Tree Seed Working Group
News Bulletin

Canadian Forest Genetics Association
l'Association canadienne de génétique forestière

66
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Featured in this Issue:

Banner photo shows seed sampling and purity analysis work being performed at the Ontario Tree Seed Plant in 1947. Archival photo from the Ontario Ministry of Natural Resources and Forestry.

Armchair Report #66

Hello, I hope everyone had a relaxing break and all the best to everyone in 2018.

I thought I'd cover the heavier materials up front. The last News Bulletin came out shortly after the passing of Ben Wang and a more appropriate celebration is provided in this issue by Dale and Steve in their memorial article. If there was a Mt. Rushmore of Canadian seed scientists and practitioners, Ben is certainly deserving of a spot on the rock. In the last issue, Michael Carlson's battle with ALS was also discussed and I am saddened to inform anyone who hasn't already heard that Michael passed away on September 25, 2017 surrounded by family and friends. The ALS Society certainly helped make Michael's last months as comfortable as possible and as part of a "Thank You", Michael and friends participated in the ALS walk raising $1,675 for the society (see photo on page 2). It is hard to describe the incredible impact that Michael had, not just in forest genetics, but silviculture, ecology, genetic conservation, respect for British Columbia's broadleaved species (quite the challenge), and just about anything related to forests. Here is a link to the slide show presented at Michael's Celebration of Life. Thank you to Ward Strong for putting it together. Although Michael's passing was not a surprise it was still very hard on family, friends and colleagues. He will certainly be missed but not forgotten; everyone who knew him has a special Michael Carlson memory.

For our small and specialized community of practice it is difficult for many to comprehend the closing of a provincial tree seed plant. The Ontario Tree Seed Plant in Angus, which has operated since 1923, is scheduled to close in September 2018. Every province is unique and has its own legislation and regulations to guide its mandate, but maintaining an interest in provincial reforestation seems like a basic and cost effective means of increasing the value of the provincial

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

All issues of the News Bulletin are freely available here.

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

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

Michael Carlson and friends partake in a fundraising walk for the ALS Society.

forest estate and resulting in a wide range of economic and ecological spin-off benefits.

Moving to more of a celebratory tone there are some significant retirements that have or are about to occur. Heather Rooke, Manager of the British Columbia Tree Seed Centre (TSC) will be retiring on January 31, 2018 after 43 years of service to the forests of BC (41 with the TSC). Everyone here is talking about the big shoes to fill and that is an understatement. Heather has been an extremely passionate advocate for the TSC and ahead of her time in seeking appropriate job classifications for her staff, developing a 2009 succession strategy (way ahead of others), commissioning a facilities condition report and being a true leader for the Tree Seed Centre. Heather is a great manager who has a good understanding of seed biology, the balance between stewardship and business, human resource management and the wisdom to seek first to understand. I wish Heather a happy and well deserved retirement from formal public service and suspect society will continue to benefit from her contributions. Personally I will miss our discussions, opportunities for me to learn from you, and your passion for seed science and technology.

Another significant retirement is that of Michael Peterson, who identifies as being retired and slowly weaning himself away from work. Michael has been performing our standard seed fungal assays for 25 years as well as helping investigate other pathogen/sanitation issues. Michael has also been actively involved in seed extension efforts helping with workshops and production of the *Seed Handling Guidebook*. Other retirements on the horizon include Dave Trotter who has helped guide the provincial reforestation program in several divergent areas such as Integrated Pest Management, a pesticide applicator instructor, extension, research, and in his current role as an agroforestry specialist. Barry Jaquish who has guided our interior spruce, interior Douglas-fir and western larch breeding programs will also be retiring soon. Rumour has it that Barry will stay on in an Emeritus status for the foreseeable future.

A significant recent retirement from the USDA is Bob Karrfalt. Some of Bob's career highlights include being Director of the National Seed Laboratory, co-editing *The Woody Plant Seed Manual* (2008), and contributing practical knowledge and expertise to seed science and technology in the United States and abroad. I wish Bob the very best in retirement on his woodlot in upstate New York.

The deadline to contribute comments on the Federal 'Recovery Strategy for the Whitebark Pine (*Pinus albicaulis*) in Canada' closed on December 17, 2017. Hopefully a final document will be forthcoming and the respective provinces can ramp up efforts for recovery of this endangered species. There have been some murmurs of above average whitebark pine cone crops next year, so if you are aware of crops, please bring them to the attention of your respective jurisdiction.

Last, but not least 2018 will be the 60th Anniversary of the British Columbia Tree Seed Centre. We plan to celebrate and tentatively are looking at having a technical meeting and open house during National Forest Week in September. More details will be available in the summer edition.

Dave Kolotelo
TSWG Chairperson

Editor's Notes

Happy New Year to everyone. Though this is technically the December 2017 issue and I received many articles well in advance of the deadline–thank you–it was held off for the holidays to include many trial results from the BC Tree Seed Centre. After Dale Simpson and Steve D'Eon's memoriam about Ben Wang, I think it fitting to follow in Ben's memory with the kind of detailed seed quality and dormancy research he spent his career on. He was proud of this group and I am still honoured to help deliver the Bulletin. I had a chance to read Ben's last publication "Seeds of the Economically Important Trees of Taiwan" (2016), which includes this wonderful quote:

A seed is an end and a beginning; it is the bearer of the essentials of inheritance; it symbolizes multiplication and dispersal, continuation and innovation, survival, renewal and birth. (Heydecker 1972)

The last six months in Ontario has felt very much like an end and a beginning. We have inherited the genetic, ecological and economic rewards of Ontario's successful reforestation programs that began in the 1920s. Seed production capacity was a long, steady climb but inevitably, valleys follow peaks. The Ontario Tree Seed Plant would've been celebrating its 95th anniversary this year, an elder in this community of practice. The rationale for its end is provided in this issue. The new beginning–a collaborative rebirth of an effective seed planning and genetic conservation system for Ontario's forest industry and rich biodiversity–is in the works and will be designed by dedicated professionals for the challenges of the next 95 years. We can't afford not to.

In the face of climate change and impacts on forest health and productivity, there is continuing momentum in seed transfer science and policy across Canada and US. Jodie Krakowski notes changes in Alberta's standards and an article by Dr. Carrie Pike of the US Forest Service indicates movement and awareness in the Eastern US as well. Dr. Sean Hoban from the Morton Arboretum highlights a wide range genetic conservation research as a follow-up to Issue 65.

On a forestry-in-other-places note, I had the opportunity to hike Torres del Paine National Park in the Magallanes region of Chile over the holidays, a once-in-a-lifetime experience. For all its beauty though, I was struck by the impact of ±45,000 hectares of man-made forest fires around Lake Pehoé. Only three species of tree (*Nothofagus* spp., southern beech) grow in the region, and obviously none respond well to fire. Old-growth beech forest is critical habitat for several endangered and endemic species as well. I asked a park ranger if they intended to replant for habitat and aesthetics but he said nursery production and labour was quite limited. In scouring Researchgate papers, I also learned it may also be an issue of low seed quality (Ben's words ringing in my ears) and enough local seed collected for hardiness to the Torres climate. But several groups are working on it; this is their seed capacity beginning. If anyone knows about Chilean forestry, I'd be interested to learn more.

Reference

Heydecker W. 1972. Seed ecology. In: Heydecker W, editor. *Seed Ecology*. University Park USA and London: The Pennsylvania State University Press. p. 1-3.

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In Memoriam: Ben Wang

Benjamin Shin-Phin Wang was not a tall man but he was a giant in the world of tree seed. He was born in Huang County, Shandong Province, China in 1928 and passed away in Pembroke, Ontario on July 21, 2017 at the age of 89.

Ben received his BScF from the University of Taiwan in 1952. He immigrated to Canada in 1955 and attended the University of British Columbia graduating with a MScF in 1960. His thesis was on the germination of *Abies grandis* seed. He started his forestry career with the Canada Department of Forestry and Rural Development in Maple, Ontario and transferred to the former Petawawa Forest Experiment Station in 1966 to develop the Tree Seed Unit. It was here that he fulfilled his career dream of working with tree seed. After retiring for the first time in 1994 Ben was granted Scientist Emeritus status at the Petawawa Research Forest in 1996 which he held until April 2017.

Amongst his many Canadian accomplishments Ben established the National Tree Seed Centre which to this day provides high quality tree seed for researchers in Canada and abroad. He was instrumental in creating the Tree Seed Working Group of the Canadian Forest Genetics Association and the *Tree Seed News Bulletin*. Seed dormancy was his career research interest and he published many papers on the topic. During the course of his research he recognized that there was a need for a better container for germination testing tree seed. This lead to the development and production of the Petawawa Germination Box, which is used throughout Canada as well as internationally. He also developed laboratory germination criteria based on the development and vigor of germinants. He was one of the founders of the IUFRO Seed Problems Working Party in 1973. This Working Party continues to be active today under the name Seed Physiology and Technology.

Over his 50+ year career Ben became recognized as one of the world's leading experts on tree seed and was invited to many international conferences and events. He authored or co-authored over 75 scientific papers. His final achievement was as senior author of a book published in November 2016, "Seeds of the Economically Important Trees in Taiwan."

Internationally, Ben worked in Taiwan, Thailand, Northeast China, and elsewhere. He was a Life Member of the Ontario Professional Foresters Association and received many honours domestically and internationally.

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

More importantly Ben mentored young technicians, professionals, and scientists. His calm enthusiasm, patience, and caring nature has touched many in the forestry community improving how we collect, store, and germinate tree seed. Ben moved to a retirement home in autumn 2016 where he quickly had residents conducting germination tests for him. Ben passed away in July and his ashes were buried in a corner of the former nursery at the Petawawa Research Forest.

A true gentleman, family man, and kind hearted individual, Ben's influence will live on in those whom he collaborated with and learned from him.

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Moisture Content Monitoring of BC Seedling Requests (2013–2017)

The BC Tree Seed Centre has a long history of monitoring seed moisture content (MC) during stratification. For most species, after the imbibition period, the seed is dried back to a surface dry status for stratification. This is the form preferred by nurseries for ease of sowing while also reducing potential for fungal growth. This maximization of internal moisture and removal of surface moisture can be a tricky balance to achieve. The presented data serves as a useful tool to help replicate stratification regimes that have shown to be effective in overcoming embryo dormancy and increasing germination rate in most of our tree species. The monitoring helps in quantifying species and seed origin (wild stand vs. seed orchard) differences that can be fine-tuned through the target moisture content concept.

Initial efforts with monitoring seed moisture at shipping utilized destructive tests which 'wasted' seed and were subject to a substantial sampling error. In moving to the concept of target moisture contents we were able to quantify stratification moisture content non-destructively knowing the storage moisture content and the fresh weight of the seed. This is based on an entire bag of seed, so one benefit is the increase in the quantity of seed 'sampled' and reduction in sampling error to quantify stratification moisture content. The calculations are simply a little bit of reorganization of the standard moisture content equation depending on which variable you are trying to calculate. All three formulas are reproduced below and these equations are very powerful Quality Assurance tools for cones or seeds (just remember to enter data in decimal, not % format).

(1) MC = (fresh wt. – oven-dry wt.) / (fresh wt.)

(2) Oven-dry weight = fresh wt. × (1 – MC)

(3) Fresh wt. = (oven-dry wt.) / (1 – MC)

The process is a two-step calculation that has been integrated into our operational systems at the Tree Seed Centre. For every seedling request (or every bag for multi-bag requests) we would know the fresh weight and the corresponding storage moisture content. The first step is calculating the oven-dry weight of that request using equation 2 above. Once we have that important variable (oven-dry weight) we can calculate moisture content at any weight (Equation 1) or the weight at any moisture content (Equation 3).

We generally look at many of our variables on a five-year running average which we feel is a good balance in providing a good sample size, but still staying relevant to current practices. The results in Table 1 provide the average moisture contents by species and origin, where applicable, in addition to the sample size and lower and upper 95% confidence limits which we use as an operational guide to gauge surface drying. In terms of Genetic Class, 'A' refers to seed orchard produced and 'B' refers to wild stand produced seedlots. There were 3,328 unique seedling requests monitored over the past five years either at surface drying or at shipping. If one looks at the upper and lower limits of the 95% confidence interval, note the relatively small range of moisture content this represents by species.

One of our interesting and consistent observations over time has been that in certain species the expected surface dry moisture level has been consistently lower for seed orchard vs. wild stand crops. For species like western hemlock (Hw) and Sitka spruce (SS) this difference has been large enough to justify soaking these species for an additional 4 hours and retaining some surface moisture at surface drying. The difference is also relatively large for interior spruce (Sx), but does not appear to impact germination. It would be interesting to see if other jurisdictions have similar observations with their seed orchard crops.

The relatively high moisture level in yellow cypress (Yc) is intentional as the species requires this high moisture status in cold stratification as well as an initial period of warm stratification to overcome embryo dormancy. For western white pine (Pw) we have introduced a delayed dryback after 7–14 days in cold stratification to achieve the desired 37% moisture content shown to enhance germination. We generally speak of 30% moisture content as being optimal for stratification as it fits with lodgepole pine (Pli) and interior spruce (Sx) accounting for about 75% of our reforestation program. Species do vary and a better understanding of each species' unique stratification moisture content preference increases the efficiency of cold stratification. I hope this information is helpful. I encourage others to implement similar Quality Assurance monitoring of stratification moisture content as it is a cheap and non-destructive method.

Table 1. The 2013–2017 average stratification moisture content, sample sizes, upper and lower 95% confidence limits for BC tree seeds by genetic class.

Species	Code	Genetic Class	# Seed Requests	Average MC%	Lower Limit	Upper Limit
Abies grandis	Bg	B	42	34.2	33.6	34.9
Pseudotsuga menziesii var. *menziesii*	Fdc	A	245	32.9	32.6	33.1
	Fdc	B	31	34.0	33.2	34.7
Pseudotsuga menziesii var. *glauca*	Fdi	A	147	32.9	32.6	33.2
	Fdi	B	223	34.0	33.7	34.3
Tsuga mertensiana	Hm	B	24	34.1	33.2	34.9
Tsuga hetetrophylla	Hw	A	55	27.6	27.0	28.1
	Hw	B	85	29.7	29.3	30.1
Larix occidentalis	Lw	A	290	35.8	35.6	36.0
	Lw	B	104	36.0	35.6	36.4
Pinus contorta var. *contorta*	Plc	B	11	28.9	27.4	30.4
Pinus contorta var. *latifolia*	Pli	A	236	29.9	29.7	30.2
	Pli	B	330	30.6	30.3	30.9
Pinus monticola	Pw	A	391	37.0	36.8	37.2
Pinus ponderosa	Py	A	10	28.3	26.7	29.9
	Py	B	204	28.5	28.2	28.8
Picea mariana	Sb	B	15	30.7	29.5	31.9
Picea sitchensis	SS	A	88	27.1	26.7	27.5
	SS	B	56	28.9	28.4	29.4
Picea glauca/engelmannii and hybrid complexes	Sx	A	486	27.6	27.4	27.8
	Sx	B	107	30.7	30.3	31.1
Picea × lutzii	SxS	B	39	30.5	29.9	31.2
Callitropsis nootkatensis	Yc	B	109	45.3	44.9	45.7
Total			3328			

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Whitebark Pine Seed Stratification Trial

A trial was initiated to improve the method used to operationally pre-treatment and break the deep and complicated dormancy in whitebark pine (*Pinus albicaulis*). In the past we have used a 48-hour soak, 28 days of warm stratification (20 °C) and 84 days of cold stratification (2–5 °C).There has been significant work on this topic and those study findings have helped guide this trial in addition to our local experience with the species (Karrfalt 2016; Overton et al. 2016; Riley et al. 2016 and Robb 2014).

The seed of this species is expensive to obtain, but the desire was to perform a trial that sampled the BC geographic distribution of the species and utilized a reasonable quantity of seed to have confidence in the results. To minimize differences between treatments, due to within-seedlot genetic variation, the seeds used were from individual trees distributed throughout the BC range of whitebark pine (Table 1). Individual trees spanned the geographic range and also represented a wide climatic range in reference to mean annual temperature (MAT) and the frost free period (FFP)[1].

The seed sources were stratified using six different stratification regimes as described in Table 2. Treatment initiation was staggered to ensure all combinations completed stratification and initiated germination testing on the same day. The soak duration was extended from two to three days based on the work of Karrfalt (Karrfalt 2016). He actually recommends four days of imbibition to maximize moisture content, but after three days of soaking the weight gain was only about 5% for nine out of ten seedlots investigated and available moisture in the media would allow for imbibition to continue. The soak treatment was performed as a continuous flow running water soak to help reduce the quantity of any seed-borne contaminants. This is the standard soak procedure used for all tree species we stratify.

Table 1. The geographic coordinates, year of collection, mean annual temperature (MAT) and frost free period (FFP) for parent trees used in the stratification trial.

Source	Year	Latitude °	Longitude °	Elevation (m).	MAT (°C)	FFP (days)
Kid Price	2013	53.924	127.432	919	1.8	80
Mt. Puddingburn	2012	49.559	116.091	2229	–0.3	93
Mt. Baldy	2010	49.159	119.256	2125	0.0	66
Kappan Mt.	2013	52.262	125.473	1810	–0.6	42
McBride Peak	2010	53.337	120.127	1885	0.0	76
Mt. Sidney Williams	2007	54.914	125.434	1577	–1.1	62
Poison Mt.	2010	51.149	122.592	2048	–1.1	62
Kicking Horse	2010	51.280	117.073	2207	–1.3	65

Table 2. The durations of the six stratification treatment components.

Treatment	Soak (days)	Warm (20°C) (days)	Cold (2–5°C) (days)	Total (days)
1	3	28	84	115
2	3	28	112	143
3	3	56	84	143
4	3	70	98	171
5	3	56	112	171
6	3	56	140	199

[1]Climate variables derived from the ClimateBC program: http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateBC

The main variables investigated in this trial were the duration of warm and cold stratification to help determine the relative length of each and total treatment duration required to maximize germination in this deeply dormant species. For each seedlot×treatment combination a total of 200 seeds were treated (4 replicates of 50 seeds). With eight seed sources and six treatments the entire trial utilized a total of 9,600 seeds. The imbibed seeds were stratified in germination dishes on top of sand without additional sanitation (hydrogen peroxide or bleach) applied to the seed. During both warm and cold stratification seed was monitored for germination, fungal growth and drying of the dishes. Moisture was added to any germination dishes that appeared to dehydrate during the trial. Germinants were counted every Monday, Wednesday and Friday for four weeks. The germination criteria was that the radicle needed to be the length of the seed coast and this allowed germinants to be recovered and forwarded to several nurseries for seedling production. Abnormal germinants were counted separately and not included in the final germination capacity. At the completion of the 28-day germination test, seeds in which the seed coat had split from internal growth were recorded, but also not included in the germination capacity.

The trial did not consider the use of the fairly common practice of clipping the radicle end of the seed which appears to reduce the mechanical restraint of the seed coat to radicle emergence. This practice is very labour intensive, even with mechanical aids, and it is desirable to avoid this practice through further refinement of the stratification protocol.

Results

The results will be presented graphically in three forms: the overall treatment germination capacity, the average germination curve for each treatment and the average germination curves for each of the seed sources, followed by a review of statistical analysis performed. The six treatment results averaged over all eight seed sources are presented in Figure 1 with the grand mean of all seedlots and treatments being 43%. Not all seedlots followed the illustrated pattern, so all Seed Source×Treatment results averaged over the four replicates are presented in Table 3 with the treatment resulting in the highest germination highlighted in green. Table 3 also contains a quantification of seeds which displayed a splitting of the seed coat, which are considered viable, but radicle emergence did not occur

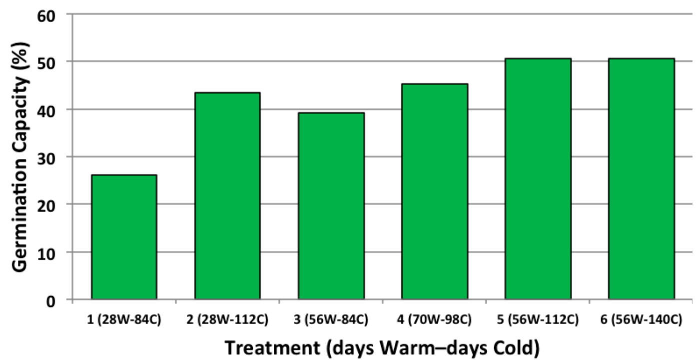

Figure 1. The average results of the six seed treatments across the eight seed sources. Numbers in bars represent total treatment duration in days.

Table 3. The average germination capacity (%) results of every Seed Source (S)×Treatment (T) combination, mean results and average percentages of split seeds and abnormal germinants.

Source	T1	T2	T3	T4	T5	T6	Seed Source Mean	Split Seeds	Abnormal Germinants
Kid Price	46.5	78.0	57.0	83.5	86.0	86.5	72.9	0.2	2.5
Mt. Puddingburn	34.0	65.5	63.5	84.5	85.0	89.5	70.3	0.9	0.6
Mt. Baldy	32.0	58.5	41.5	59.0	69.5	79.0	56.6	1.2	0.7
Kappan Mt.	23.5	45.5	42.5	52.0	55.5	57.0	46.0	5.4	0.1
McBride Peak	29.0	32.0	29.0	36.5	38.5	38.0	33.8	2.6	0.3
Mt. Sidney Williams	28.0	25.5	38.5	24.5	43.0	27.5	31.2	2.8	0.6
Poison Mt.	12.5	22.5	31.0	13.5	19.0	15.5	19.0	1.6	0.4
Kicking Horse	3.5	20.5	10.5	9.0	8.5	12.0	10.7	2.3	11.2
Treatment Mean	26.1	43.5	39.2	45.3	50.6	50.6			

within the test period and not included in the germination capacity. The proportion of abnormal germinants, which are not considered capable of producing seedlings, was relatively low for all seedlots with the exception of Kicking Horse which showed a very high proportion. These were primarily germinants in which radicle emergence was restricted through a 'looping' of the radicle within the seed (Fig. 2).

In Figure 3, which illustrates the same final germination as Figure 1, treatment results are presented as cumulative germination curves. Virtually all of the germination occurred within the first 14 days of the germination test and speed of germination was directly related to treatment duration. The average results have been displayed as it is desirable to recommend a standard pretreatment for the species, but seed quality varies tremendously between seedlots and some flexibility is warranted in this unique species. In Figure 4 the cumulative germination curves, averaged over all six treatments, indicate the seedlots used varied from an average germination capacity of 11% to 73%.

In terms of statistical analysis with Analysis of Variance, all factors (Seed Source, Treatment and S×T interaction) are statistically significant at the 95% confidence level. Looking at the proportion of variance attributed to each component clearly shows the importance of the seedlot differences with it accounting for 70% of the variation with the remaining variation allocated as follows: Treatment (11%); Seed Source×Treatment (10%) and Error (9%). The variation attributed to seed source is very large and to explore the relationship further the analysis was performed again by first removing the two poorest quality seedlots (52% germination for remaining six seedlots) and then the four poorest quality seedlots (61% germination for the four best seedlots). In both additional analyses all three terms (Seed Source, Treatment and the S×T interaction) were still statistically significant at the 95% confidence level. The proportion of variance did change with the top six seedlots the proportion of variance was as follows: Seed Source (52%); Treatment (22%); S×T (13%) and Error (13%). When only the top four seedlots were analyzed the effect of seed source continues to diminish and treatment is the most prominent source of variation: Seed Source (29%); Treatment (51%); S×T (5%) and error (15%).

Figure 2. An example of two seeds showing abnormal germination or 'looping' of the radicle with a normal germinant in the middle associated with the Kicking Horse seed source.

Discussion

In keeping with previous results, increases in the duration of cold stratification resulted in increased germination (compare results of treatments 1 vs. 2 and 3 vs. 5 in Figure 1). Extending the cold stratification period from 112 to 140 days seemed to have no impact on average germination, but did increase the germination rate (Fig. 3). There is an advantage to extending warm stratification from the current 28 days to 56 days (compare results of treatments 1 vs. 3 and 2 vs. 5 in Figure 1). The extension of warm stratification to 70 days in treatment 4 did not appear to benefit any seedlot. In comparing Treatments 4 and 5, which are both 171 days in length, the higher germination was obtained by extending cold stratification rather than extending warm stratification beyond 56 days. Seedlot differences were interesting with the four highest germinating seedlots performing best with the longest pretreatment (Treatment 6) and the two worst seedlots performing best with shorter pretreatments (Treatment 2 for Kicking Horse and Treatment 3 for Poison Mt.) (Table 2).

The seeds which displayed splitting, but no radicle emergence are potentially viable. For Kappan Mt., this represents an additional 5.4% germination and this seed source displayed continued increase in germination with increased stratification. It may be due to the very short frost free period (42 days) associated with this seed source and need for increased pretreatment duration to compensate. For abnormal germinants, the Kicking Horse source was an order of magnitude greater than the other sources and many had the atypical 'looping' presented in Figure 2. This is the

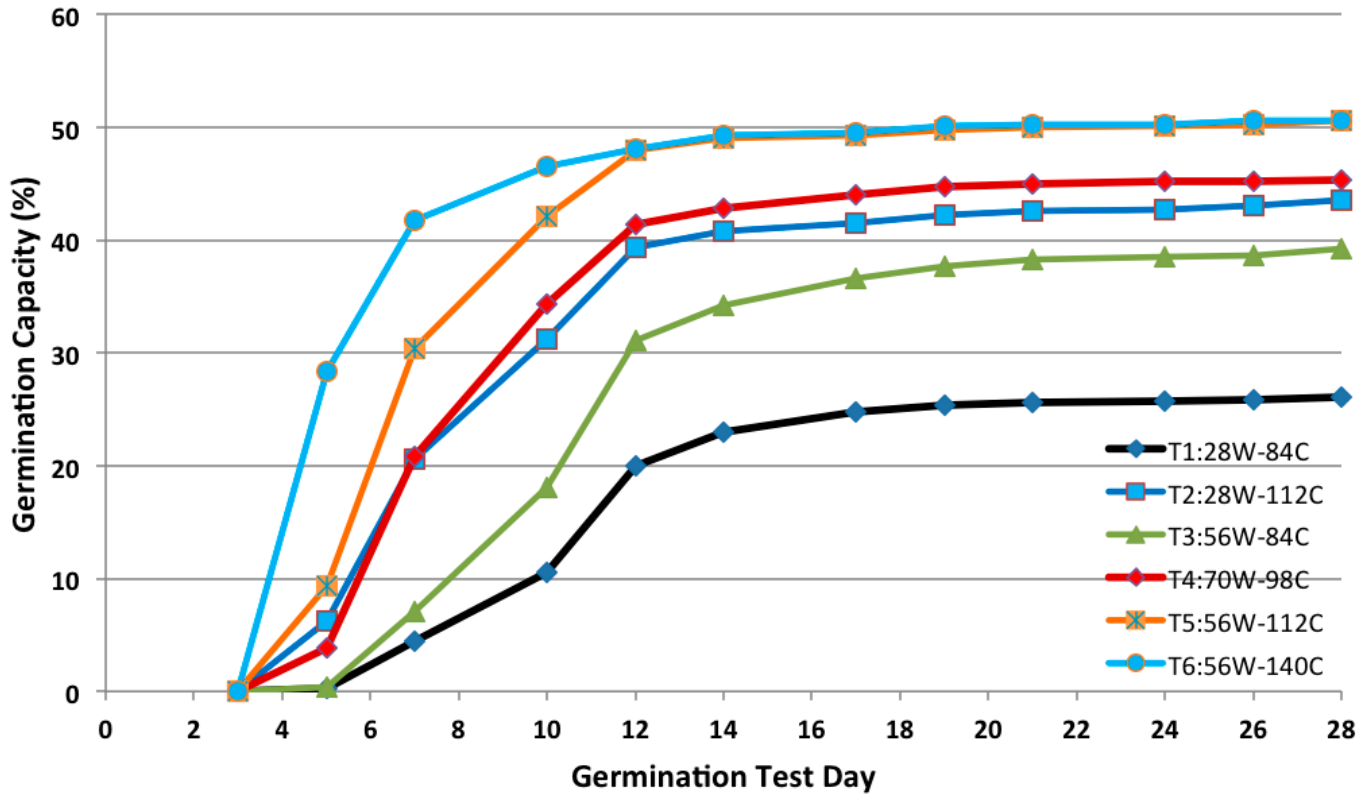

Figure 3. The average cumulative germination curves of the six seed treatments across the eight seed sources.

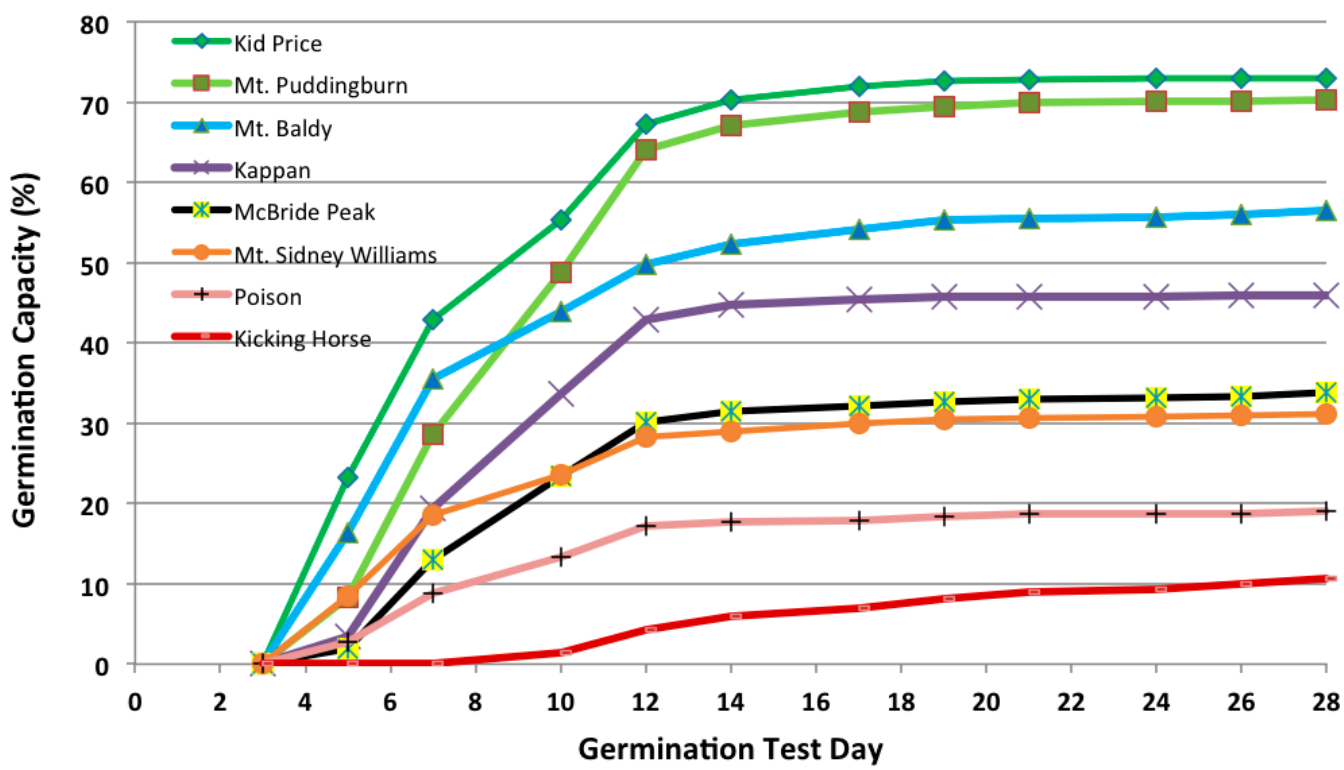

Figure 4. The cumulative germination curves for each seed source averaged across all six treatments.

site with the lowest Mean Annual Temperature (–1.3 °C) and embryo immaturity was evident, but not significantly less mature than some of the other collections.

Seedlot differences are very large and some of this variation can be attributed to seed dormancy and/or seed maturity, but I strongly feel that it is a primarily a function of the extent of seed processing applied. Some seedlots have simply had their seeds removed from the cones resulting in large proportions of empty seeds, while others had specific gravity separation applied to try and maximize viable seeds. Retaining all seeds can result in very low seedlot germination potentials and inefficient nursery production. Common in most seedlots is a large variation in embryo maturity resulting in a more continuous distribution of seed specific gravity. Efficient density separation is based on having a discreet density to separate upon, so one concern is that immature, but viable, seeds would be removed through specific gravity separation reducing the number of potential seedlings obtainable. The best approach would be to try and remove only totally empty seeds and retain immature seeds to increase nursery efficiency and seedling potential. This can be challenging with a gravity table and small seedlots, so this certainly is an area requiring improvement to help maximize seedlings available to aid in species recovery.

There was considerable fungal proliferation in some seedlots and the problem was highest in the McBride Peak and Poison Mt. seed sources (Fig. 5). I regretted not applying a hydrogen peroxide treatment prior to stratification as I expected the sand media to aid in this regard. The bottom line is that placing seeds on sand doesn't help decrease fungal loads, but placing seeds within a mass of sand seems quite effective at controlling fungal growth. The mechanism may simply be limiting spore transport or it may change the humidity immediately surrounding the seed. The experience of our facility and others is that pretreating seeds in loose mesh bags surrounded by sand is effective at controlling fungal growth and overcoming dormancy on larger quantities of seed (hundreds of grams). In future trials, I would try and more closely replicate the operational pretreatment by enclosing the seed replicates in mesh bags immersed in sand. Due to the value of the seed, germination testing is focused on understanding and improving operational procedures while seedlot quality is estimated via x-ray analysis in which the viable seed percentage is used to guide seed requirements.

Considering these and others trial results a standard stratification regime is being implemented and includes: a three-day running water soak; 56 days of warm stratification and 112 days of cold stratification. For very poor quality seedlots there may be an advantage to reducing the treatment duration based on the results of Kicking Horse and Poison

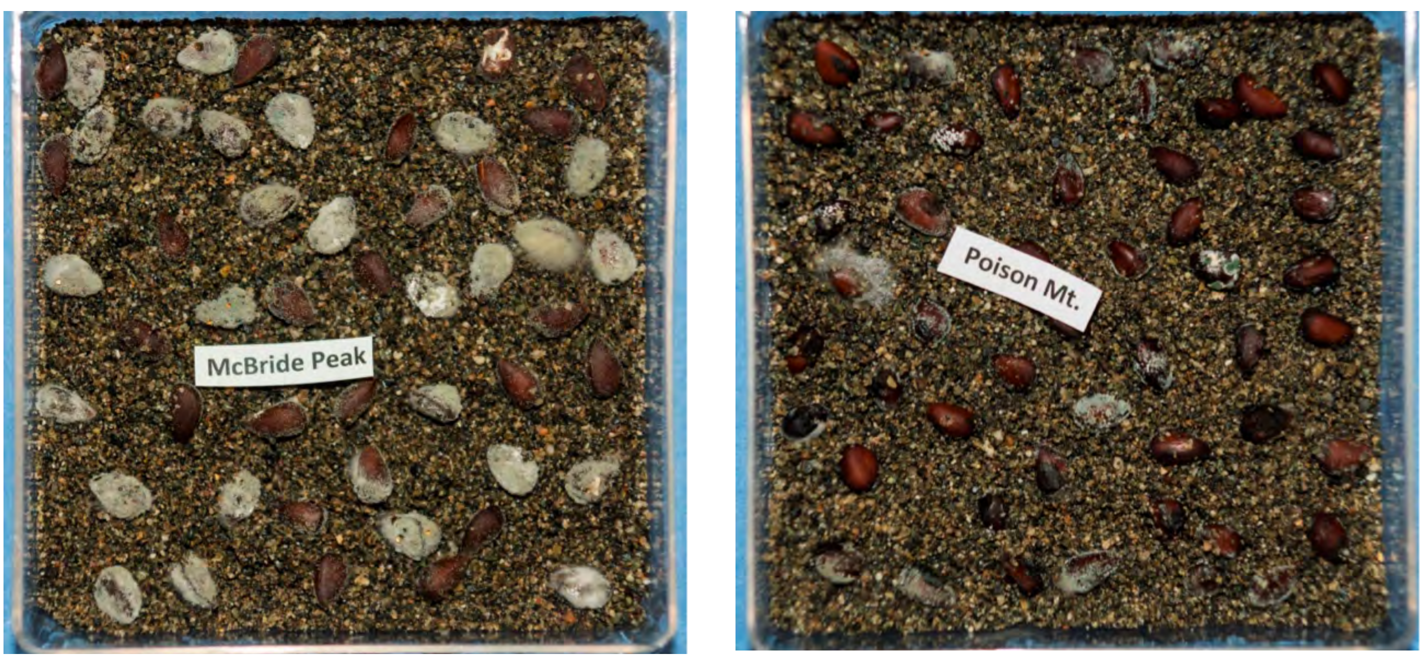

Figure 5. Examples of significant fungal buildup on the seeds during stratification for McBride Peak and Poison Mt.

Mt. Although even the shortest stratification treatment at 115 days is considered long in comparison to most conifers it results in just over half the germination that could be obtained with treatment 5 at 171 days. With the value of the seed it is very important to allocate six months for planning and pretreatment to maximize germination in this species.

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Alberta: Interim Genetic Resource Management Rules Approved for Whitebark Pine and Limber Pine

The (2016) Alberta Forest Genetic Resource Management and Conservation Standards[1] are the framework that genetic selection, collection, handling, registration, testing, and deployment must follow in the province's forests. They were developed based on attributes of commercial reforestation species. Because the unique biology, ecology, and genetics of whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) differ from most operational species, recovery plan goals for these endangered species could not be achieved under this regulatory framework without adjustments. After the following provisions were assessed for their scientific rationale, consistency with other forest policy and objectives, and risks and benefits to forest values, approval was granted under section 10.14 of the Standards.

The following provisions are in place for a 5-year period until the end of 2022, and will be reviewed to determine if any changes are needed in the future.

Species-Specific Seed Zones

Established for whitebark pine and limber pine based on health status, ecology, genotypic and adaptive studies:

- 1 seed zone for whitebark pine encompassing the entire Alberta range
- 2 zones for limber pine split at Highway 1
- A registered seedlot will have at least 10 unrelated, phenotypically selected and/or screened disease resistant and/or tolerant parents, with a long-term goal of three seedlots of 20 screened parents each per seedlot per species-specific seed zone; selected based on provincial protocols

Seed Transfer Limits

- Whitebark pine: +400/–300 m elevation, 3°N/2°S, 3E°/2°W, transfers outside Natural Subregion of origin permitted.
- Limber pine: +400/–300 m elevation, 3°N/2°S, 3E°/2°W, transfers outside Natural Subregion of origin permitted, with a north/south break at Hwy 1 (no transfer across zones).
- Transfer from outside Alberta as per above.

Please contact me for further information.

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[1]Climate variables derived from the ClimateBC program: http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateBC

Lodgepole Pine Filled Seeds Per Cone Statistics

Lodgepole pine (*Pinus contorta* var. *latifolia*) [Pli] cone crops provide an opportunity to document Filled Seeds per Cone (FSPC) at receipt since their cones are serotinous in nature. Other species produce cones which often open before receipt and therefore have FSPC averages that are difficult to estimate. Pli FSPC averages are calculated through cone and seed dissections performed on a random sample of cones after shipment arrival as part of our initial seedlot evaluation. Table 1 and the following and graphs represent 227 different seedlots from either Alberta (82) or BC (145) over the last five years from both seed orchards and natural stands. Sample sizes per seedlot ranged from 10 cones for the 2013 and 2014 data sets to as many as 30 cones for the subsequent years.

In Figure 1, the Alberta (AB) natural stand collections have a higher FSPC average over five years than the natural stand collections from BC. There was a statistically significant difference between the natural stand FSPC averages for AB and BC at the 95% confidence interval.

In Figure 2, BC natural stand collections had, on average, a FSPC average of almost double that of BC orchard collections. It should be noted that 2015 was a low year for FSPC values for both orchard and natural stand collections in BC. There was a statistically significant difference in the BC FSPC averages for orchard stand and natural stand collections at the 95% confidence interval.

Table 1. Provincial Interior Lodgepole Pine Filled Seeds per Cone averages for seedlots processed over 5 years.

Province	Cone Source	Sample size (n)	FSPC average
Alberta	Natural Stand	71	21.2
Alberta	Seed Orchard	11	20.5
British Columbia	Natural Stand	23	18.3
British Columbia	Seed Orchard	122	10.9

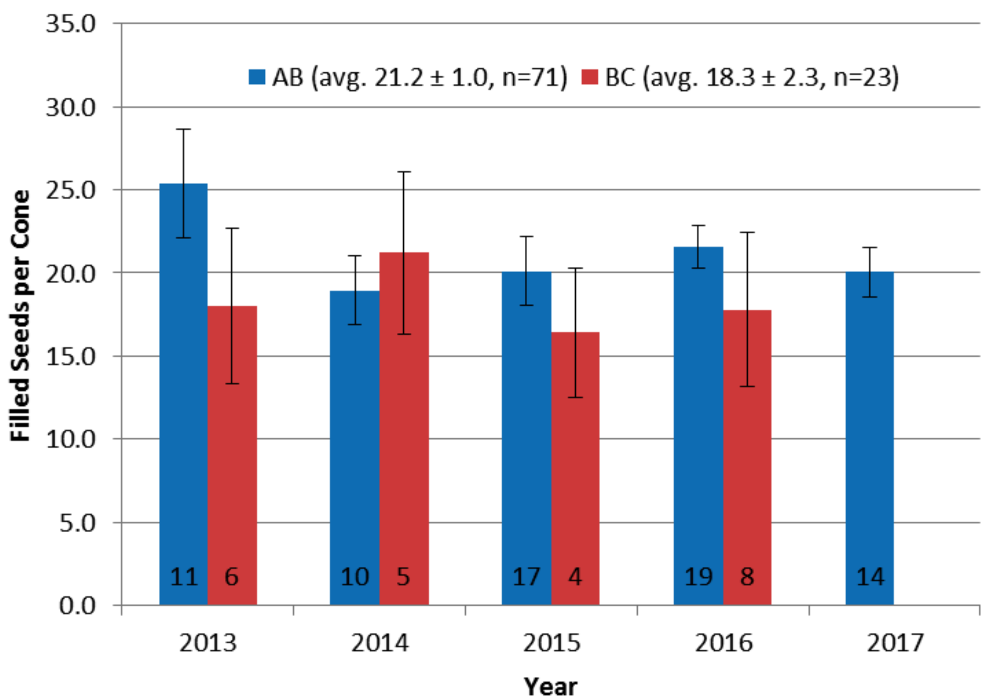

Figure 1. Provincial interior Lodgepole pine filled seeds per cone averages for natural stand seedlots processed over the past five years. Values on data bars in the graph represent sample sizes, and error bars represent the 95% confidence interval.

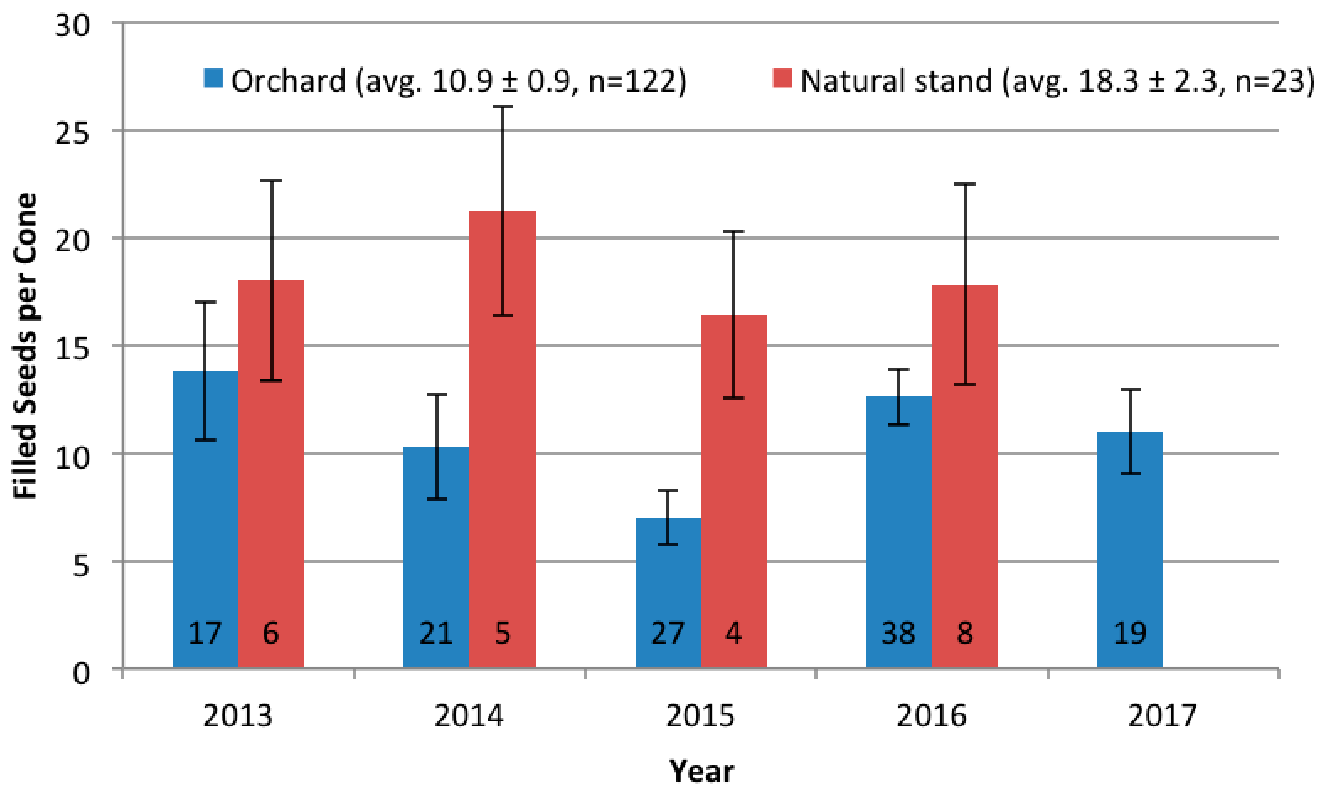

Figure 2. BC interior Lodgepole pine filled seed per cone averages from seed orchard and natural stand collections. All values on data bars in the graph represent sample sizes and all error bars represent the 95% confidence interval.

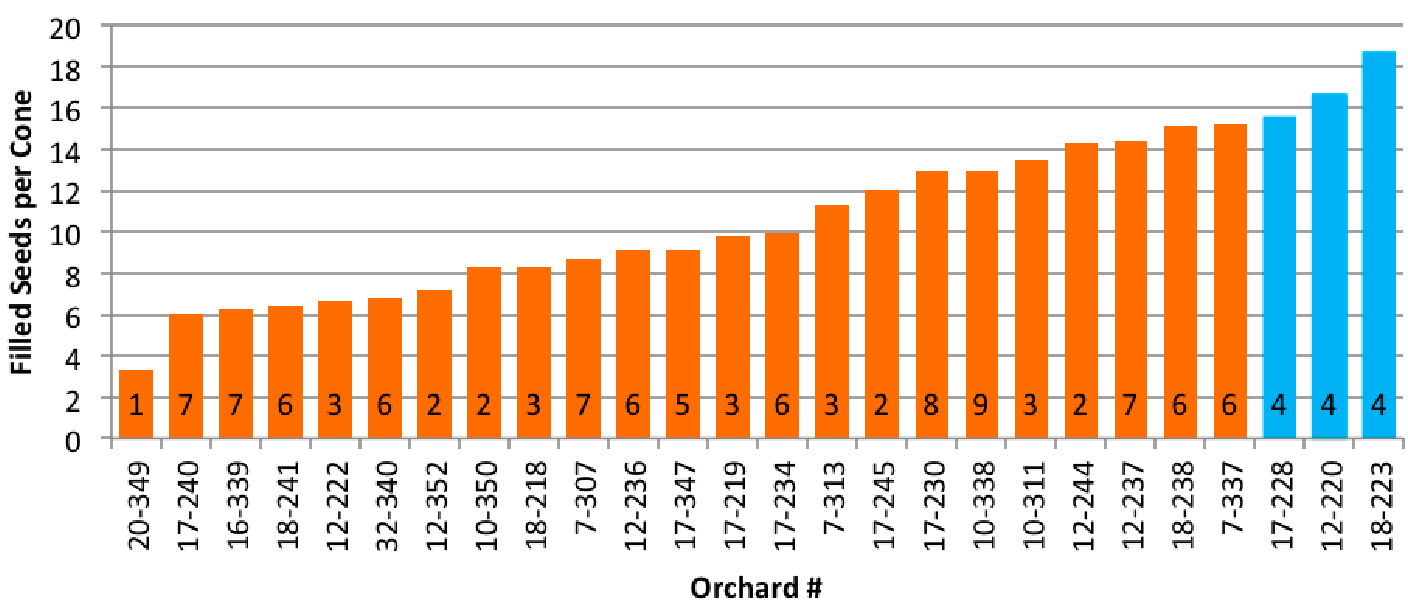

Figure 3. Five year Filled Seed per Cone averages for BC Interior Lodgepole Pine orchards. All data points have been labeled with their Seed Planning Unit (SPU) values and orchard number. All values on data bars in the graph represent sample sizes.

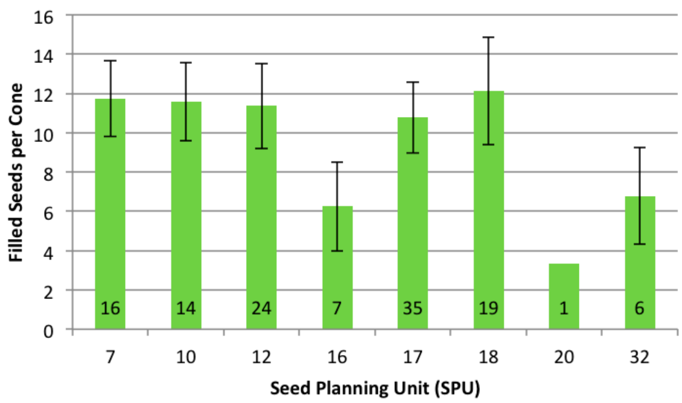

Figure 4. Average Filled Seed per Cone for each BC Seed Planning Unit. All values on data bars in the graph represent sample sizes and all error bars represent the 95% confidence interval.

In Figure 3, FSPC averages for BC seedlots processed over the last five years ranged from 3 to 19. All data points labeled in blue in this figure represent orchards in the Prince George area. Orchard 349 is a relatively new orchard with its first collection observed, while many other orchards are well established and in peak production. The young trees at orchard 349 will not have produced as many cones or as many seeds as the more mature orchards, such as 228 or 223. Orchard 223 has been the most prolific orchard in regards to its FSPC average, producing four filled seeds per cone more than the next most productive orchard, 220. These findings agree with previous works that highlight the difference between the Prince George seed orchard and the Kalamalka Seed Orchard (Owens 2006) . However, this article also points out that the Prince George orchard had low cone initiation and even lower cone survival compared to the Kalamalka orchard. Therefore, FSPC numbers are just one part of Interior Lodgepole Pine cone and seed production in BC.

In Figure 4, the Seed Planning Unit[1] area with the highest FSPC averages was #18 (Central Plateau Low, 700–1300m elevation) followed very closely by Seed Planning Unit area #7 (Nelson Low, 700–1600m elevation) and #10 (Thompson Okanagan area, 700–1400m elevation). There was certainly a high variability in the FSPC averages across the SPU values seen in Figure 4, although SPU 20 only has one, young orchard that just produced its first collection.

This initiative is intended to form a dataset to be used for further analysis and to maintain a five-year rolling average of FSPC for Interior Lodgepole Pine collections.

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National Tree Seed Centre Update

Where has the time gone, and has anyone seen Dale Simpson? It has been 10 months since Dale left the NTSC and not a day has gone with out a question coming to mind for him, yet we move on.

It has been an incredibly busy fall and winter here at the NTSC. Field trips to Cape Breton and Southern Ontario resulted in the addition of over 130 new seed lots from 26 different species. Going into the early fall we were hoping for a big ash collection year in Ontario and Quebec, but Mother Nature had different plans and we adapted. We are hoping that all the planning and collaborative efforts that laid this year between the NTSC and our partners–Invasive Species Centre of Ontario, Forest Gene Conservation Association of Ontario, Ministère des Forêts, de la Faune et des Parcs in Quebec, Kahnawà:ke Environment Protection Office in Quebec and Parks Canada–will be put to use in the coming years to fill the gaps in our Ash conservation collections.

We are extremely grateful for the help we received in making collections this year from the Mikmawey Forestry and Unama'ki Institute of Natural Resources in Nova Scotia and to the Guelph Arboretum and private seed collector Allison Thomson. We also received a surprise collection of black ash seed (30 seed lots) from Newfoundland.

[1]Seed Planning Unit (SPU): A combination of terms to include species, planning zone and elevation band. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/seed-planning-use/seed-planning-units-species-plans

The seed center is buzzing with activity as we wrap up the cleaning and storing process from these 2017 collections and are diving into our annual testing of seed lots that have been in storage for 10 years. Peter Moreland and I have been joined by three technicians (part-time) Sarah McLean, Katie Burgess and Roger Graves for the winter.

An exciting addition to the NTSC is our upcoming ability to monitor conditions in all our germinators and freezers via data loggers and an iPhone app.

All the best.

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Closure Notice for the MNRF Ontario Tree Seed Plant

August 23, 2017: We are advising you of business changes that we are undertaking with the Ontario Tree Seed Plant. As you may know, the Ontario Tree Seed Plant has provided an important service in processing and storing billions of seeds since it first opened in 1923. Our dedicated staff are widely respected for their expertise and the quality of product that they deliver.

As Ontario's forest renewal practices have evolved, processing demand at the plant has decreased significantly. As a result of this, Ontario will be phasing out our industrial processing plant and closing it between now and September 2018. MNRF will focus our efforts on a modern and efficient science-based native seed genetic archive, which will better support biodiversity and meet the needs of climate change science. Ontario will contract services from private suppliers to maintain its native seed genetic archive, in keeping with government policies.

This change is expected to open new opportunities for Ontario's nursery industry, who will now have a new opportunity to respond to market demand for native tree seeds from forestry companies, the public and government.

We have built time into our plan to support the transition of our clients and stakeholders, sell our inventory and relocate valuable genetic materials to the new archive. The location for the genetic archive is currently being reviewed and we will share more information with you when we know more.

Ontario will continue to work with all affected partners, such as Forests Ontario to support ongoing delivery of the 50 Million Tree Program (50MTP), to prevent any business disruptions during this change in services.

Managing and protecting our natural resources remains a priority for Regional Operations Division, and the Ministry of Natural Resources and Forestry as a whole. We look forward to assisting in transitioning with our clients and stakeholders as we move forward.

Supplementary: Anticipated savings from the closure of the plant include reduced operating and capital costs associated with a large-scale industrial facility.

The plant does not close until September 2018. The government will consider any internal needs it may have for the buildings, equipment or land before considering what to do with the buildings, equipment, and land.

For more information please contact:

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Modernizing Ontario's Seed Transfer Policy

The Ontario Ministry of Natural Resources and Forestry (MNRF) in cooperation with their partners ran an intensive two day workshop on August 30th and 31st at the Natural Resources Canada building in Sault Ste. Marie Ontario. This meeting of experts represented operations, as well as science and policy aspects of seed transfer from both inside and outside government and across the province. Guest participants included both Jean Beaulieu, retired Canadian Forestry Service (CFS) Scientist, from Quebec and USDA Forest Service Geneticist, Brad St. Clair, from Corvallis, Oregon. As well as our own well-known scientists Dan McKenney and John Pedlar from the CFS, Bill Parker from Lakehead University (Fig. 1), Pengxin Lu with MNRF and

Dennis Joyce (retired MNRF). Materials were presented and facilitated sessions were used to exchange ideas and obtain advice on potential direction for a new seed transfer policy that is better positioned to meet the needs of today and tomorrow.

The workshop also included a backdrop of the prior week's announcement of the Ontario Tree Seed Plant closure and the creation of a new Genetic Archive. Although this clearly weighed on many of the participants, they took this in stride and proceeded as valuable contributors throughout.

At any given workshop table a company forester may have been sitting next to nursery growers, government policy folks, geneticists and tree improvement experts. The diversity of participants matched the agenda which ranged from concepts such as zone versus point, climate change adaptation, breeding zones, and gene conservation. The facilitators used techniques varying from classic break-out flip chart sessions to 'clicker polls'. This along with adequate break time and an evening social dinner allowed the participants get to know each other and feel comfortable providing their unique advice.

Figure 1. Bill (William) Parker of Lakehead University (left) poses with Bill Parker of the Ontario Forest Research Institute (right) at the MNRF Seed Transfer Technical Workshop, August 30–31, 2017.

The participant identified goals for the policy included: providing clear seed transfer direction, which is scientifically based, reflects climate change, is provincially applicable and includes commitments to assisted migration. It was generally agreed that the current fixed zone approach for procurement and deployment does not meet these goals and that movement towards a focal point or focal zone approach may be more effective. Three optional scenarios were proposed: cautious enabling, conservative and aggressive. The advantages and disadvantages of these approaches were explored in break-out sessions and summary notes were collected. Each of the regional genetic resource management associations were provided with an opportunity to comment on the Ontario tree improvement program and provide a vision for the future. A large amount of information and ideas were collected including a running list of issues and questions.

Moving forward the MNRF has shared the results with the participants, is notifying Indigenous organizations, is exploring technical questions, and will be drafting a policy for posting on the Environmental Registry and for discussions at broader policy outreach sessions. This technical workshop served the important role of starting the project off on the right foot. The MNRF would like to thank all the participants and encourage them to stay engaged as the seed transfer policy moves ahead.

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The Eastern Seed Zone Forum: Developing Seed Zones for the Eastern Region of the US

The Seed Zone Conundrum

The genetic composition of the future forest is shaped by the species or seed sources planted through artificial reforestation. Geneticists are well-acquainted with the high level of adaptation that plants and trees possess to their local climate. The unprecedented rate of climate change will require the use of non-local seed sources for reforestation or restoration plantings (assisted migration) to increase growth and survival of trees in the future (Erickson et al 2014; Williams and Dumroese). The need for genetically appropriate plant material is further enhanced by stresses from exotic invasive species, and secondary effects that climate change imparts in the form of increased herbivory from deer herds of unprecedented size. Land managers tasked with increasing resiliency of ecosystems under their care need an array of options, including access to novel seed sources, for their plantings to be successful in the long-term.

Traditionally, seed zones were surrogates for seed transfer guidelines, so that seed or seedlings were planted into the seed zone from which seed was collected. At its core, however, *seed zones are the smallest unit to define locality*, and may not be optimal surrogates for seed transfer in the future. In the Eastern region, seed zone development has been hampered by fear that seed zones would be too diminutive for nurseries (public and private) to adopt and implement. In addition, the science of seed transfer is still in its infancy: range-wide provenance trials installed in the 1960s and 70s to address regionally-specific questions about seed transfer sampled the landscape too coarsely to be applicable at local scales. Funds to support new regional provenance trials, to answer questions about seed transfer at a state or regional level, are scarce. The forest geneticists who designed, installed, and analyzed these landmark studies are increasingly rare, a casualty of attrition-related downsizing across agencies and companies. Efforts to develop regionally-applicable seed zones have been hindered by the dearth of science to support their use as surrogates for seed transfer, with few funds to advance the science. Herein lies the seed zone conundrum.

The Eastern Landscape

The US has an estimated 766 million acres of forest land (Oswalt and Smith 2014), 81% of which resides in the Eastern region. The Eastern region is broadly defined as 33 states that are largely east of the Mississippi River. Between the Southern Region (13 states), and the Northeastern Area (20 states), the USDA Forest Service manages 52 different National Forests occupying more than 24 million acres (9.7 million hectares) of land (Fig. 1). Other public landholdings are managed by State, county or municipal governments, but roughly half of all the eastern forests are held in private ownerships (Butler et al. 2016; Oswalt and Smith 2014).

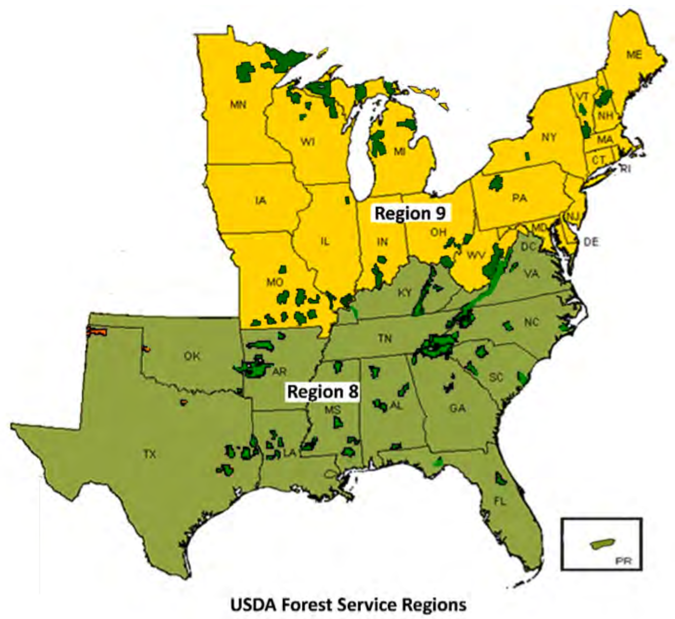

Figure 1. Eastern region of the US, consisting of the Northeastern Area (Region 9) and Southern Region (Region 8) of the USDA Forest Service. National Forests are drawn within each region.

The Eastern Seed Zone Forum

We recognize the importance of developing seed zones that are universally adopted, not just for use by the Forest Service. To achieve this goal, we are using an inclusive, rather than a regulatory, approach. Engaging such a diverse group of land managers, and nurseries/companies is challenging at best. We developed a website hosted by the Southern Regional Extension Forestry office (SREF) to facilitate collaboration among non-Forest Service partners and to serve as a landing page for the effort. http://easternseedzones.com/

Our hope is that this effort will be acceptable to the diverse set of nurseries, managers, and federal agencies who manage land in the Eastern region. We are asking for future users to participate in every step of the process. For starters, we are asking for help to develop a lexicon for seed zones to define the geographic origin of seed, and develop clear guidelines for labeling. Instead of developing new seed zones from scratch, each team will start with the Provisional Seed Zones (PSZ), developed by colleagues in the western US (Bower et al 2014). The PSZ were developed using winter minimum temperatures and aridity, and include the Omerick Level III ecoregions to separate distinct ecological zones. The seed zones might serve as transfer zones for trees and plants that lack other transfer guidelines, but some plant species may be exempt because of rarity or demonstrated resiliency to seed transfer (ie.,'workhorse' plants used along roadsides).

For nurseries, we anticipate that universally adopted seed zones may facilitate seed transfer among states in the long run, but our intention is not to limit seed transfer across different zones. For example, a nursery may decide to lump seed from a variety of seed zones into a nursery bed and sell the seedlings as a bulked source. If the seed zones are defined, even if the seed source represents multiple zones, consumers would at least have transparency in the sources diverse origin. Nurseries that wish to sell to State or federal managers would need to adhere to their seed zone requests to acquire the contracts.

In 2017, we invited nine different speakers to participate a webinar series that was launched in March with a webinar presented by Dr. Ron Schmidtling (Professor Emeritus), "Determining seed zones for the southern pines: past and future." Combined, the webinars have been viewed over 5,000 times from federal, state, NGO and private companies (viewer data is tracked by SREF). All nine webinars are archived and freely available to watch on the website. At least two additional webinars are in preparation for 2018.

Next Steps for 2018

One key aspect of this effort is to provide a forum to solicit input on seed zone construction, application, and terminology. To do this, we divided the Eastern region into eight team areas (Fig. 2). The team boundaries were based loosely on ecological regions, but are not intended as boundaries for seed zones. Those who wish to participate are invited to register for a team, in the area in which they reside. A leader will be assigned to each team, and teams will communicate by email/conference call in early 2018. Teams will either choose to adopt the Provisional Seed Zones for their area, or make adjustments to make them more applicable locally. They will also discuss terminology, species to exclude, and areas with unique biodiversity that should be recognized in some way.

Figure 2. Eight team-areas for delineating seed zones. Register for a team at http://easternseedzones.com/events/forms

We are planning to invite representatives from all eight teams, along with others from outside the Eastern region, to a Seed Zone Summit being held May 9–10, 2018 at the University of Kentucky at Lexington. The purpose is to unite representatives from across the eight areas to create one map for the Eastern region and to serve as a capstone for the effort.

Future Direction Beyond 2018

We plan to document the final recommendations from the eight teams, and the rationale used by each to adjust the Provisional Seed Zones in a capstone report. A copy of the report, and the final seed zones, will be posted on the website and printed in limited quantities. Our goal is to register the new seed zones as a federal standard for the National Forest System, and append the Seedlot Selection Tool with the new zones (pending available funding). We also hope to promote the seed zones to private nurseries and companies through communications at meetings, and on-site visits. Lastly, we hope this effort may promote new resources aimed at developing new common garden studies to evaluate seed transfer within and among the new seed zones.

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Genetic Conservation at The Morton Arboretum

Hello! My name is Sean Hoban. I'm a conservation biologist interested in trees and seeds, especially conservation of genetic variation, the use of seed for restoration, and collecting seed of rare species to grow in botanic gardens. I work at The Morton Arboretum, a large botanic garden and "living museum" in the suburbs of Chicago, founded in 1922. The Morton Arboretum grows many plants (around 4,000 species) but has particular focus, horticultural knowledge, and scientific expertise in oaks, elms, maples, crabapples, lindens and magnolias. Our living tree collections of these genera, which are accredited by APGA's Plant Collections Network, hold thousands of individual trees from hundreds of species. Geographic areas of interest include plants of the Midwest, Appalachians, southeastern US, Asia, and the Caucuses. We also sponsor one tree species for the Center for Plant Conservation, *Abies fraseri*. In the past I have studied genetics and conservation of butternut (Fig. 1), *Juglans cinerea*, including in New Brunswick and Ontario. I don't currently have any butternut research projects but I'd like to tell you about some other seed and conservation work at The Morton Arboretum.

In recent decades, The Morton Arboretum has performed field expeditions (typically two to three major trips per year) around the world so we can grow more plants from wild-collected seed, of known provenance and verified identity, accompanied by herbarium voucher specimens. Specifically, since 2012, the Arboretum has completed nine major national and international collecting expeditions, adding 1,136 new accessions of documented wild origin, such as *Malus orientalis*, *Tilia dasystyla*, *Acer griseum*, and *Quercus boyntonii* from the Republic of Georgia, Azerbaijan, China, and southeastern USA, respectively). The Morton Arboretum does not have a traditional seed bank, so we are growing seedlings to plant on the grounds or sharing seeds with other botanic gardens, seed banks or seed researchers (as yet, no Canadian institutions but we are open to collaboration!). Wild-sourced and documented plants provide the highest contribution to conservation, as each new wild collected individual brings more new genetic variation into gardens. They are also the most useful to researchers who seek to study plant variation. Detailed data on the geographic location and the local habitat of

Figure 1. Searching for butternut in Wisconsin.

the source populations will allow researchers or breeders to return to the location of origin for collecting new seed or for study. For conservation collections we typically accession the seed from each maternal plant separately, so the genetic lineages can be tracked.

A specific example is our participation in a pilot project with the US Forest Service in order to collect seeds from wild populations of species that are not currently well represented in botanic gardens (often rare species) and share them with many partner gardens. The idea is that the conservation impact of a seed collection can be amplified by sending seed to five to ten other gardens with suitable climate. The plants can then be better preserved against loss because the collection is "backed up". The added benefit is that more people can see, study, and learn about these species. For example, in 2016 I collected seed of the desert adapted oak *Quercus havardii* (Fig. 2) across five Western US states and more than a dozen locations, to share with ten partner institutes. Other collection trips under this program (primarily completed by The Morton Arboretum's Curator and Head of Collections, Matt Lobdell) have helped locate new populations of threatened species, identify in situ threats, and recruit new conservation partners.

Figure 2. Collecting samples of Havard oak (*Quercus havardii*) in 2016. This species grows in sand dunes primarily in New Mexico, Oklahoma and Texas, with western populations in the Navajo Basin of Utah and Arizona.

Other botanic gardens are collecting wild-sourced seed as well. The Brenton Arboretum in Dallas Centre, Iowa, has spent the past decade collecting Kentucky coffeetree seed from 100 locations across sixteen states (*Gymnoclaudus dioicus*), in partnership with the USDA National Plant Germplasm System (Schmitz 2017). This species is widespread but uncommon and increasingly rare in forests, though it performs well in urban environments and has ornamental value. As another example, the Millennium Seed Bank and Kew Gardens have nearly completed a massive undertaking over five years to seedbank 50 of their woody species with accessions from across the UK under a program called the National Tree Seed Program. I have been working with Kew to evaluate how much genetic variation is preserved in their collections of *Fraxinus excelsior* (European ash, threatened by the fungal disease ash dieback), which encompass more than one million seeds. I am also working with the US Forest Service to determine the effectiveness of white ash conservation programs (*Fraxinus americana*), which is threatened, as with all North American ash, by the emerald ash borer.

Another interesting project in my lab concerning seeds and genetics is called "Safeguarding Tree Species". The goal is to determine how many specimens botanic gardens should hold in their collections in order to best "safeguard" genetic diversity. I am working with the project lead, Dr. Patrick Griffith at Montgomery Botanical Center, and my research assistant, Emma Spence, to determine appropriate sampling strategies for ten species (two each from magnolias, oaks, palms, cycads, and hibiscus) in terms of number of populations and trees to sample from, and also to evaluate how well botanic gardens have done so far–are we succeeding in our mission to protect most of the genetic diversity, and if not, how much more should we add to our collections?

The Morton Arboretum, via Dr. Murphy Westwood and the Global Trees Conservation Program, also performs and assists with IUCN Red List Assessments of tree species of conservation concern. The Red List Assessment is a formal procedure for determining how endangered a species is based on recent declines in population size, species' geographic range, number of populations, recent threats and other factors and information. Dr. Westwood, Diana Jerome, and colleagues recently released a booklet containing Red List assessments and other useful information for all US oak species (Jerome et al 2017).

Speaking of oaks, I co-authored (the project was led by scientists at the University of Notre Dame including Dr. Jeanne Romero-Severson) the first study of genetic diversity across the geographic range of northern red oak (*Quercus rubra*), a common, majestic oak growing from Alabama to Ontario (Borkowski et al 2017). Red oak can survive a wide variety of temperatures and soil conditions. The study finds that northern populations have the lowest genetic diversity and some suffer from inbreeding, including several populations on Isle Royale in Lake Superior. This is important because these northern populations would be the likely trees to expand northward under climate warming (naturally or with assisted migration), but low genetic diversity could hinder a successful response. Proactive management may be required to assist northern red oak, but further research is needed on functional genomics, interspecific interactions, and species distribution modeling–all areas of expertise for The Morton Arboretum scientists!

I hope this article has given interesting insight into some of the tree and seed conservation work at The Morton Arboretum. In sum, we focus on wild-collected seed, distributed among botanic gardens; evaluation of progress towards achieving our conservation missions; collection of common species that are now threatened by new pests and pathogens; quantitative and rigorous assessment of species' threat status; and conservation genetic studies (including determining when genetics can and can't inform conservation, see Flanagan et al 2017). We also hope to raise the public awareness of the value of genetic variation and the fascinating lives of seeds!

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Further Reading

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"Warning for oaks" (2017) Seasons. Fall Issue. Available at: http://www.mortonarb.org/visit-explore/latest-news/member-publications/seasons-archive

About the Plant Collections Network: https://publicgardens.org/programs/about-plant-collections-network

About the UK National Tree Seed Project: https://www.kew.org/blogs/archived-blogs/collecting-national-tree-seed-project

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Upcoming Meetings

ISTA Annual Meeting 2018
June 11–14, 2018
Sapporo, Japan
https://www.seedtest.org/en/event.html

BC Seed Orchard Association (BCSOA)
June 19–20, 2018
Penticton, British Columbia
Penticton Lakeside Resort and Convention Centre
http://www.fgcouncil.bc.ca/bcsoa/

ISTA Workshop on Quality Assurance and ISTA Accreditation for Beginners
June 19–21, 2018
Note: Registration is due by May 18, 2018, limited to a maximum of 20 participants
Tsukuba city, Ibaraki, Japan
https://www.seedtest.org/en/event.html

Reforestation Challenges
June 20–22, 2018
Belgrade, Serbia
http://www.reforestationchallenges.org/index.php

International Society for Seed Science: 2nd International Workshop on Seed Longevity
July 30–August 1, 2018
Fort Collins, Colorado USA
https://conferencereg.colostate.edu/SeedLongevity2018

Recent Publications

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