particles, made of regrind high density polyethylene (reprocess) were then tested: cylindrical pellets (Fig. 5) and rather spherical pellets (lens type, Fig. 6).

In both cases, dewinging was effective. But, to achieve the same efficiency as with the JP scales, we had to double the time of the operation. However, seeds were not damaged and there was no introduction of additional particles which facilitated the final cleaning.

Figure 1. Cement mixer used for dewinging yellow birch seeds. The white cloth limits dust inhalation by staff.

Figure 2. Jack pine cones scales. These scales are obtained by stirring cones in the kiln after seed extraction.

Germination rates of dewinged seeds with both types of particles were similar to or slightly higher than those obtained after dewinging with JP scales. When deciding which of the two types to use, the research center suggested using the lens type particles (Fig. 6) because they would be stronger. This type was then selected and ordered at a price of $1/kg from a local supplier.

Acknowledgments

Éric Leclair from Coalia who guided us on particle selection. Sylvie Carles (DGPSPF, MFFP) for her helpful comments on all three articles in this Bulletin.

Figure 3. Yellow birch seeds before (a) and after (b) dewinging with jack pine scales. Dewinging results with the new lens type granules (Fig. 6) are similar to (b). Seed length is around 3 mm.

Figure 4. Polypropylene granules (PP regrind). Note the irregular shape.

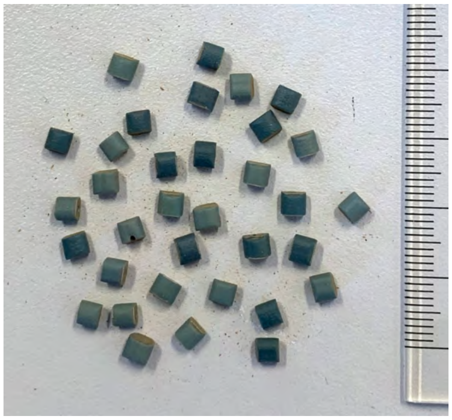

Figure 5. Cylindrical granules made of recycled high-density polyethylene regenerated (reprocess). Each particle measures approximately 4 mm.

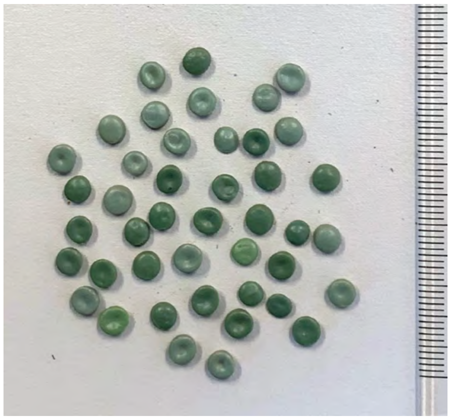

Figure 6. Spherical granules (lens type) made of regenerated recycled high-density polyethylene (reprocess). Each particle has a diameter of about 5 mm.

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Thermal Priming and Seedling Production at Berthier Nursery

The team at Berthier public forest nursery is looking for solutions to speed up seed germination with the goal of increasing the length of the seedling growing season. In his presentation entitled "Forgotten Gems and What's on the Horizon for Seed Science and Technology" Dave Kolotelo (2018) presented thermal priming as the best investment that can be made in a nursery. As a result, trials have begun, first at the Berthier Tree Seed Centre (BTSC) for an initial exploratory phase, and then quickly in the nursery during the 2019 production season.

Exploratory Phase

Trials under artificial conditions were initiated during winter 2019 at the BTSC with white spruce (*Picea glauca* (Moench) Voss; WS), a species whose seeds are shipped stratified to Québec's forest nurseries and represent about 75% of the Berthier nursery's softwood seedling production.

As suggested by Kolotelo (2018), the first step was to establish the sufficient heat amount (or degrees per hour of heat (Dh[1])) to apply to initiate germination. This first step defined the different treatments to be applied to the WS seeds. Five different treatments were tested, in addition to the control corresponding to the standard ISTA test at BTSC (Table 1).

Four WS seedlots from four different sources were used. After stratification (21 days at +3°C), seeds were placed in an unsealed bag in a germination cabinet (G30, Conviron) with ambient humidity set at 85%, at the tested temperature and in the dark. The mass of the seed bags was monitored to ensure that the seeds did not dry out, which would have affected the treatment. The potential for mold growth was also checked, but the risk was limited by stirring the bag content daily (see Kolotelo 2020 for more details on methodology). During treatment, the seeds accumulated heat and started to crack (Figs. 1a and b).

Seeds were then transferred for germination under the required conditions for WS according to ISTA (2015). The control was a stratified-only WS seedlot that did not undergo heat treatment. Germination percentage and germination value (Czabator 1962) were determined after 21 days (Figs. 2a and 2b).

Table 1. Treatments tested to initiate germination of white spruce (WS) seeds.

Treatment	Temperature (°C)	Duration (days)	Degree-hour (Dh)[1]
1	15	3	720
2	15	4	960
3	15	5	1200
4	20	2	720
5	20	3	1080
6 (Control)	Standard	NA	0

[1] Dh = (Temperature (°C)-5°C) x 24 h x number of days.

Figure 1. WS seeds after thermal priming for 3 days at (a) 15°C and (b) 20°C. Note the cracked seeds. The proportion is more important for the 20°C treatment (b).

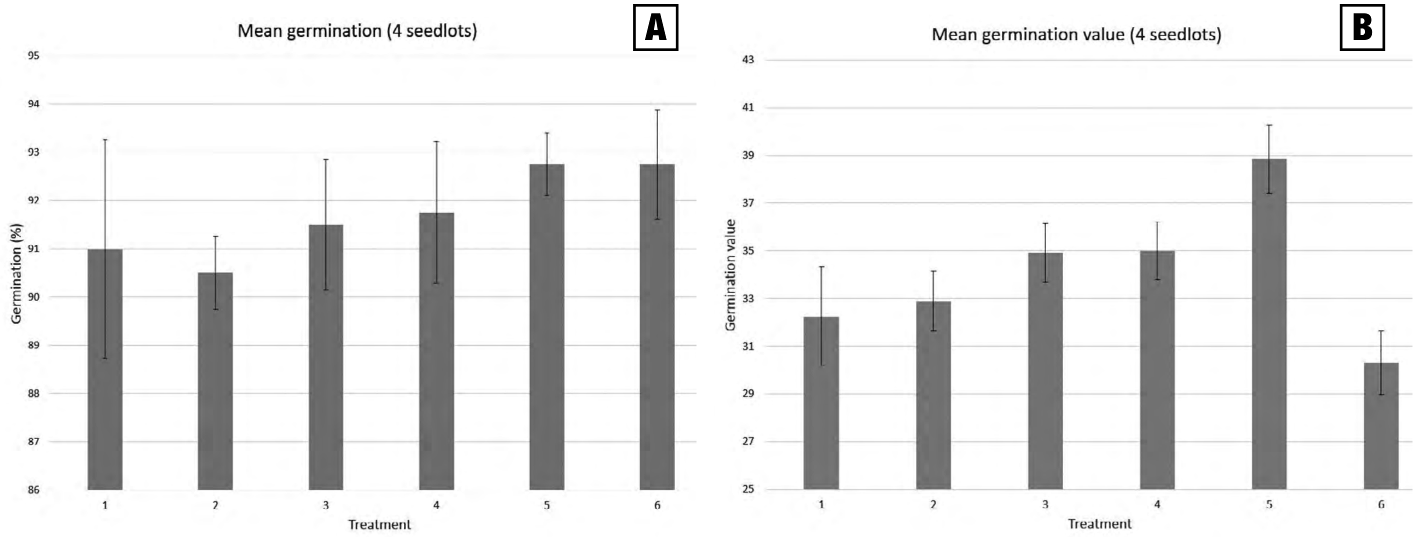

Figure 2. Results observed for four WS seedlots subjected to five distinct heat priming treatment conditions and a control treatment without priming (Table 1) after 21 days of germination in germination cabinet. (a) Average germination percentage. (b) Average germination value.

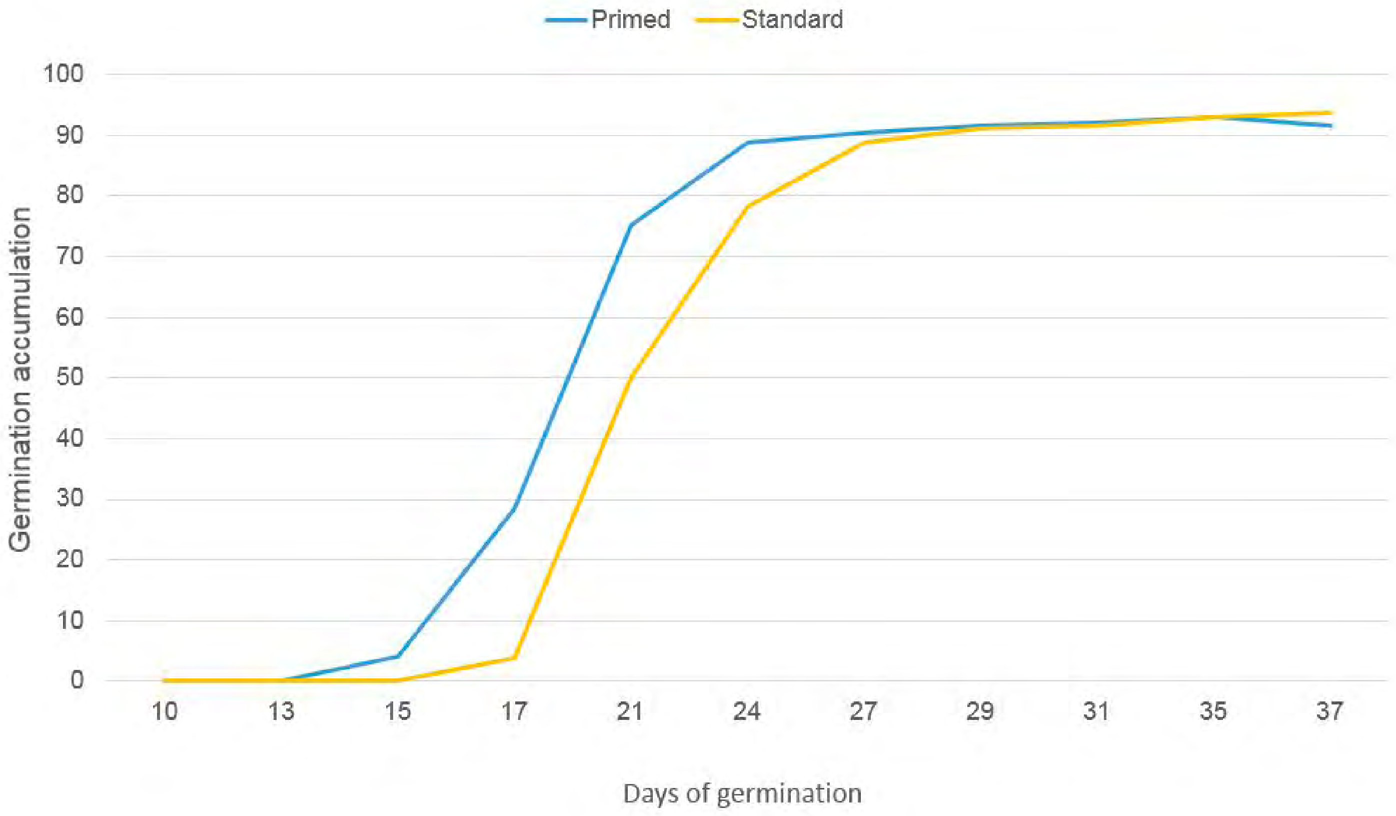

Figure 3. Germination accumulation for eastern white pine (*Pinus strobus*) seeds at the Berthier nursery for the 2 treatments: in blue stratification and heat priming (Primed), in yellow stratification only (Standard).

Regardless of the treatment, germination percentage after 21 days was not significantly different. However, germination value was significantly increased with heat accumulation even with Treatment 1 and 2 (720 accumulated Dh) compared to the control (Treatment 6, Fig. 2b). Treatment 3 at 15°C for 5 days (=1,200 accumulated Dh), i.e. the treatment associated with the greatest heat accumulation, resulted in the best germination value, but the seed coat of these seeds was very cracked. This could become problematic in an operational context where seeds are mechanically sown. This treatment was discarded for the operational phase.

Operational Trial at Berthier Nursery

The Berthier Forest Nursery is characterized by a significant proportion of its production seeded in 4 or 10 cc mini-cells (45% in 2019). Once the seedlings have reached the desired stage, these mini-cells are mechanically transplanted into the cavities where the seedlings finish their growth. By better controlling germination and making it more predictable, it would be possible to have a better organization of the transplanting period. In addition, earlier germination would also maximize the first growing season length of the seedlings. Thanks to the encouraging results obtained during the exploratory phase, it was decided to conduct a trial with thermally primed seeds under the operational conditions at the Berthier Nursery.

As suggested by Kolotelo (2018), initial trials were conducted with conservative conditions using seeds that had accumulated 0 (control) and 700 to 865 Dh of heat. In 2019, in addition to WS seed, eastern white pine (*Pinus strobus*, EWP) seeds were also thermally primed under the same conditions, even if preliminary trials had not been conducted with this species in the lab. The biggest challenge was to match the priming and seeding dates, because once the seeds are primed, there is no turning back.

In addition to the seed treatment, the test tunnel in which germination took place was also heated to maintain a higher temperature during the cold spring periods (minimum of 10°C at night and 20°C during the day).

With primed seeds, results showed germination 2–3 days earlier (Fig. 3), which is equivalent to the heat treatment duration before sowing.

Only EWP results are presented since we found that for WS, the heat input from the supplementary heater was located directly on the control tray. Germination results were then influenced by this localized excess heat. As a result, the control treatment (not primed) was not representative.

Results

For EWP, maximum germination was achieved three days earlier than non-thermally primed seed, and the transplanting period could also be advanced. By combining thermal priming and additional heat during germination beneficial effects of both treatments were added.

The Berthier nursery continued testing in 2020. This treatment is now integrated into the production method and in 2021, nearly 40% of the softwood seeds used at the nursery were thermally primed.

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Thermal Priming Trial with Western Hemlock Seed

Introduction

At WADNR Webster Nursery (Olympia, WA) we find western hemlock (*Tsuga heterophylla*) to be notoriously slow to germinate and establish in greenhouse culture. We don't even consider sowing the seed in our cool bareroot soils. In addition to the expense of extended greenhouse heating, newly emerged hemlock seedlings are sensitive to sunscald near the ground line. It must be frequently misted to prevent damage, which cools the germination environment and slows emergence and early growth. Since this is a particularly important crop to establish before spring "heatwaves", we thought it would be a good candidate for thermal priming. Thermal priming simply refers to intentionally pre-warming dormancy-released seed in a controlled environment for a head start on germination prior to sowing.

To get a sense of industry use, we surveyed respondents during an online webinar for US and Canadian growers this past year (Khadduri 2020). Out of 59 total responses on the topic of thermal priming, 74% had never tried it, 7% had tried it, but don't currently use the technique, 17% use it for some species/seedlots, and 2% use it for all species/seedlots (Fig. 1).

Dave Kolotelo recently wrote about thermal priming in the May 2020 issue of this bulletin, encouraging more growers to experiment with the practice. We took the bait.

In his article, Dave suggested using degree hours instead of the more familiar, but coarser degree day calculation to track thermal accumulation. "This uses the same threshold (5°C) used for Growing Degree Day (GDD) calculations, but accumulates them on an hourly basis." For example, an average hourly temperature of 25°C yields 25°C–5°C or 20 degree hours. Based on radicle emergence observed during standardized germination tests, Dave estimated between 880 and 2200 degree hours as a conservative place to start (Kolotelo 2020).

Preliminary degree hour determination

The first step was to get an idea of degree hour accumulation before hemlock radicle emergence in our specific warming conditions, which was simply a room temperature counter top. We plated four 50-seed samples of three seedlots of 28-day stratified Class B western hemlock seed that represented unique zones and elevation bands (WADNR lots 915, 1463 and 1542, Fig. 2). We wanted to see whether supplemental moisture would be needed in operations, and assigned two plates for "wet warming" and two plates for "dry warming". For the wet warming, we moistened blotter paper within the plates with five "spritzes", or the equivalent of 10 mL of water. After enclosing in a 1 mil thickness plastic bag, relative humidity of the ambient air rapidly rose to 100% within 4 hours, as measured by a Kestrel™ temperature/relative humidity logger. For the "dry" warming treatment, we only

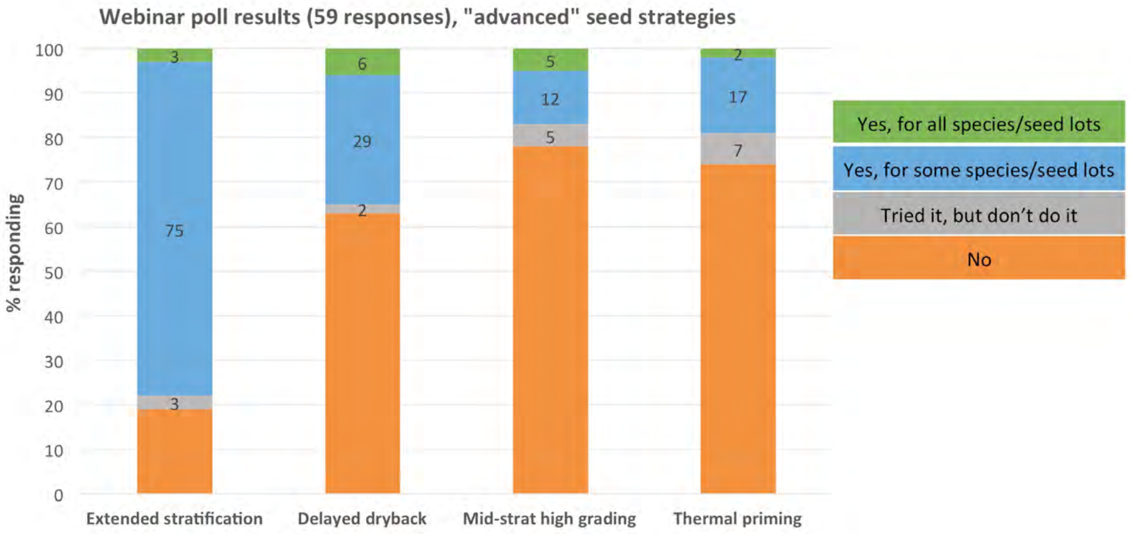

Figure 1. Live industry polling results including thermal priming, from the September 16, 2020 webinar "Seed preparation techniques to maximize germination in the nursery". Webinar recording available at https://vimeo.com/458771879.

Figure 2. Determining degree hours and amount of supplemental moisture needed for western hemLock radicle emergence in our "cool" 16°C warming room.

added one spritz (2 mL) of water initially prior to sealing the plate within a bag, with relative humidity only slowly increasing from 60% to 100% over the course of 4–5 days.

The hemlock seed started at 28% moisture content prior to warming. It turns out that adequate moisture during warming (in this case, 10 mL vs. 2 mL) was necessary for the small-seeded hemlock to germinate. We plated seeds to easily observe radicle emergence, but the dry warming test may have artificially desiccated the relatively small hemlock seed due to the small seed surface area to large container volume ratio.

Later testing with larger-seeded coastal Douglas-fir (*Pseudotsuga menziesii*) showed that, within either small sample bags or a large operational bag of surface dry (33% moisture content) seed, no additional moisture was required. The ambient air within Douglas-fir bags quickly rose to and remained at 100% relative humidity for at least 24 hours, even with a 1 cm opening at the top of the bag, followed by excellent greenhouse and field germination.

Note that the temperatures we have warmed seed to date are less than 20°C. Warmer conditions will obviously require closer attention to desiccation damage, an increased need for air exchange, etc. According to unpublished work by Drs. Carole Leadem and George Edwards, total energy accumulated, rather than how quickly or what pattern it is received, dictates germination. We decided to be conservative and start on the cool side of things. However, some nurseries, for example, K&C Silviculture (Oliver, BC) have warmed seed at temperatures as high as 25°–30°C (Dawes 2008).

For our three western hemlock seedlots, the earliest radicle emergence started at just over 1400 degree hours. At our relatively cool average temperature of 16.3°C (a drafty room), that came to a little over four days of warming.

Greenhouse Trial

For the greenhouse trial, we chose two warming durations, a "short prime" of 530 hours and a "long prime" of 1060 hours. As with the preliminary test, average hourly warming temperature came out to just over 16°C. We returned seed after warming to a 2°C cooler, where it remained for up to two days before sowing. We generally stratify western hemlock at 2°C for 45 days, and operational timing came out to 43, 45 and 50 days from the production seedlots we sampled from.

We used a randomized complete block design, with each treatment occurring in each block (415D styroblock container, Stuewe and Sons, Portland, OR). At three rows of seven cells per treatment and 12 replications (containers), the total number of seeds evaluated per seedlot × treatment combination came to 252. We blocked containers by seedlot, and randomized blocks by seedlot within a replication (Fig. 3).

We defined germination as emergence of the entire seed coat above the grit surface, and evaluated daily for 28 days. Average greenhouse temperature for the trial was 23°C. We ran a two-way ANOVA using the aov function in the R statistical package (seedlot × treatment) to check for interaction and treatment significance. Day 14, 21 and 28 results were analyzed using a Tukey's HSD means separation test and considered significant when $p < 0.05$ (R Core Team 2021).

Results

Cumulative Germination

We found no significant seedlot by treatment interactions. For all three lots, both long and short priming (seed pre-warming) treatments significantly increased cumulative germination over non-treated seeds at Day 14 and Day 21 (Figs. 3a–c). At Day 14, long priming significantly increased germination over the short prime treatment as well. By the end of the test, Day 28, no significant differences remained between treatments, although the priming treatments averaged higher final germination for two of the three lots.

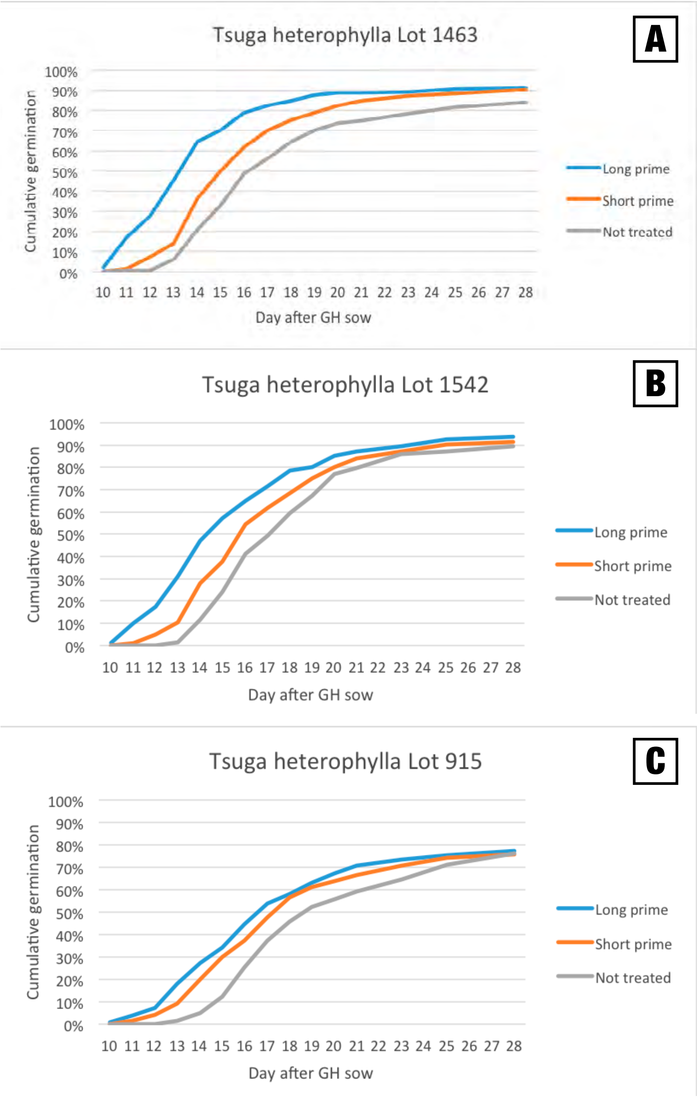

Figure 3. Cumulative germination for western hemLock seed lots (a) 1463, (b) 1542 and (c) 915 for long prime, short prime and non-treated seeds.

Germination Speed

For each seedlot, long priming shifted the germination curve to the left, that is, increased germination speed. On average, long priming decreased GC/2 (time to 50% of germination capacity) over non-treated seeds by roughly 3 days.

Another way to evaluate germination speed is the peak value metric, the ratio of highest cumulative germination divided by the day of evaluation (Kolotelo 2001 Seed Handling Manual). Lengthening durations of priming incrementally increased the peak value for all three seedlots (Table 1).

Table 1. Peak value increased for all three seed lots with increasing durations of thermal priming.

Seedlot	Long prime	Short prime	Not treated
1463	4.9	4.2	3.7
1542	4.4	4	3.8
915	3.4	3.2	2.8

Discussion

Based on this first trial we plan to expand thermal priming with western hemlock and also apply the technique with other species. We have recently tested seed pre-warming with coastal Douglas-fir in both greenhouse and field sowing. By accelerating germination and narrowing the germination window, thermal priming reduces greenhouse heating, misting and general pest attack. It also has the potential to increase crop uniformity. Initial results show even more promise in the cool soils and unpredictable environmental conditions of field sowing.

For all its benefits, thermal priming must be weighed against its potential risks. Avoid pre-warming seed that has shown signs of mold, decay, splitting or pre-germination during stratification.

As noted above, our pre-warming to date is 10°C+ cooler than a nursery that does thermal priming operationally. While warmer priming makes sense for production and perhaps for certain species in particular, extra care must be given to monitoring seed for uniform heating and potential desiccation.

Acknowledgments

Thanks to WADNR colleagues Kila Benge and Meaghan Stuke for their assistance in conducting the trial and Henry Yang of K&C Silviculture (Oliver, BC) for his technical advice.

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Western Larch Germination Test Adjustments

The goal of this trial was to direct what changes need to be incorporated into the germination testing of western larch (*Larix occidentalis*, LW) to better reflect actual seedlot quality.

Background

The basic problem we have been encountering is that germination tests of LW have been displaying many seeds that initiated germination (emergence of radicle), but did not 'normally' complete the process. The radicles succumbed to some form of fungal infestation resulting in rotting of the root tips and seeds never reached our germination criteria of the radicles being 4× the length of the seed coat (Fig. 1a, b). Germination dishes show a consistent black staining which can appear as early as Day 5 in a germination test and becomes progressively worse with time. The black staining seems to radiate from specific seeds indicating it as the likely origin.

We have also tested our germination test media (filter paper and Kimpack®) and they did not seem like the origin of the problem. The causal organism (if only one) has not been confirmed. Initial evidence indicated *Alternaria* spp. as likely candidates, but the symptoms have been seen on seedlots without evidence of this genus. Similarly the same symptoms have been found on seedlots with and without evidence of *Fusarium* spp. Larch seed pathology has a long history, but our main efforts have been since 2016 when we were doing family lot testing and there was a very high proportion of out of tolerance tests due to these rotting radicles and very low resulting germination capacity (GC) estimates. The problem has predominantly, but not exclusively, been restricted to seed orchard western larch seedlots.

Materials and Methods

Four LW seedlots from different seed orchards were used (Table 1). The trial utilized the 2020 orchard seedlots with the exception of Orchard 332 as the seedlot had not completed processing when the trial was initiated.

Each seedlot was germination tested with 12 different treatments which varied in terms of type of soak (standing vs. running water), seed sanitation treatments, germination dish moisture level and media. The description of the

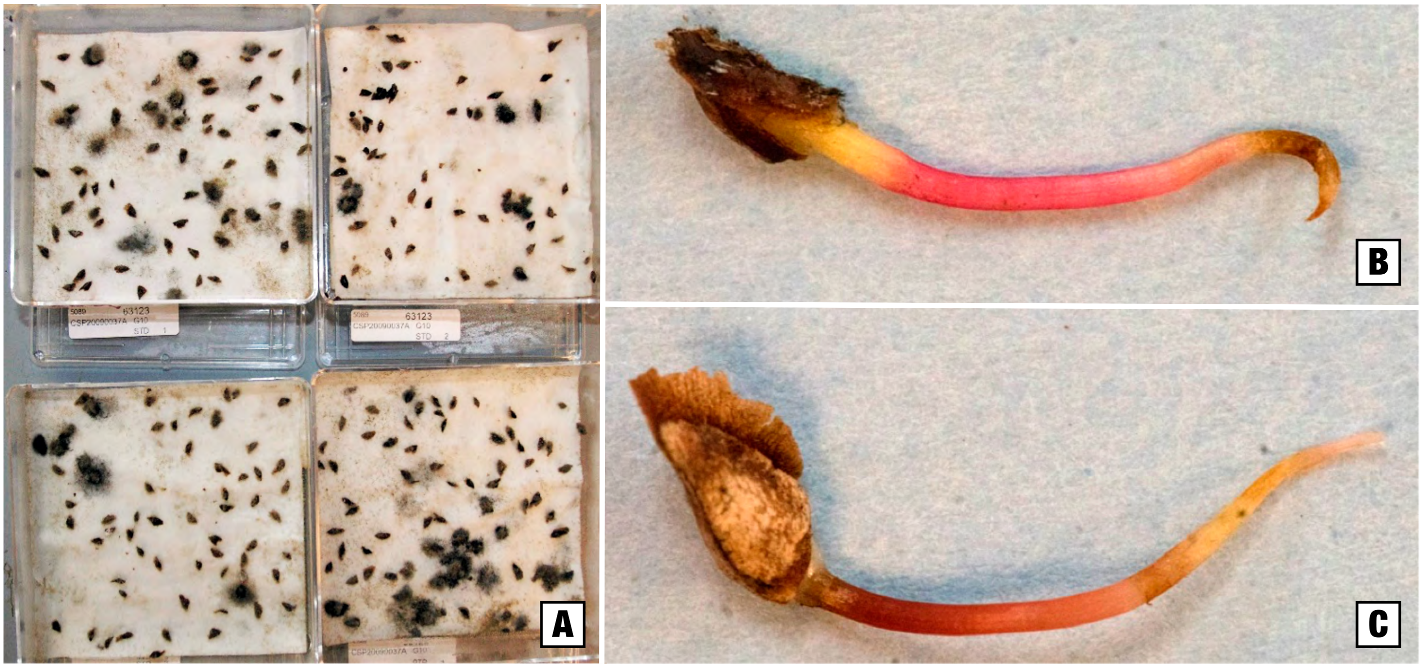

Figure 1. Characteristic black staining of germination dishes (a) and close-up of (b) an abnormal germinant displaying a rotten radicle and (c) a normal germinant.

Table 1. Seedlot variables of seedlots used in the western larch germination test improvement trial.

Seedlot	Orchard #	Collection Year	Balance (Kg)	Seeds per gram	Germination Capacity (GC) – G10	*Fusarium* spp . Contamination Level
63768	332	2018	163.3	289	91%	0.0%
63914	334	2020	142.5	251	73%	0.0%
63915	994	2020	55.4 (to USA)	212	86% (68% initially)	1.2%
63941	353	2020	23.9	216	68%	5.8%

treatments can be found in Table 2.

The G10 treatment is our current standard testing method for LW and considered the control to which all other treatments should be compared. An obvious variable was to use the running water soak treatment (vs. standing water), especially with the success of this treatment in reducing seed-borne contaminants (*Fusarium* spp.) with Douglas-fir. The BCTSC testing staff have been concerned that the standard 37.5 mL of water in the germination tests was too much and responsible for the high proportion of rotting radicles observed. Water was reduced to 25 mL for one set of treatments and for another set we used accelerated aging (AA) trays to hold the seed above direct contact with the media (Fig. 2). These trays are used in our standard testing for western white pine (*Pinus monticola*) and yellow

Figure 2. The accelerated aging (AA) trays used in some of the treatments to eliminate direct seed and moisture contact.

Table 2. The 12 treatments used for evaluating potential changes to western larch germination testing practices.

Treatment	Soak: Standing Water or Bleach	Soak: Running Water	Post-Stratification Sanitation	Moisture (mL, AA (Fig. 2)) in Germination Test
G10 (control)	Standing water			37.5
A	Standing water			25.0
B	Standing Water			AA trays; 37.5
C		Yes		37.5
D		Yes		25.0
E		Yes		AA trays; 37.5
F		Yes	3% H_20_2 – 2.5 hrs	37.5
G		Yes	3% H_20_2 – 2.5 hrs	25.0
H		Yes	3% H_20_2 – 2.5 hrs	AA trays; 37.5
I (Webster)	1.3% bleach – 10 mins	Yes	3% H_20_2 – 2.5 hrs	37.5
J (Webster)	1.3% bleach – 10 mins	Yes	3% H_20_2 – 2.5 hrs	25.0
K (Webster)	1.3% bleach – 10 mins	Yes	3% H_20_2 – 2.5 hrs	AA trays; 37.5

cypress (*Callitropsis nootkatensis*) and include three layers of Kimpack and 112.5 mL of water beneath the tray.

Post stratification (pre-sowing) hydrogen peroxide (H_2O_2) treatments are commonly used for western larch in BC nurseries. The additional pre-soak bleach (1.3% for 10 minutes with a one minute rinse) was used due to the high germination results obtained in the United States with this treatment incorporated. Results from the US have indicated that seedlots often benefit from extended stratification up to six weeks, but this trial focused on the other germination testing elements and three weeks of stratification was used in all treatments.

Each Seedlot × Treatment combination consisted of four replicates of 100 seeds, each contained within its own germination dish. Due to the time required for performing these 48 treatments; only one seedlot (12 treatments) were initiated on a given day. The four replicates received the indicated treatment individually, but the replicates were not randomized within the growth chamber to reduce the potential of human error. It is assumed that the controlled environmental in the growth chamber is homogeneous. One item that was different was that after the seed stratification period the Kimpack and filter paper were changed prior to placing the replicates into the germinator. This resulted from not tracking the seed replicates to individual germination dishes when removing the seed for the hydrogen peroxide treatments. It was decided to change the media for all treatment dishes to keep this consistent.

After the treatments the seeds were stratified in the germination dishes for 21 days and then transferred to a germinator maintained with a 30°C temperature for eight hours with light and 20°C for 16 hours in the dark. Germination was assessed every Monday, Wednesday, and Friday for 21 days. A seed was considered germinated when it's radicle was 4× the length of the seed. The number of abnormal germinants, primarily rotting radicles, was also tallied for each germination dish. The results will be presented graphically and with averages, using Analysis of Variance (ANOVA) and also presented in terms of the estimated time and effort required to implement the changes associated with these potential test regime modifications.

Results

The plot of the germination capacity and its variance as well as the average number of abnormal germinants is provided for all treatments averaged across the four seedlots (Fig. 3). All treatments showed an improvement over the G10 control (67% = red horizontal line). The standard 37.5 mL of water in the germination dishes (G10, Treatments C, F and I; average=x=77%) was inferior to reducing moisture to

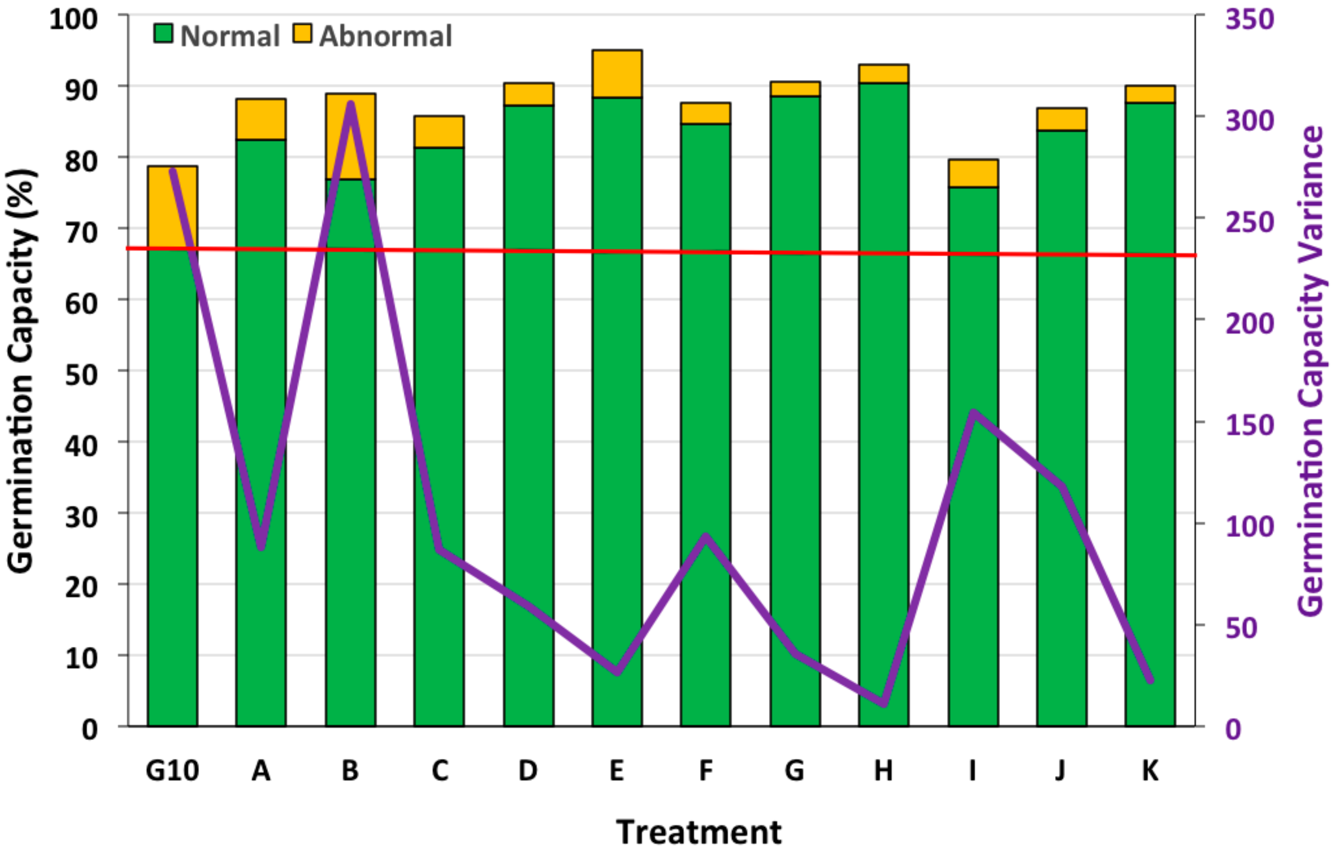

Figure 3. The normal germination capacity (%) and variance and percentage of abnormal germinants averaged over all four seedlots for the 12 treatments.

25 mL (Treatments A, D, G and J; x=86%) or the use of the accelerated aging trays (Treatments C, E, H and K; x=86%). The change to a running water soak improved germination by 10% and the further addition of the post stratification hydrogen peroxide soak increased germination by 2%, on average. The addition of the pre-soak bleach treatment to the running water soak and hydrogen peroxide treatment actually decreased germination by 6% on average!

The average germination of the individual seedlots across all treatments varied as follows: 63768 (89.1%); 63915 (89.0%); 63914 (82.0%) and 63941 (71.0%). Seedlot 63941 also had a higher level of *Fusarium* spp. contamination at 5.8%. The germination difference between the best and worst treatment in each seedlot varied from 11.5% (63768) to 40.5% (63941).

In terms of statistical analysis, a two-way ANOVA was run with Seedlot (S), Treatment (T) and the interaction S×T using both the raw germination capacity data and the arcsin square root transformation commonly used for percentages. Both analyses indicated the Seedlot, Treatment and S×T interaction terms were all statistically significant at a 95% probability level. It is generally considered to be incorrect to run mean separation tests on a variable when an interaction it is involved in is significant. To investigate statistical differences between the treatments each seedlot had a one-way ANOVA performed and in all cases treatment was a significant variable at the 95% probably level. Tukey's mean separation test was then run for each seedlot and the results presented in the apologetically large Table 3 which shows all of the 48 treatment combination averages. Means of the same seedlot with the same letter are not statistically different from each other at a 95% probability level.

In terms of the implementation of the various tests there are different costs (mainly time) involved. Time estimates for tasks vary by person and numbers given are considered average with an experienced technician. The simplest change is to adjust the amount of moisture added to our germination

Table 3. The average germination capacity (%) results of the four seedlots and 12 treatments. Within a seedlot the same letter indicates no statistically significant differences exists with 95% confidence. Treatment D highlighted for discussion.

Seedlot	Treatment	Average	Significance
63768	D	95.5	a
	G	94.3	a
	E	94.0	a
	J	91.8	ab
	A	91.5	abc
	H	89.5	abc
	K	89.3	abc
	C	89.0	abc
	F	87.0	abc
	I	84.8	bcd
	G10	84.0	cd
	B	78.8	d
63914	E	91.0	a
	H	90.3	ab
	K	89.5	ab
	G	89.0	ab
	B	88.3	abc
	F	82.5	abc
	A	81.0	abc
	D	80.8	abc
	I	78.3	abc
	J	76.5	bc
	C	74.8	cd
	G10	62.8	d
63941	H	86.8	a
	E	82.3	a
	D	80.8	a
	K	80.5	a
	G	80.3	a
	F	73.0	a
	J	72.5	ab
	C	72.0	ab
	A	70.0	ab
	I	57.5	bc
	B	51.5	cd
	G10	46.3	cd
63915	F	96.25	a
	H	94.75	a
	J	94.25	a
	D	92.25	a
	K	91	ab
	G	90.75	ab
	C	89.75	ab
	B	88.75	ab
	A	87.5	ab
	E	86.25	ab
	I	82.25	bc
	G10	76	c

dishes from 37.5 to 25 mL water = no additional time involved. The move to using accelerated aging trays involves an approximate doubling of time to spread seeds evenly due to spreading seeds across a metal screen vs. a filter paper (15 vs. 8 minutes). The use of a running water soak, which involves additional labelling, placing and removing seed from small perforated soaking vials, and cleaning the tanks afterwards would add an additional 15 minutes for each test. Adding a hydrogen peroxide step after stratification would add an additional 18 minutes to each test including the re-spreading of the seed in the germination dishes. This does not include the 2.5 hour treatment time, but that needs to be considered in daily planning involving this treatment. The bleach treatment added about 15 minutes for each test. It is acknowledged that there are potential gains in timing efficiency by applying the specific treatments to multiple seedlots (i.e. an entire germination tray) simultaneously.

Discussion

In selecting a new testing regime one wants to select a new standard method that increases germination capacity consistently across seedlots. It seems clear from the results that anything we do will be better than the current testing regime (G10) for LW. In three of the four seedlots it was the lowest ranking treatment in this trial. The moisture level of these treatments (37.5 mL in treatments G10, C, F and I) consistently did poorer than the other two moisture 'treatments'. On average, there is no GC difference between the 25.0 mL of moisture and the use of AA trays, but the additional time required in spreading seeds on AA dishes is considerable.

Looking at Figure 3, my expectation is that the GC would vary by treatment, but the viable seed estimate (normal and abnormal germinants combined) would be relatively equal.

This was not the case and in some cases there was a large decline in the estimate of viable seeds (i.e. Treatment I). In general, the bleach treatment did not appear to help, but caused reduced germination, and is not being considered for operational implementation in testing. It was never a practical consideration for operational seed preparation due to seed preparation volumes, but incorporated due to the large success experienced in Washington state.

The Seedlot×Treatment interaction was significant, so no one treatment performed best for all seedlots. In Table 3, you can see that many treatments exhibiting 'good' germination were not statistically different (all illustrated by the letter a). Table 3 also unapologetically foreshadows what our new LW testing regime will look like and that is indicated by Treatment D–moving to a running water soak and only using 25 mL of water in our germination dishes. It doesn't include bleach, accelerated aging trays nor a post-stratification hydrogen peroxide treatment. The latter is generally used operationally at BC nurseries and greater effort will be placed on emphasizing the importance of this practice. These are fairly simply adjustments to testing, but do increase the time involved per test. I believe this treatment is the best trade-off between improvements in results and the increase in effort required to conduct the tests.

I appreciate that some of you will question the results of seedlot 63941 in which treatment means of 86.8% and 70.0% are considered not statistically different. The primary statistic used in Tukey's procedure is the Mean Square (Error), equivalent to variability between replicates, and in this seedlot the value was 60 while in seedlot 63768 it was 15.2. The poor general result of seedlot 63941 is concerning and I think the high 5.8% *Fusarium* contamination estimate is responsible for the lack of consistency among replicates. This is the highest level of Fusarium ever found in a seed orchard LW seedlot and ranks 15th out of a total of 260 western larch seedlots, regardless of genetic class, tested for this pathogen.

The new testing method will be implemented and we will initiate a retesting plan for seed orchard LW seedlots in the summer of 2021. This plan includes initially testing the 18 largest LW seedlots with the modified G10 test (running water soak and 25 mL of water in germination dish). This accounts for over 95% of the grams of seed orchard LW in storage. We will also test a small number (4) of wild stand seedlots that have still been used operationally over the past few years.

To further address the potential benefit of extended stratification, not tested in this trial, the eight largest seed orchard LW seedlots (78% of grams in storage) and an additional three seedlots showing germination capacities under 80% will be tested with six weeks of stratification, the running water soak and 25 mL of moisture in the germination dishes. To further address seedlots which show high levels of fungal contamination or have low unexplained germination results (7 seedlots) we will be testing five seedlots with post-stratification hydrogen peroxide (Treatment G). We will also be testing a few seedlots (7) with Treatment H which includes post-stratification hydrogen peroxide and the use of the AA trays as this treatment was not statistically different from the best treatment in all seedlots. It is a much more intensive testing methodology, but the number of LW seed orchard seedlots in storage is limited compared to other species. It will be good to have additional results on other seedlots for this treatment and Treatment G, but we need to also move on with updating seedlots with my recommended Treatment D and investigating extended stratification. Based on the results of this suite of retests (51) we will evaluate further efforts. It's continuous improvement, not an open-and-closed book case, and this species has been particularly tricky due to the highly variable results obtained over the past five years of investigation.

In terms of seed pathology, it unfortunately has been difficult to determine a causal organism responsible for the 'rotting radicles', but we have not given up. We will continue that work with some exploratory DNA barcoding work at UBC and continue to push for improved *Fusarium* diagnostic tools. At this point *Fusarium* spp. and *Alternaria* spp. are our primary genera of interest. It also appears like our relatively high moisture level in our G10 test was conducive to the fungi becoming a pathogen. In general, nursery feedback on western larch has not been a problem, but many nurseries employ a pre-sowing hydrogen peroxide treatment. The treatment has traditionally been employed as a sanitation effort against losses from *Fusarium*, but it potentially was also a protective measure from the impacts of other seed-borne contaminants.

I am confident that the introduced changes will greatly improve the estimated germination capacity of LW seedlots and better reflect actual seed quality. We will continue to look for improvements based on our planned testing and feedback from others experience and I'll update you in a future News Bulletin. There will also be greater effort directed at advocating the benefits and means of seed sanitation.

Acknowledgments

I'd like to acknowledge the significant contributions of Johanna Walker for scheduling the trial, preparing the germination tests and performing the various seed treatments – that was a significant amount of work. I'd also like to acknowledge the efforts of my current Seed Testing dream team, Victoria Lei and Laura Boivin, in performing the upcoming LW germination tests.

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BC Seed Orchard Seed:Seedling Conversion Factors

To assist with reforestation and orchard capacity planning a species specific seedling recovery factor (seeds required to produce a seedling) is an important variable. In BC, we have a default set of Sowing Guidelines in our Seed Planning and Registry (SPAR) system that calculates potential seedlings of a seedlot and the amount of seed required to produce a specific seedling request. These calculations are based on an individual seedlot's germination capacity and seeds per gram result and an estimate of seeds required to produce a seedling. The seeds supplied per seedling value varies depending on the germination capacity of the seedlot. These are general guidelines, not species-specific, and actual minimum seed quantity required varies greatly by nursery location, space and efforts employed to maximize seed quality. The seed:seedling conversion factor is controversial and for those unfamiliar with seed quality and the economics of seedling production the numbers can seem high. Seed efficiency is a priority, but ensuring the nurseries have enough seed to produce the requested seedlings takes precedence. Details are provided in the Methodology section and additional background can be found here: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/seed-planning-use/sowing-guidelines

For longer-term provincial planning, to identify seed gaps and plan seed orchard capacity a set of species-specific seed:seedling conversion factors have been agreed to at our Coastal and Interior Technical Advisory Team meetings. The factors assumed an average germination capacity for orchard seedlots within a species and that seemed adequate for the longer range planning this factor is used for. With a renewed look at seed planning, orchard capacity and the move to Climate Based Seed Transfer (CBST) reporting, it seemed appropriate to review these seedling conversion factors for seed orchard seed. Jack Woods, Stephen Joyce, Kevin Astridge, Sabina Donnelly and Dave Kolotelo were tasked with this. Sabina Donnelly put together the datasets.

Methodology

Requested Seedlings and Seed Supplied

In SPAR, clients place seedling requests in terms of Requested Seedlings and the sowing guidelines calculate:

Grams required = (Number of seedlings requested × seeds supplied per seedling) / seeds per gram

Nurseries or the clients that will plant the seedlings can adjust the grams required in SPAR. Seed efficiency is strongly encouraged (only order what will be sown) and incentives or hard limits on seed quantities used by some clients. These gram adjustments are recalculated in SPAR to provide an estimate of Calculated Seedlings based on actual grams used, but seedlings requested remains the same. Most gram adjustments are reductions in seed use, but not all. The difference between Requested and Calculated seedlings due to gram adjustments (seed use efficiency) has resulted in savings of between 30 to 40 million seedlings worth of seed per year over the past decade.

The values in Table 1 represent figures used by the Forest Genetics Council (FGC) and seeds supplied per seedling based on calculated grams from seed orchard seed used in the 2016–2020 seedling production years. The calculated grams (after gram reductions) was multiplied by the seeds per gram for that specific seedlot, summed and then divided by the sum of requested seedlings by species and year to

Table 1. Seeds per seedling estimates for orchard produced seed: historic values and five-year averages based on seedlings requested for the entire program and seedlings lifted for the Ministry program. Recommended values for planning are presented. Yellow indicates recommendations adjusted based on the lifted seedling information.

Species (Code)	FGC Now	Seedlings Requested Basis (2016–2020)	Seedlings Lifted Basis (2015–2019)	% Lifted	Recommendation
Thuja plicata (CW)	3.00	2.61	3.10	84	2.85
Alnus rubra (AR)		2.22	2.28	97	2.22
Pseudotsuga menziesii var. *menziesii* (FDC)	1.90	2.01	2.34	86	2.20
Pseudotsuga menziesii var. *glauca* (FDI)	1.90	1.89	1.73	109	1.89
Tsuga heterophylla (HW)	2.22	2.31	2.23	104	2.31
Larix occidentalis (LW)	2.20	2.66	2.32	115	2.50
Pinus contorta (PLC)	1.50	1.58	1.56	101	1.58
Pinus monticola (PW)	2.50	2.54	2.60	98	2.54
Pinus ponderosa (PY)	1.80	2.39	1.62	148	2.00
Picea sitchensis (SS)	1.90	2.12	2.20	96	2.12
Picea engelmanii × *glauca* (Sx)	2.20	2.42	2.65	91	2.42

provide a representative estimate of seeds per seedling. This weighting by the number of requested seedlings provides a more realistic seeds per seedling estimate for the program compared to simply averaging the seedlots or seedling requests.

The advantage of this data is that it is easily reproduced from SPAR data queries and accounts for the entire seedling production program. It does assume that seed sent to the nursery is the actual amount sown to produce seedlings. Although the returned seed program is small, we never know exactly how much seed was sown to produce seedlings. This downside of this data set is that it does not reflect the actual number of seedlings produced, just the number requested.

Lifted Seedlings and Seed Supplied

For government requests, we have the advantage of being able access the number of lifted seedlings through a BC Timber Sales database. This represents actual seedlings obtained, so a much better estimate than requested seedlings, but it represents only about one third of the entire seedling production program. The seeds per seedling estimate based on seedlings lifted is presented in Table 1 with a % Lifted column with values >100% indicating overruns and values less than 100% indicating deficiencies relative to seedlings requested.

Discussion

Species specific seedling conversion factors are highly variable depending on seedlot quality, stock type, client, and nursery. The use of a variable that is weighted by seedlings requested is more reflective of the program than simply the seedling request average. The benefit of using requested vs. the lifted seedlings are that it reflects the entire reforestation program and is relatively easy to duplicate. It is considered an improvement on the former method of haggling over a realistic number that may not have provided a true provincial image. The limitation of using requested seedlings is that it reflects requested seedlings and not seedlings actually obtained at the nursery. The lifted seedling information is a very useful and informative dataset, but it is recognized though that Ministry practices (larger stock types, provision of incentives for seed efficiency, and more rigid seedling specifications) may not be reflective of the entire seedling production program. The calculation of both estimates assumes the amount of seed sent to the nursery was the amount sown.

In consideration of all of the information available our committee recommended to use the seed per seedlings values calculated based on seedlings requests with a few adjustments (Table 1). There appears to be greater efficiency in producing Pinus ponderosa (PY) seedlings than the seedling requested results indicate and we recommend adjusting the seedling conversion factor to 2.00. Seed orchard seed has only recently been available with this species. Larix occidentalis (LW) also shows greater efficiencies and we have adjusted the factor to 2.5. There are concerns with under-run production in Thuja plicata (CW) and Pseudotsuga menziesii var. menziesii (FDC) and we have adjusted the seedling conversion factors to 2.85 and 2.20 respectively. The FDC issue is likely due to significant root rot losses that nurseries have experienced. The reason for the CW underruns is not as clear.

Recommendations

The group recommended using the seeds per seedling estimates based on the weighted average of requested seedlings for a rolling five -year term (2016–2020 used here). The estimates for CW, FDC, LW and PY have been adjusted based on the lifted seedling information. We recommend that this variable be updated on an annual basis.

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2021 Forest Genetics: Student and Postdoc Symposium

On May 19–20, 2021, the Canadian Forest Genetics Association (CFGA) and Western Forest Genetics Association (WFGA) co-hosted its first virtual conference due to the COVID-19 pandemic.

The 2021 Forest Genetics Symposium showcased the research of forest genetics students and post-docs–our next generation. Generous sponsorships afforded us the opportunity enlist professional conference services and offer additional prizes. 220 people participated from around the world.

Over 80 submissions were received in response to the Call for Abstracts. T25 oral presentations, consisting of 10-minute pre-recorded videos, were selected and grouped into 10 sessions. A live Q&A forum followed each session. Most of the 55 posters were also accompanied by short pre-recorded videos. Two poster sessions allowed participants to pose their questions in real time. Attendees could view all the oral and poster presentations at any time immediately prior to, during and after the conference.

A panel of 23 judges, led by Dave Kolotelo, evaluated the presentations. Not any easy task with so much talent on offer. Table 1 summarizes prizes awarded to the top student and postdoc presentations.

Keynote speakers Dr. Nathalie Isabel, Natural Resources Canada, and Dr. Patrick Von Aderkas, University of Victoria, respectively opened and closed the Symposium with words of wisdom.

A Career Panel featuring Dr. Marcus Warwell, Dr. Raju Soolanayakanahally, Dr. Jill Hamilton, and Greg Adams, also served to inspire all with their stories, insights and advise. Several breakout sessions allowed participants to discuss relevant topics and network in smaller groups. The full proceedings are now posted here: https://cfga-acgf.com/wp-content/uploads/2021/07/CFGA-WFGA-Forest-Genetics-Student-Symposium-Proceedings-July-2021.pdf. A Vimeo showcase is still available for viewing here: https://vimeo.com/showcase/8561936

This successful event would not have been possible without the support from our sponsors and dozens of volunteers, including scientific and career panel members, Q&A moderators, breakout session leads, and judges. Thank you very much for your support and contributions. Thank you especially to all the students and postdocs who submitted posters and oral presentations.

As Dave outlined in his Armchair, the CFGA and WFGA are planning to co-host an in-person meeting in BC's Okanagan Valley during in summer 2022, possibly in conjunction with a tree seed workshop and a meeting of the BC Seed Orchard Association. Further information will be provided in the next TSWG Bulletin.

2021 Forest Genetics Co-chairs
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CFGA-ACGF
Canadian Forest Genetics Association
l'Association canadienne de génétique forestière

WFGA
Western Forest Genetics Association

Table 1. Award winners presented at the conclusion of the 2021 Forest Genetics Student and Postdoc Symposium.

Award	Winner	Title	University / Affiliation
WFGA Critchfield Award			
Best Student Poster: $300 USD	Kaylee Rosenberger	Creating practical sampling guidelines for endangered IUCN Red List Oak species through simulation	Northern Illinois University / Morton Arboretum
Runner-up Student Poster: $150 USD	Aaron Onufrak	Variation in Juglans nigra phytobiome driven by geographic and host genotypic variation has implications on Thousand Cankers Disease severity	University of Tennessee
Best Student Oral Presentation: $700 USD	Francois Du Toit	Use of Remote Sensing Technology for Phenotyping in Tree Improvement Programs in British Columbia, Canada	University of British Columbia
Runner-up Student Oral Presentation: $350 USD	Eddie Lauer	Broad-spectrum resistance genes in the co-evolved fusiform rust-Pinus taeda pathosystem	North Carolina State University
CFGA Gene Namkoong Award			
Best Student Poster: $500 CDN	Lorinda Bullington	Above and below-ground fungal symbionts alter tree defenses, with potential consequences on resistance to fungal pathogens and disease	University of Montana / MPG Ranch
Runner-up Student Poster: $250 CDN	Bronwyn Moore	Economic return of planting improved coastal Douglas-fir at four initial planting densities	University of BC / Natural Resources Canada
CFGA Carl Heimburger Award			
Best Student Oral Presentation: $1000 CDN	Susan Mcevoy	Genomic characterization of two maples highlights genes involved in the stress response to acidic soils across seasons	University of Connecticut
Runner-up Student Oral Presentation: $500 CDN	Heather Dun	Sudden larch death – variation in host response to infection	University of Oxford
2021 Forest Genetics Postdoc Award			
Best Poster: $500 CDN	Sam Belton	GeneNet: mapping the genetics of Ireland's native forests in a European context	National Botanic Gardens, Dublin, Ireland
Best Oral Presentation: $1000 CDN	Antonio Castilla	Genetic rescue by distant trees mitigates qualitative pollen limitation imposed by fine-scale spatial genetic structure.	Michigan State University
Runner-up Oral Presentation: $500 CDN	Claire Depardieu	Integrating dendroecology and genomics approaches to identify genes underlying drought adaptation in white spruce	Laval University
2021 Forest Genetics Genome BC Award			
Best Student Genomics Poster: $300 CDN	Cynthia Webster	Comparative Transcriptomic Analysis of Juvenile and Adult Leaf Morphologies in Conifers	University of Connecticut

ISSS 2021 & Call for Abstracts

The International Seed Science Society (ISSS) hosted their 13th Triennial Meeting virtually, August 9–13, 2021, titled "Seed Innovations for the 21st Century". Plenary speakers included Prof. Richard Ellis, Prof. Françoise Corbineau, Prof. Gerhard Leubner, and Dr. Guillaume Née. Themed sessions and invited abstracts covered:

- Seed memory: how environment influences traits during development
- Seed lifespan: the science of maximizing survival
- Seed innovation systems for the 21st century (local to global)
- Seed form and function: the morphology of success
- Seed germination and stress: niches and coping strategies

As per conference emails, "The natural traits of the wild relatives of the world's main crops make them potential sources of genes and adaptive traits for agriculture. Beyond this narrow focus, other species offer exciting possibilities for new medicines, fibre plants and other uses. [...], can the seed supply chain meet the projected long-term sustainable use?".

Frank Lanfermeijer (Senior Scientist, Physiology, Bejo Zaden, Netherlands) and I were invited to present during the August 12th workshop on "Innovations for the Seed Industry" to generate priority research agenda items for ISSS members. Dr. Hugh Pritchard moderated and broadly considered 'innovation' any tool that addresses challenges in delivering benefits from wild seed diversity or advancing existing agronomic crops. I was asked, "Is training all that is needed to enhance the native seed supply industry?". Frank, Dave Kolotelo and our 2019–2020 TSWG Membership survey provided support for our perspective and why we are not in a position to adopt advanced seed phenotyping (yet): seed collector shortages, loss and reductions in critical seed testing and storage facilities, and difficulties in wild seed standardization (echoed in Dave's recent IUFRO video here).

I recognized a long list of Canadian and global organizations that have been foundational in building forestry and native seed supply, but needing fresh innovation themselves in core funding and outreach. My three 'innovative' ideas proposed were:

1. What makes 'seedy-people' stick with it? Studies into successful mentorship styles and STEM-predictive personalities at an early age may help our cause.
2. What has COVID taught us about hybrid and virtual training? While there is irreplaceable benefits to 'hands-on' work, I believe accessibility, cost/time-savings and majority of users with smart phone capacity offer real-time decision-making support for wild crop diversity across vast distances and in the field (text-a-pic!).
3. Drones and labour-saving automations: promise of but need to continually evaluate establishment efficacy where seed supply is not stabilized or increasing.

Hugh's question to Frank as "How instructive is seed phenotyping (artificial intelligence, machine learning, germination characteristics, etc)? Frank bridged my topic, comparing ecological seed quality to industrial seed quality, but ultimately, it is easier to develop or utilize advanced phenotyping tools on uniform crops or stabilized cultivars.

Dr. Richard Ellis and Dr. Shelagh McCarten also gave interesting presentations; Richard reviewed his career trajectory thanks to key mentorship opportunities and discoveries on fundamental seed lifespan factors, and Shelagh demonstrated new X-ray image analysis training with R on *Abies* spp. from the UK Forestry Commission. This is timely as several North American seed conservation centers recently have or are in the process of upgrading their X-ray systems. I intend to follow up with all three of the above presenters in the near future for TSWG-related material. Thank you to ISSS for a very fruitful conference!

Call for Abstracts Extended: December 31, 2021

A Special Issue of Seed Science Research will feature invited papers from the conference, but additional submissions are welcome. Please see the original SSR Special Issue flyer here, or contact Dr. Louise Colville for more information: l.colville@kew.org.

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2021 Northern Forest Genetics Association Virtual Meeting

Editor's Note: I missed the opportunity to promote this event for Carrie in August, but attended to offer a small CFGA-TSWG update at the end of the second day. Being yet another informal working group whose membership strength has waned, the virtual format was especially accessible for Canadian participants this time.

The presentations covered recent activities from a diversity of long-standing forest genetics programs and new initiatives in the eastern half of the United States and Canada. All presentations were recorded and posted on RNGR.net website: https://RNGR.net/resources/webinars/2021-northern-forest-genetics-association-zoom-meeting. Individual presenters and topics noted again below for easy reference:

September 8, 2021

- Carolyn Pike (USDA Forest Service): Introduction to the Northern Forest Genetics Association
- Mark V. Coggeshall, Ryan Russell, Amy Byrne (The Genetic Conservation Consortium for Oaks (GCCO)): Case Study: A new gene conservation program for *Quercus acerifolia*, an endangered oak species in Arkansas
- Ron Zalesny (USFS Northern Research Station): Phytotechnologies Program Update
- Ron Revord (University of Missouri): Eastern Black Walnut Cultivar Improvement
- Rebekah Shupe (Purdue University): Digitization of Genetic Tree Improvement Trials
- Jennifer Koch (USFS Northern Research Station): Emerald Ash Borer Resistance Breeding: The Future of Ash
- Marcus Warwell (USDA Forest Service): Region 8 Genetic Resource Management Program
- Paul Bloese (Michigan State University): Lake States Genetics Updates: Michigan State University
- Andy David (University of Minnesota): Lake States Genetics Updates: University of Minnesota
- Stuart Seaborne (University of Wisconsin/WI DNR): Lake States Genetics Updates: University of Wisconsin / Wisconsin Department of Natural Resources
- Rachel Kappler (Holden Arboretum, Great Lakes Water Basin Forest Health Collaborative): Holden Forests & Gardens
- Donnie McPhee (CFS National Tree Seed Centre): Genetic Data of Today For the Challenges of Tomorrow

September 9, 2021

- Keith Woeste, Rich Cronn (USFS Northern Research Station): A New SNP Panel for Black Walnut
- Laura Leites (Penn State University): Reanalyzing Old Provenance Studies to Advance Ecological Genetics Knowledge of Temporal and Boreal Forest Trees
- Cornelia (Leila) Pinchot (USFS Northern Research Station): American Elm Resistance Breeding and Restoration Program
- Nick Labonte (USDA Forest Service): Region 9 National Forest System Genetics Update
- C. Dana Nelson (USFS Southern Research Station): Southern Research Station Program Update
- Laura DeWald (University of Kentucky): White Oak Genetics and Tree Improvement Project
- Ken Elliott (Ontario MNDMNRF): Online Tool Supporting Ontario Tree Seed Transfer Policy 2020
- Melissa Spearing (CFS National Tree Seed Centre): Canadian Forest Genetics Association Program Update
- Carolyn Pike (USDA Forest Service): Resistance Screening Updates: Black Ash, Butternut

Training & Meetings

AtlanTIC White Pine Weevil Management and Tree Improvement Workshop
November 3–4, 2021, Virtual
https://pheedloop.com/EVETBDGFERQOF/site/home/

Breeding and Genetic Resources of Pacific Northwest Conifers
November 8–10, 2021, Virtual
Registration ends: November 5, 2021
https://pnwconifers2021.sciencesconf.org/

Driftless Area Adaptive Silviculture for Climate Change (ASCC) Site
December 2, 9, 10, 2021, Virtual
Intended for managers and scientists in Iowa, Minnesota and Wisconsin to be part of the ASCC network.
https://forestadaptation.org/learn/DriftlessASCC

Seed Functional Ecology 2022
Short course by the University of Pavia, Italy
January 24–28, 2022, Virtual
Registration ends end of October 2021
http://seedschool.unipv.it/

BC Interior Technical Advisor Committee (ITAC) Extension Meeting
January 19, 2022, Virtual
https://register.gotowebinar.com/register/7813546759448547597

7th IUFRO International Workshop on the Genetics of Tree-Parasite Interactions in Forestry
September 12–17, 2022
Pontevedra, Galicia, Spain
Email Dr. Richard A. Sniezko for more information: richard.sniezko@usda.gov ; https://www.iufro.org/events/calendar/current/

Recent Publications

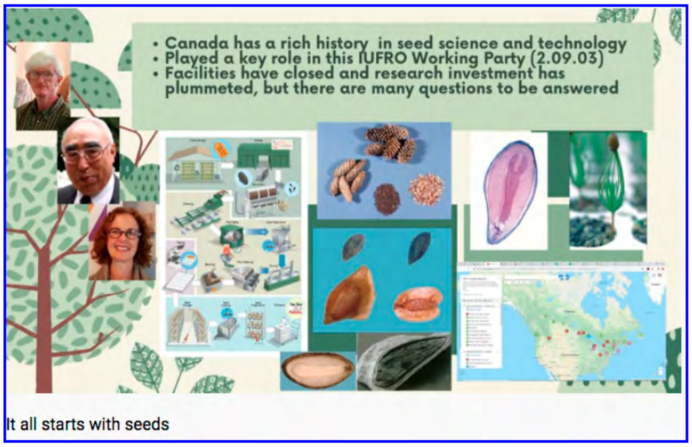
Recent Online Content

Canadian Food Inspection Agency, October 5, 2021. Hemlock Woolly Adelgid confirmed detection in Fort Erie, Ontario. https://www.canada.ca/en/food-inspection-agency/news/2021/10/hemlock-woolly-adelgid-confirmed-detection-in-fort-erie-ontario.html; updates to Infested Places Order: https://inspection.canada.ca/plant-health/invasive-species/insects/hemlock-woolly-adelgid/infested-place-order/eng/1591829961468/1591829961828

If you are on Facebook, the Group "Tree Propagation" has been incredibly active with seed collection posts, issues, tips and videos this summer. As of October 14, 2021, has 16,649 members worldwide, created January 13, 2020. https://www.facebook.com/groups/1592381707581200

@Treesfromseed is another Facebook page, run by retired forester Ray Major of Indiana, USA. He has demonstrates a number of forest regeneration techniques, including his "Iron Squirrel" for sowing large-seeded recalcitrant species. 6,487 followers, created September 2019. https://www.facebook.com/Treesfromseed

International Union of Forest Research Organizations World Day. September 28–29, 2021. Representing Unit 2.09.03, Seed Physiology and Technology, Dave Kototelo featured in "Its All Starts with Seed" below. https://www.youtube.com/watch?v=aay6WPJYBvo



- Canada has a rich history in seed science and technology
- Played a key role in this IUFRO Working Party (2.09.03)
- Facilities have closed and research investment has plummeted, but there are many questions to be answered

It all starts with seeds

2021 BC Forest Genetics Council eNewsletters and sign-up page: https://forestgeneticsbc.ca/home/news-and-events/

Forest and Conservation Nursery Technology Webinar Series. August 25, 2021. Approaches for Assisted Migration, presented by Carrie Pike and Vicky Erickson. https://vimeo.com/592390739

Forest and Conservation Nursery Technology Webinar Series. September 8, 2021. Turning Valves on the Reforestation Pipeline, presented by Kas Dumroese and Diana Haase. https://vimeo.com/600589808

International Seed Testing Association. June 21, 2021. ISSS–ISTA Seminar on Fundamental and Applied Aspects of Seeds, presenters Dr. Steve Jones, Prof. Henk Hilhorst, Dr. Manuala Nagel, and Dr. Christina Walters. https://www.seedtest.org/en/isss-ista-webinars-_content---1--3529.html

36th Southern Forest Tree Improvement Virtual Conference "Overcoming Tree Improvement Bottlenecks with New Technologies", June 7–9, 2021. On-Demand Webinars require a passcode: https://forestrywebinars.net/webinars/sftic-2021-session3

Peer-Reviewed Publications

Abeli, T., Albani Rocchetti, G., Barina, Z., Bazos, I., Draper, D., Grillas, P., Iriondo, J.M., Laguna, E., Moreno-Saiz, J.C., and Bartolucci, F. 2021. Seventeen "extinct" plant species back to conservation attention in Europe. Nature Plants 7(3): 282–286. Nature Research. doi:10.1038/S41477-021-00878-1.

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