TIC*talk*

FGC Forest Genetics Council of British Columbia

Information for and from the tree improvement community of British Columbia

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Twelth Edition

After nineteen years, 12 editions, and 196 articles, TIC*talk* has reached a milestone. Diane Douglas, the editor behind the scenes who has searched for ideas, requested input from sometimes-reluctant authors, prodded contributors to meet deadlines (including this often-late author), and done the desktop publishing, is retiring. Diane will be missed and TIC*talk* will echo with her memory for many years. This edition of TIC*talk* will be her last and we will be challenged to continue to produce the series at the same level of quality Diane has done so much to give it.

Looking back over TIC*talk* editions since 1996, a short history of forest genetics activities is revealed. Early articles on what now seem to be long-past events, such as the restructuring of the Forest Genetics Council of BC from the old Coast and Interior Tree Improvement Councils, introduction of seedlot genetic worth as a standardized measure of genetic quality, and the formation of GenSeed (now SelectSeed Ltd). Old editions also discuss the many issues that have occupied time and effort over the years; many of which have been solved due to good research, focussed actions, and collaboration.

Articles also track progress in breeding programs and highlight the milestones-of-the-time such as significant awards and meetings.

This edition of TIC*talk* continues the strong tradition set out by the previous 11 editions. Reading through the articles submitted reinforces my pride in the people, continued advancements in knowledge, and programs that have made BC a world leader in the discipline of tree improvement and forest genetics. Looking at the list of more recent awards at the end of this edition clearly shows that this tradition continues.

We move forward. We collectively do our best. And most importantly we work together to make all components of this high-quality cooperative program meet the objectives set by the Forest Genetics Council. Enjoy this 12th edition of TIC*talk* and perhaps take a moment to visit the FGC website and scan through the 11 previous editions. To Diane, my personal thanks for a job well done.
http://www.fgcouncil.bc.ca/new-tict.html

Jack Woods
Program Manager
Forest Genetics Council of BC
CEO SelectSeed Ltd.

Editor's Note: some of the hyperlinks may require you to copy and paste in a browser.

INSIDE

FGC Forest Genetics Council of British Columbia

Report on the Quality Assurance (QA) Results with pelleted seed of western redcedar, red alder and paper birch for the years 2010 to 2014

submitted by Hester Williams

Pelleting is primarily used in forestry to aid in the sowing of small, light, winged, or irregularly shaped seeds (Kolotelo et al, 2001).

Introduction

Pelleting is primarily used in forestry to aid in the sowing of small, light, winged, or irregularly shaped seeds (Kolotelo et al, 2001). In BC pelleting of the seed of western redcedar (Cw) and red alder (Dr) has been performed since the early 1990s (Klade, 2010), and paper birch (Ep) more recently in 2013. The minor negatives of the pelleting process include a slight reduction in germination (possibly due to the imbibitional delay and additional barrier the radicle must penetrate); and pellet contents that do not conform to the standard of one seed per pellet and thus resulting in empty cell or multiple seeds per cell in nursery container production. In this report the impact of pelleting on germination success of seed was investigated and results of quality assurance tests with pelleted seed of western redcedar, red alder and paper birch are presented and discussed.

Materials and Methods

Germination

Falldown (decline) in average germination percentages was determined by comparing data on the germination percentages of pelleted seed to that of unpelleted seed of corresponding seedlots for each year. Delay in rate of germination was determined by comparing the Peak Values (PV) (the point at which the cumulative germination percent divided by the number of days is the maximum) between pelleted and unpelleted seed of corresponding seedlots. Results are reported in Table 1.

Pellet assessment tests

To determine the success of the pelleting process in consistently delivering pellets that contain only one seed, Pellet Assessment Tests (PAT) quantifying the contents of pellets were performed. Contents were classified as i) single-seeded (acceptable pellet); or ii) empty, debris-filled; multiple-seeded and other species (unacceptable pellet contents). Results are reported in Table 2.

Results and Discussion

Germination

Western redcedar

Overall, the falldown in average germination percentage across the five years amounted to 2.0% for western redcedar (Table 1). This is a large improvement over the average falldown percentage of 6.9% for the years 2000 to 2004 (Kolotelo, 2004). This indicates a notable improvement in the pelleting process by Mr. Carl Happel[1] and better seedlots. Over the five years the average rate of germination was slightly higher for unpelleted seed (PV=5.0) compared to pelleted seed (PV=4.6) (Table 1).

Red Alder

Estimated falldown in average germination percentage for red alder across the five years amounted to 1.4% and average rate of germination was higher for unpelleted seed (PV=8.2) compared to pelleted seed (PV=6.8) (Table 1).

Paper Birch

Estimated falldown in average germination percentage for paper birch across the two years amounted to 1.0% and average rate of germination was higher for unpelleted seed (PV=8.4) compared to pelleted seed (PV=8.1) (Table 1). Only two tests have been performed for paper birch and data may not be representative of the species.

The difference in test results between unpelleted and pelleted seed has several possible explanations, including:

1. Differences in test age between pelleted and unpelleted germination results. Based on germination retest frequencies this difference should be a maximum of 18 months.

1 Carl Happel is the provider of pelleting services for the Tree Seed Centre and nurseries in BC and beyond. He operates the business out of Vernon, BC and can be contacted via e-mail at seed-pelleting@shaw.ca or by phone at 250.558.0746.

2. Sampling. The germination lab test is performed on a representative sample of the seedlot, but withdrawal for pelleting does not involve as rigorous sampling procedures. It is not feasible to perform representative sampling for all sowing requests.

3. The pellet-coating can reduce or delay germination due to several reasons, including:

- the pellet restricting or slowing water uptake;
- oversaturation of the pellet restricting O_2 uptake;
- the pellet removing moisture from the seed delaying germination;
- the pellet being a physical barrier slowing or preventing radical emergence;
- age of seedlot.

Pellet assessment tests

Western redcedar

In general, the pelleting of western redcedar seed resulted in a highly acceptable product with 98.7% of all pellets tested containing one seed across the five years (Table 2). The portion of failed pellets was on average 1.3%, with pellets containing multiple seed contributing the highest portion (Table 2).

Red alder

Pelleting of red alder presented more challenges. Mr. Happel commented on the process being more difficult to get started because of the small size of the seeds. An acceptable product was achieved with 96.8% of all pellets tested contained one seed, and the portion of failed pellets was on average only 3.2% (Table 2). Multiple seed contributed the highest portion to the failed pellets (Table 2).

Paper birch

It is early to comment on the success of the pelleting of paper birch, as only two seedlots were pelleted since 2013. The same problems were experienced by Mr. Happel with regards to seed size and the process taking longer than with western redcedar. On average 99.25% of pellets tested contained one seed (Table 2). The portion of failed pellets was on average 0.75%, with pellets containing debris contributing the highest portion (Table 2). It should be noted that debris-filled pellets are a function of seedlot purity and not a problem that can be attributed to the pelleting process.

In general, the pelleting of western redcedar seed resulted in a highly acceptable product with 98.7% of all pellets tested containing one seed across the five years.

Species	# of tests	Average % germination (pelleted)	Average % germination (unpelleted)	Average germination falldown %	Average PV (pelleted)	Average PV (unpelleted)
Western redcedar	147	79.1	81.0	2.0	4.6	5.0
Red alder	36	76.3	77.2	0.9	6.8	8.2
Paper birch	2	94.0	95.0	1.0	8.1	8.4

Table 1: Comparison of the weighted average germination percentages of seedlots that were pelleted and unpelleted; estimated pelleting falldown and number of days to reach Peak Value on sowing requests from 2010 to 2014.

Species	# of tests	Average % 1-seeded pellets	Average % failed pellets				
			Empty	Debris	Multiple Seed	Other species	Total
Western redcedar (Cw)	146	98.7	0.07	0.58	0.66	0.01	1.3
Red alder (Dr)	36	96.8	0.62	1.16	1.47	0.00	3.2
Paper Birch (Ep)	2	99.25	0.00	0.50	0.25	0.00	0.75

Table 2: Average pellet classification (%) by content category of pelleted Cw, Dr and Ep seed on sowing requests from 2010 to 2014.

The pelleting process overall delivers a satisfactory product.

Conclusion

Pelleting in general seems to cause a very slight falldown in germination percentages for both western redcedar and red alder and a slight delay in rate of germination. The pelleting process overall delivers a good product. The benefit of accurate sowing appears to outweigh the costs as most BC nurseries request seeds of western redcedar and red alder to be pelleted. It is recommended that annual updates and five-year averages for pelleted germination capacity (GC) falldowns and pelleting 'efficiency' be maintained.

Figure 1. An example of the relative size and shape of pelleted western redcedar.

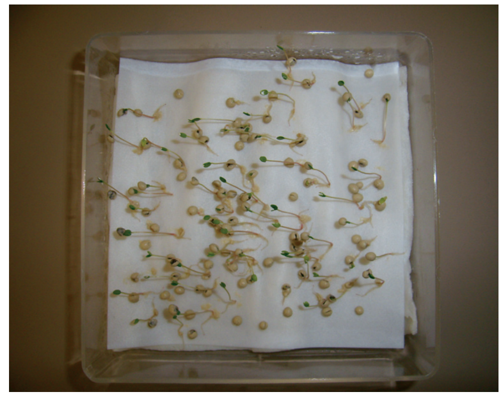

Figure 2. Quality Assurance germination test of pelleted western redcedar.

References

Klade, L. 2010. Pellet Assessment (PAT) quality assurance program. Western redcedar and red alder. Internal Report. Tree Seed Centre, British Columbia Ministry of Forests.

Kolotelo, D. 2004. Western redcedar seed. Seed and seedling extension topics Vol. 15 pg.5-6. Tree Seed Centre, British Columbia Ministry of Forests.

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Kolotelo, D., E. van Steenis, M. Peterson, R. Bennett, D. Trotter, and J. Dennis. 2001. Seed Handling Guidebook. Tree Improvement Branch, British Columbia Ministry of Forests.

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Low germination seedlots for certain species overinflate the seed supply inventory on SPAR

submitted by Spencer Reitenbach

Does your current inventory of seed stored at the Tree Seed Centre accurately reflect the potential trees that you have available for future sowing? Seedlots with low germination rates (< 50 %) may have huge physical balances and large associated potential trees calculated by SPAR that will never be used in sowing thus overinflating your inventory. If you look at a SPAR summary report by species you may have a few million trees reported as available but if the germination is too low you might not find a nursery to grow the crop or they may have a hard time meeting your requested number of trees using poor quality seed.

You may want to review your entire seed inventory to see which seedlots could be used in the next few sowing seasons before they continue deteriorating to a point where they are unusable. Take a look and see which seedlots in your inventory could be moved partially or entirely to surplus on SPAR for potential seed sales to other clients via pending sowing requests or as part of a bulk sale. You may also be able to identify which seedlots could be discarded and removed from inventory at the Tree Seed Centre if they are no longer required, are too poor of quality or too small of a quantity to use in your planting program. Actively managing your seedlot inventory will not only give a more realistic view of the potential seedlings you have in storage but also helps us to better manage the overall inventory including eliminating the retesting of seedlots that are no longer required for reforestation purposes.

If you have any seed inventory for the eight species identified in Table 2, reviewing them will have the most impact on the accuracy of the overall seed inventory for the Province. In the past 4 sowing seasons (2011-2014) only 40 different seedlots with lower than 50% germination have been used in 70 sowing requests for a total of 2.1 million seedlings grown. This relatively small total is less than 1% of the 9,249 requests producing a total of 982.9 million trees ordered over the same four years. Almost half of the 2.1 million trees were for *Abies lasiocarpa* sowing with 8 million of those trees coming from one seedlot which is now expired on SPAR. Another 0.34 million western redcedar and 0.44 million yellow cypress accounted for almost 30% of the trees grown from the poor germination seedlots. Eight other species were used in 29 requests for another 0.32 million trees.

If you have any questions or concerns about your inventory or need assistance with SPAR reports or how to move seed from reserve to surplus status on SPAR do not hesitate to contact Spencer Reitenbach, Inventory Management Supervisor at the Tree Seed Centre. Spencer.Reitenbach@gov.bc.ca or by phone at 604.541.1683 ext. 2229

Which seedlots could be used in the next few sowing seasons before they continue deteriorating to a point where they are unusable?

Germination % Range	1-25	26-50	51-75	76-90	91 +	Grand Total
Potential Trees (K) - all species	4,607.1	23,132.3	708,685.6	3,252,384.4	4,066,878.8	8,055,688.2
Percentage of total inventory	0.1%	0.3%	8.8%	40.4%	50.5%	as of 2014-04-17

Table 1. Breakdown of active, registered seedlots on SPAR by germination range in potential trees (K).

Species	Amabilis fir (Ba)	Grand fir (Bg)	Sub-alpine fir (Bl)	Western redcedar (Cw)	Western hemlock (Hw)	Western larch (Lw)	Ponderosa pine (Py)	Interior spruce (Sx)	All Others
Trees (K)	3,965.5	1,220.3	5,156.7	6,215.1	2,154.0	2,069.2	0.4	3,197.9	3,317.6
kgs	1,062	194	495	69	34	63	168	48	116
# Seedlots	31	7	24	49	33	14	6	8	

Table 2. These totals are only for seedlots with 1 – 50% germination.

New Retesting Frequencies and Deterioration Rate Estimates by Dave Kolotelo
http://www2.gov.bc.ca/gov/DownloadAsset?assetId=F763000B343B4F619433301964E126C5&filename=tsc_retesting_frequencies_deterioration_2002.pdf
Seed Longevity by Dave Kolotelo
http://www2.gov.bc.ca/gov/DownloadAsset?assetId=69F4AC70069B4CB18A25C97B72DFE692&filename=tsc_conifer_seed_longevity_2007.pdf

Water activity is now being used to try and maximize the longevity of conifer pollen and seed.

Water Activity

submitted by Dave Kolotelo

Water activity (Aw) is a concept and technology that was developed in the 1950s to extend the shelf life and stability of food products. It is used extensively by food formulators to ensure different components are not engaging in water transfer and changing the intended characteristics of the product. A good simple example is raisin bran – if the raisins are much moister than the bran, then water will migrate from the raisins making the bran soggy and the raisins hard. Water activity is the best way to equilibrate food components or at least better understand where moisture may flow. Water activity is now being used to try and maximize the longevity of conifer pollen and seed. This article will discuss the principles of Aw, its advantages, and its applications in drying.

Water in seeds, for example, can be thought of as being composed of water that is more or less tightly bounded to the seeds hygroscopic matrix. In its simplest form one can think about water as being tightly bound to the matrix or water that is not directly associated with the matrix (free water). This free water is what is measured via water activity and indicative of what is available for evaporation or product deterioration through the actions of microorganisms, enzymes and other chemical reactions. The unique properties of water as a permanent dipolar molecule create a diverse array of binding strengths with different seed matrix components representing a large grey zone between strictly bound and free water.

There are a variety of online references on water activity that define it through partial vapour pressures, matric potentials, or equilibrium relative humidity with the associated jargon of the source. The good news is you don't need to be an engineer or physicist to understand or apply water activity to the conservation of your seed or pollen. I think it is most easily understood as the equilibrium relative humidity (ERH) of your seed in a closed system when the temperature of the seed and instrument are the same. This is critical to aligning ERH and Aw.

In addition to Aw being a much better predictor of 'deterioration potential' it is also a non-destructive test. Currently, we destructively test seed to determine the sum of the free and bound water in relation to the fresh weight of the seed. We destroy the seed and don't get an accurate indication of free water available for deteriorating processes.

Water activity results can be obtained relatively quickly (5 to 10 minutes) and with dedicated meters the precision and therefore time per measurement can also be adjusted. The Aw results are also independent of seed size, maturity, purity or percentage of empty or dead seeds. The operating of water activity meters is quite simple and reference humidity standards are available for in-house calibration. These are great advantages, but the 'general' acceptance of a universal value is what has made it practical for introduction at our facility. This universal value is based on the recommendations of researchers from Quebec and France [**0.35**] (Colas et al 2010) and the United States [**0.30**] (Karrfalt 2014).

Dedicated water activity equipment can be costly and with tree seeds and pollen this has often resulted in it being used in research more than operations. Bob Karrfalt at the USDA seed lab (Karrfalt 2014) and others at Kew gardens (Gold and Manger 2014) advocate the use of a hygrometer and a self-constructed sealed chamber. This is far cheaper than a dedicated water activity meter, but its inability to determine when the ERH is reached lowers the productivity or number of samples that could be tested in a day. It is probably the most practical way to introduce water activity into operations that don't have funds for a dedicated Aw meter.

Our experience at the Tree Seed Centre (Figure 1) has primarily been using water activity to assess whether our genetic conservation samples could be freezer stored. Due to the small sample sizes we didn't want to sacrifice seeds with traditional moisture content testing to make this determination. The measurement was relatively simple, but the required subsequent drying of most samples was often inefficient, especially during the more humid warmer months of the year. Fortunately water activity can also play a role here as plans for a water activity regulated dryer based on the two–pressure principle are available (Baldet & Colas 2013). This plan basically creates a humidity chamber that reduces seed moisture content down to the set ERH value. My Quebec colleagues, who have been using this cabinet to dry seed and pollen for several years joke about drying seed with humidity, but that is basically what is happening. Quebec has also converted their larger-scale drying line to be based on Aw ensuring that seeds dried in this manner are at equilibrium with the programmed chamber environment. This drying has also resulted in a significant savings in electricity (Colas and Bettez 2012). We hope to integrate both of these water activity based drying schemes into our facility in the coming year.

References

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Karrfalt RP. 2014. Assembling seed moisture testers, seed dryers, and cone dryers from repurposed components. Tree Planters' Notes: 57:11-17.

Figure 1. The Portable water activity meter (a) packed for transport and (b) in use at the BC Tree Seed Centre.

Fortunately water activity can also play a role here as plans for a water activity regulated dryer based on the two –pressure principle are available (Baldet & Colas 2013). This plan basically creates a humidity chamber that reduces seed moisture content down to the set ERH value.

Assisted Range and Population Expansion of Western Larch for Use as a Climate Change Adaptation Strategy in British Columbia

submitted by Lee Charleson

This amendment will continue to serve as "interim measures" for western larch until replacement with the new Climate-Based Seed Transfer system.

On May 26, 2014, Tree Improvement Branch amended the spatial dataset for western larch (*Larix occidentalis*) areas of use for seed planning zones Lw1, Lw2 and Lw3. The changes reflect "best available scientific information" and can be implemented immediately since the spatial data (geometry and map products) of tested parent tree areas of use do not require a formal amendment to the *Chief Forester's Standards for Seed Use*.

This amendment follows a review of the June 2010 interim measures that established western larch (climate change) seed planning zones, Lw1, Lw2 and Lw3. The purpose of the review was to evaluate the effectiveness of the interim measures and to investigate options for improvement.

The scientific information contributing to these changes is based upon the research and analysis conducted by Dr. Gerald E. Rehfeldt (USDA Forest Service, retired) and Barry Jaquish (MFLNRO, Tree Improvement Branch), as reported in their publication, "Ecological impacts and management strategies for western larch in the face of climate change" (March, 2010, Mitigation and Adaptation Strategies for Global Change; ISSN 1381-2386, Volume 15, Number 3).

The spatial amendments include the following changes:

- Combining seed planning zones Lw1 and Lw3 as they are represented by one seed orchard population,
- Expanding the seed planning zone boundaries of Lw1 and Lw2, and
- Smoothing the raster data of seed planning zone boundaries of Lw1 and Lw2 (to remove the 'blocky' pixel-based shapes).

This amendment will continue to serve as "interim measures" for western larch until replacement with the new Climate-Based Seed Transfer system. Spatial data (i.e. shape files and geodatabase) and a provincial scale PDF map are available on Tree Improvement Branch's FTP site (please see below for link). Plans are to load the Lw1 and Lw2 seed planning zones in the BC Geographic Warehouse later in the year so that it is available for viewing in SeedMap and available for download with all Seed Planning Zone spatial data.

http://www.for.gov.bc.ca/ftp/HTI/external/!publish/Western_Larch_Interim_Measures/

The Problem of Being a Tree in a Forest: getting along with your neighbors is important!

submitted by Alvin Yanchuk, Chang-Yi Xie and Michael Stoehr

Although we don't think much about it, trees are social beings. Plants of course generally have it more difficult than animals, as where the seed lands, or where somebody planted you, that is where you have to make do. If nobody is within your proximity, you have to simply tough it out with the rain, wind, sun, and things that like to snack or invade you. If you are surrounded by aggressive and unfriendly neighbors, you may be in for a rough ride! How does a tree in a forest interact with its neighbors? For our purposes in tree improvement, we specifically want to know what are the effects of a trees genotype on its own phenotype, as well as on the phenotypes of its neighbors? Population genetics and group selection theories that describe how selection works on this type of heritable variation, have been around for some time, but with the advent of better statistical models, more (mature) data and better computational power, breeders are now able to get at some of these questions.

In other words, we can not only predict the genetic effects of individual genotypes on their own phenotypes (i.e., direct breeding values) but also the genetic effects on the phenotypes of their neighbors (i.e., indirect breeding values). Knowing both the direct and indirect breeding values of a tree, one can predict its potential contribution to the overall productivity of the plantation and hopefully make better selection decisions for seed orchards.

In animal breeding, it has been shown that selecting for the best growing individual genotypes in a cage-type environment with other animals present (usually six per cage for broilers) lowers the overall productivity per cage; the best producing genotypes also tend to be more aggressive (e.g., Muir 2005). If you think about it, the stand or plantation is sort of a cage for trees! We've also known that competition among trees in progeny tests exaggerates the differences among families, once the trial attains an age with heavy competition (15-20 years), so we've typically stop measuring them at this age to avoid biases in predicting gain. However, with these new statistical approaches, we are starting to get some insight on how the offspring of seed orchard genotypes might fare in plantations (e.g., Cappa and Cantet, 2008, Costa e Silva and Kerr 2013).

Some recent work with Douglas-fir in the old EP708 diallel series, with the help of Dr. Eduardo Cappa, has been an interesting development, and may down the road lead us to having another type of breeding value for our elite trees, and perhaps making adjustments to the clones we may want in our orchards. One thing has surfaced from the research, not surprisingly, is that diameter growth is subject to much more competition effects than height. Foresters have known this for a long time, e.g., spacing has large effects on diameter class distributions, and height growth is more affected by site quality. Jumping ahead to one of the conclusions, is that we may have gotten lucky in that in the BC programs we've been selecting almost exclusively on height growth. So we may have avoided selecting for fatter aggressive genotypes that produce a lot of volume on a per tree basis, but may ultimately reduce final stand volumes. That is the thought, as of now, and it will take some time before we can prove it … but what a fun thought, eh? Stay tuned.

References:

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Although we don't think much about it, trees are social beings.

Knowing both the direct and indirect breeding values of a tree, one can predict its potential contribution to the overall productivity of the plantation and hopefully make better selection decisions for seed orchards.

Inbreeding Depression in Douglas-fir and Seed Orchard Genetic Gains

submitted by Michael Stoehr

Most conifers have a predominantly outcrossing mating system promoting high levels of genetic diversity.

Introduction

Most conifers have a predominantly outcrossing mating system promoting high levels of genetic diversity. As a result, inbreeding, the mating among relatives and/or selfing leads to inbreeding depression (ID) lowering the fitness and increasing in homozygosity (Sorensen 1999). It is well established that ID is most severe in survival and growth traits (height, diameter and single tree volume) and to a lesser extent in wood properties as fitness traits suffer more under inbreeding (Wu et al. 2002).

This study was initiated by the previous coastal Douglas-fir breeder. The question arose as to what will happen to seedlings originating from seed orchard seed that are either the result of mating among relatives such as mating among parent and offspring or two full-sib seedlings (i.e., low level of inbreeding) or as a result of selfing (a more severe form of inbreeding).

Material and Methods

To study the effect of inbreeding on performance in the nursery and during stand development in the field, seedlings with different levels of inbreeding were obtained by control crossing using a 9-parent base population. These 9 parents were selfed, used to create crosses with their progeny (i.e., parent-offspring crosses) and between their progeny (i.e., half-sib and full-sib crosses). Selfing leads to an inbreeding level of f = 0.5, full-sib and parent offspring crosses lead to f = 0.25 and half-sib crosses create f-levels = 0.125. A total of 148 families with these various levels of inbreeding were created and sown in the nursery. Inbreeding effects were already noticed in the seed production phase and the nursery at the time of lifting (Woods and Heaman, 1989; Woods et al. 2002) resulting in different culling rates to achieve operational seedling standards (Table 1). Thus, all seedlings to be planted were of very similar size. Seedlings were planted on two farm-field tests in a replicated, single-tree plot trial in Langley, BC and North Arm (Cowichan, BC). Heights and diameter were measured and wood density (using increment cores and the maximum moisture method) was determined for all trees growing in four (out of 8) randomly chosen blocks at age 26 on both sites.

Results and Discussion

In Table 1, survival, growth and wood density measurements are shown for both sites and all inbreeding levels. Outcrossed seedlings grew best and had the highest survival. Inbreeding depression rose with

Site	Inbreeding Level	Culling[1] %	Survival %	Height 26 (m)	Diameter 26 (cm)	Wood Density 26 [0]
Langley	0	5	63	13.9 (2.2)	11.2 (4.2)	0.501 (0.028)
	0.125	10	40	13.1 (2.4)	9.8 (3.6)	0.496 (0.027)
	0.25	10	24	13.0 (2.1)	9.6 (3.3)	0.497 (0.026)
	0.5	15	10	13.2 (2.5)	10.8 (4.7)	0.484 (0.016)
North Arm	0	5	95	16.3 (2.5)	14.1 (3.5)	0.458 (0.025)
	0.125	10	86	14.9 (2.8)	12.0 (3.5)	0.452 (0.027)
	0.25	10	68	13.5 (2.9)	10.3 (3.2)	0.458 (0.029)
	0.05	15	16	12.6 (3.8)	9.6 (3.9)	0.441 (0.022)

Table 1. Means (standard deviations) for traits measured in four levels of inbreeding at age 26 in coastal Douglas-fir planted on two sites in southern British Columbia.

[1]Seedlings prior to planting were culled according to Culling Standard 2 (minimum/maximum height 15/30 cm and 3/3.5 mm diameter) resulting in all planted seedlings being of similar size (Woods et al. 2002).

levels of inbreeding for growth traits and survival, but remained relatively stable for wood density (Figure 1). Inbreeding effects are continuously increasing (Figure 2) and are most severe in survival. However, it is not clear if the continuous rise of inbreeding depression is due to inbreeding *per se* or if it is the result of earlier competition causing a stunted growth pattern (and now the elimination of small trees from the developing stand). Figure 3 illustrates the difference in tolerance of the parental trees to inbreeding. For example, parent tree 33 shows strong inbreeding depression, while parent 499 seems to thrive with increased inbreeding. These various parental responses will have impacts in the breeding and testing program in coastal Douglas-fir as the breeding population is structured in sublines, where inbreeding within sublines is allowed to accumulate and selections are then used in outcrossing seed orchards. Without recognizing the need of testing selections in an outcross situation, tree 499 may have been chosen (or its offspring), only to perform poorly in an orchard. Thus the need to GCA-test all selections is confirmed.

These results also show that a certain level of inbreeding in orchards can be tolerated either by including full-sibs to each other or original parents and advanced-generation selections

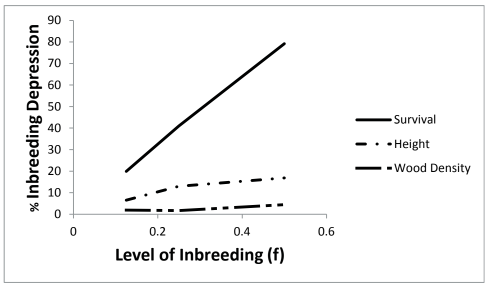

Figure 1. Inbreeding depression in height, survival and wood density in 26-year old Douglas-fir growing on two sites in coastal British Columbia.

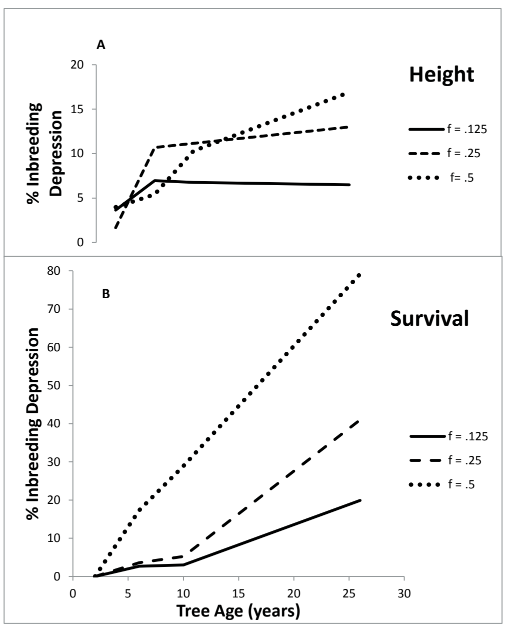

Figure 2. Inbreeding depression increases with plantation age in height (A) and survival (B).

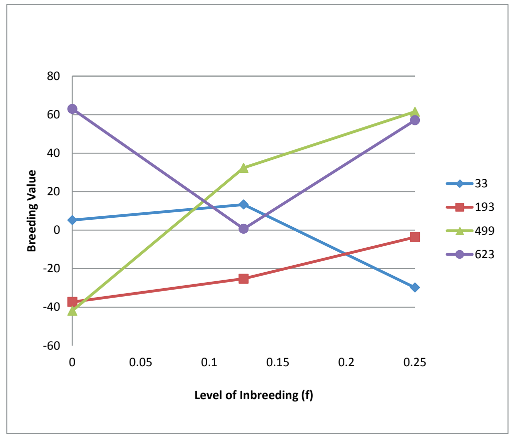

Figure 3. Effects of level of inbreeding (f) on breeding value estimation of four parents used in inbreeding study of coastal Douglas-fir.

These various parental responses will have impacts in the breeding and testing program in coastal Douglas-fir as the breeding population is structured in sublines, where inbreeding within sublines is allowed to accumulate and selections are then used in outcrossing seed orchards.

Thus, the reduction of inbreds in a mature plantation is a gradual but continuous process starting with the seed and ending at crown closure. As a result small inbreds are rare in the final crop and the predicted genetic gains of orchard seed will not be affected.

(leading to the possibility of parent-offspring matings) as under current operational planting densities of 3x3 m (1111 trees/ha) at site index of 30, 743 trees are expected to be harvested at rotation (TIPSY 4.3). Thus the combination of more culling of inbreds during lifting and higher mortality and reduced growth during crown closure, will in all likelihood remove the inbred trees from the final crop. In addition, it is important to remember that in this study, inbreeding was "forced" by making control crossings. In nature, i.e. in wind-pollinated orchards, the observed inbreeding depression in seed set (Woods and Heaman 1989) will naturally and preferentially have reduced the number of inbred seeds going to the nursery. Thus, the reduction of inbreds in a mature plantation is a gradual but continuous process starting with the seed and ending at crown closure. As a result small inbreds are rare in the final crop and the predicted genetic gains of orchard seed will not be affected.

A more detailed description of the trial and discussion of the results are found in the published version of this study (Stoehr et al. 2014).

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Thermocouples, iButtons, and Lepto-cams: understanding the low Pli seedset problem

submitted by Ward Strong

Executive Summary

Lodgepole pine seed loss in late summer is prevented by installing mesh bags over the cones, but it is unclear whether this is due to exclusion of western conifer seedbug, cone cooling, or increased relative humidity (RH). Internal cone temperatures and RH around cones were monitored both inside and outside mesh bags. Time-lapse cameras were also aimed at unbagged cones near to bagged cones. The bags increased internal cone temperatures in all cases, so cone cooling is not the cause of increased seedset in bagged cones. Humidity was slightly higher inside bags than outside, but for several reasons described below, this is unlikely to be the cause of increased seedset. Seedbugs fed for many hours on the unbagged cones through the season; seedbugs are known seed feeders so seed loss is expected compared to bagged cones. When the seeds were extracted, seed loss compared to bagged cones was strongly correlated to the number of hours the exposed cones had been fed upon. This is convincing evidence that seedbug feeding is the main factor responsible for late-season seed loss in lodgepole pine.

Introduction

Pine seedset, as measured by the number of filled seeds per cone (FSPC) or percent filled seeds (%FS), in Interior seed orchards has been low in all but the Prince George Tree Improvement Station orchards. The potential number of filled seeds is somewhere around 30-40 per cone (Owens 2006), but many orchards experience fewer than 15, even as low as 3 to 5, FSPC. It was discovered in 2010 that a large portion of this seed loss occurs from late July through August; this has been substantiated in 2011 and 2012. One feature of the late-season seed loss is that it is completely preventable by putting mesh bags over the 2nd-year cones. Other forms of seed loss exist (there are still empty seeds inside the bags), but it has been known since 1994 that installing insect bags increases seedset (Strong et al 1999).

Research from 1996 through 2006 has repeatedly demonstrated that one reason mesh bags increase seedset is exclusion of the Western Conifer Seedbug, *Leptoglossus occidentalis* (e.g. Bates et al. 2002, Strong 2006). The possibility that mesh bags might also influence seedset by altering microclimate has never been rigorously addressed. It was theorized that the southern Interior seed orchards are too hot and dry for good seed production; mesh bags may cool the cones and increase humidity, thus preventing the seed loss. Furthermore, seedbug densities were suspected to be low from 2010 to 2012, therefore the thought that they were responsible for the seed decline was drawn into question.

This experiment was designed to determine whether temperature, humidity, or seedbug exclusion were responsible for the increased seedset due to mesh bags.

Materials and Methods

Ten Pli trees were selected, 5 in Orchard 307 (Kalamalka) and 5 in Orchard 339 (Tolko Eagle Rock). On each tree, four cone clusters were selected, with 3-4 2nd-year cones in each, of approximately equal aspect, height, and size.

Internal cone temperatures: Thermocouples are tiny temperature measuring devices made by soldering together the ends of two wires of different types of metal. They produce a voltage potential related to the temperature. On each tree, two cones on each of two clusters were drilled with a 1 mm bit, and a thermocouple was inserted into the seed-bearing portion of each cone (Figure 1). The thermocouples were attached to a thermocouple datalogger (model SD947, Reed Instruments, Ste. Anne De Bellevue, Quebec) that measured the internal cone temperatures every 5 minutes. One cone cluster was enclosed in a mesh bag; the other was left open. Thus on each experimental tree there were two cones inside mesh bags, and two outside, whose internal temperatures were being measured every 5 minutes.

This experiment was designed to determine whether temperature, humidity, or seedbug exclusion were responsible for the increased seedset due to mesh bags.

Mean cone temperatures during the critical seed-loss period of July 15 - Sept 6 were significantly higher inside the bags than outside.

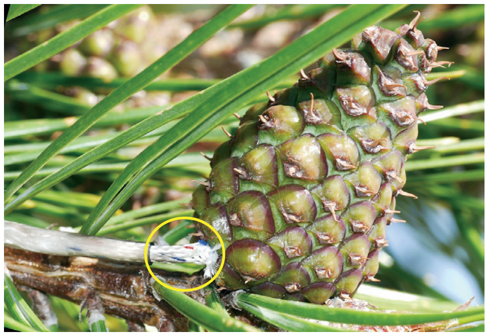

Figure 1. Thermocouple wire inserted into a 1-mm hole drilled into the seed bearing portion of a lodgepole pine cone.

Relative humidity (RH): To measure RH, weatherproof iButtons (Maxim Integrated, San Jose, CA) were used. These are about the size of a stack of dimes (Figure 2), can be preprogrammed to measure temperature and RH at desired intervals, then left in the field to run independently. One iButton was taped to a 3rd cone in each of the cone clusters used for thermocouple measurements. iButtons were programmed to measure RH every 5 minutes; one was inside a mesh bag and one was outside.

Figure 2. iButtons showing the relative humidity (RH) monitoring hole.

Seedbug feeding: The other two cone clusters on each tree were used for measuring seedbug feeding. On one cluster, a mesh bag was installed to exclude seedbugs from the cones. Near the other cluster, a time-lapse camera (Wingscapes Inc, Alabaster, AL, Figure 3) was installed and aimed at the cone cluster. It was set to take one photo every 5 minutes from 06:00 through 22:30, starting May 13 and ending Sept 9. At the end of the season, all cones were collected from the clusters that the camera pointed at, as well as the paired cluster that was covered with a mesh bag. Seeds were extracted at the Kalamalka Forestry Centre by routine extraction methods, and x-rayed to determine

Figure 3. Time-lapse camera aimed at an unbagged cone cluster.

filled and empty status. All photos were examined for the presence of seedbug adults and nymphs, and their activity was classed as walking, resting, or feeding. Seed loss in the cones exposed to seedbug feeding was regressed against the number of hours those cones were fed upon by seedbugs.

Results and Discussion

Internal cone temperatures: In eight of the 10 trees, mean cone temperatures during the critical seed-loss period of July 15 - Sept 6 were significantly higher inside the bags than outside (Figure 4; two-tailed paired t-test

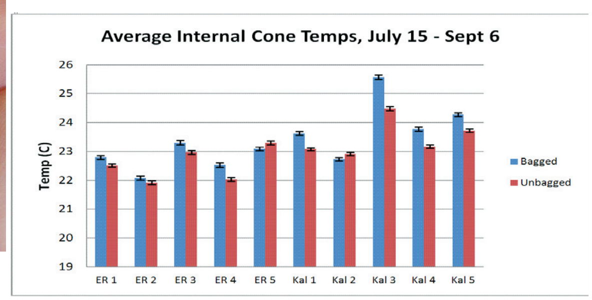

Figure 4. Mean late-season internal cone temperatures (±SE) of bagged and unbagged cones in each of the 10 experimental trees. ER, Eagle Rock seed orchard 339, Kal, Kalamalka seed orchard 307.

P=0.014). Peak temperatures might also be important, so I also calculated the amount of time spent above hypothesized critical temperatures, as degree-days (DD) above a threshold temperature. Accumulated DDs over 35 °C were significantly higher inside bags than outside (Figure 5; one-tailed paired t-test P<0.01), and DDs above 40 °C occurred almost exclusively in bagged cones (Figure 6; one-tailed paired t-test P=0.028). We

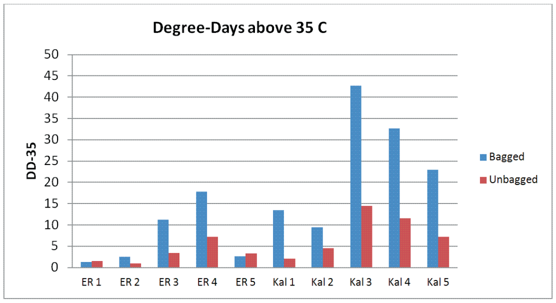

Figure 5. Degree-day sums above a critical temperature threshold of 35^0C, as measure by Degree-Days with a base of 35^0C.

conclude, therefore, that bags do not protect seeds by cooling the cones. It seems unlikely that heating cones beyond the already hot Okanagan summers would protect seeds. Thus we infer that temperature is not the reason that mesh bags prevent seed loss.

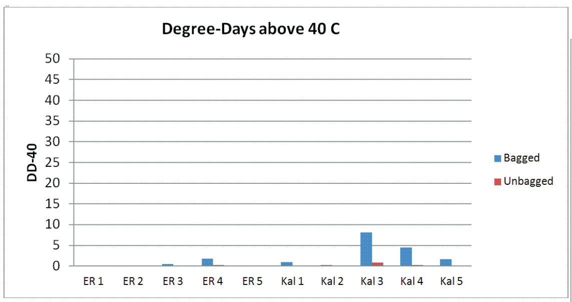

Figure 6. Degree days sums above a critical temperature threshold of 40^0C, as measured by Degree-Days with a base of 40^0C.

Relative humidity: The iButtons were active for 10 days in late May and early June before they ceased collecting data. It was July 22 before I got them working again, and they worked through August. In early season, there was no significant difference between RHs inside and outside bags (Figure 7, z-test P=0.24). The later season measurements

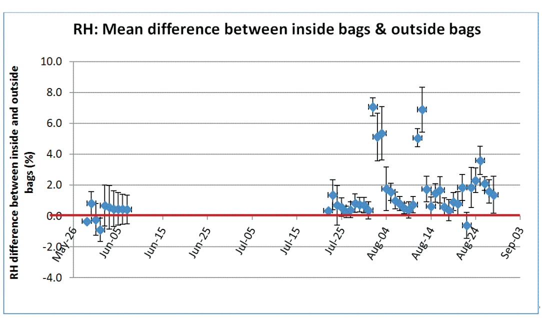

Figure 7. Difference in relative humidity (RH) ±SE between inside and outside mesh bags, calculated as RH (inside) - RH (outside). Therefore positive values, above the red line at 0, indicate higher humidity inside bags

were from the key seed loss period. During this time, the RH was significantly higher inside bags (z-test P<0.001). When each date was analyzed individually, 19 of 38 days had significantly higher (P≤0.05) RH inside the bags. Despite there being a statistically significant difference, I have trouble seeing how an increase of approximately 2% RH can be biologically significant, enough to result in the dramatic seedset reduction we have been experiencing. Furthermore, the variation in RH between trees is greater than the variation between bags within a tree. For example, tree ER 3 was within 20 m of tree ER 4 in the Eagle Rock orchard. Yet on August 5 (Figure 8), the "dry" unbagged cones of ER 4 were more humid than the "humid" bagged cones of ER 3. This example holds true for every single day that RH was measured. Thus we infer that humidity is not responsible for the seed loss prevention by mesh bags.

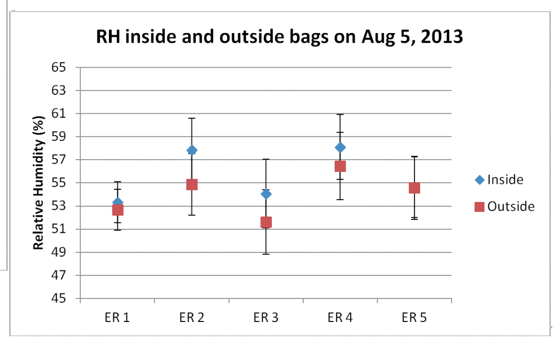

Figure 8. RH (%) inside and outside bags ±SE on 5 trees from Eagle Rock seed orchard 339. The difference between trees is greater than the difference between bags within a tree.

Seedbug feeding: Over the course of the summer, 185,550 images were taken (e.g. Figure 9). Feeding of adults and nymphs

Figure 9. One image from a time-lapse camera, with a seedbug clearly visible on the entire cone.

The variation in RH between trees is greater than the variation between bags within a tree.

were summed on a weekly basis (Figure 10). Through late May and June, overwintered

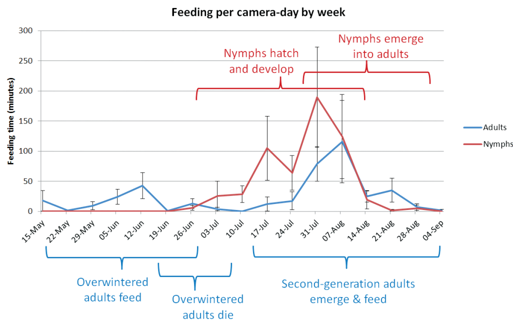

Figure 10. Hours ±SE of seedbug feeding observed summed for each week of the summer.

adults invaded the orchards and fed on developing cones. They were laying eggs that hatched to nymphs, which started to feed in late June. Feeding by overwintered adults declined as they died off by early July. Nymph feeding increased to a peak in late July. As they matured, they emerged to the 2nd generation of adults, which started to feed in mid July. Nymph and 2nd generation adult feeding declined through August, as nymphs matured to adults, and as adults left the orchard for overwinter sites. The bulk of feeding occurred during the time of major seed loss, mid July through August.

Because overwinter adult feeding had declined by July 1, and nymph feeding had barely started, I divide summer into early season (May 15 – June 30) and late season (July 1 – September 1). Seedbug feeding in early season averaged virtually nil for nymphs, and 3.3 minutes of feeding per cone per day for adults, ranging from 0 to 8.9 min/cone/day. Feeding in late season averaged 12.5 min/cone/day for nymphs, and 6.3 for adults, ranging from 0.06 to 25.2 minutes per cone per day (Figure 11). Seedbugs are known seed feeders; their presence for so long on each cone cluster strongly indicates they are reducing the number of seeds inside those cones. This reduction is prevented by the insect exclusion bags.

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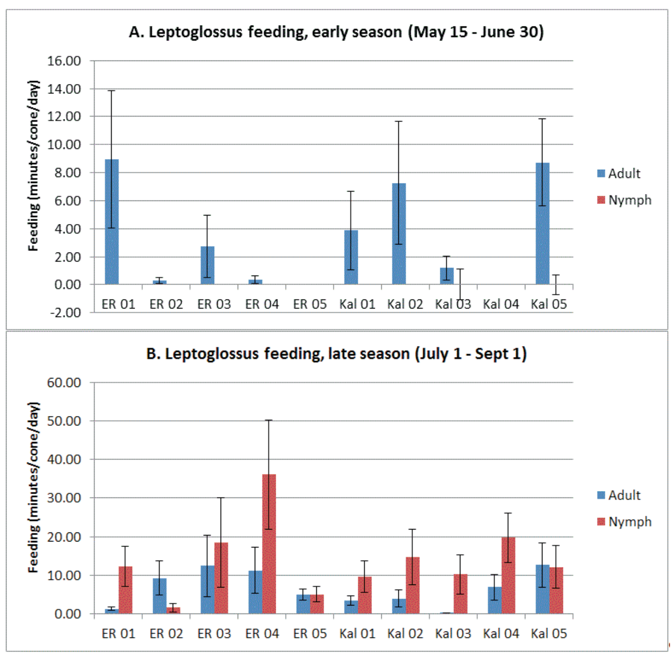

Figure 11. Cumulative early-and late-season feeding by tree ±SE.

After extraction of bagged and unbagged cones, there were a mean of 12.5 filled seeds per cone (FSPC) inside the mesh bags, and significantly fewer on exposed cones at 2.4 FSPC (two-tailed paired t-test P<0.001) (Figure 12). Similar significant

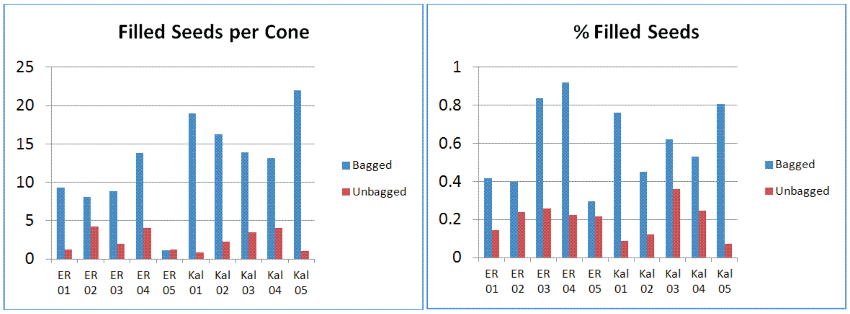

Figure 12. Seed extraction results for bagged and unbagged cones on each of the 10 trees.

reductions (P<0.001) in percent filled seed were experienced. If the feeding causes seed reduction, then the amount of seeds lost should increase as the time cones were fed upon increased. Seed loss was positively correlated to hours spent feeding on each cone cluster (Figure 13), showing that increased seedbug feeding caused increased

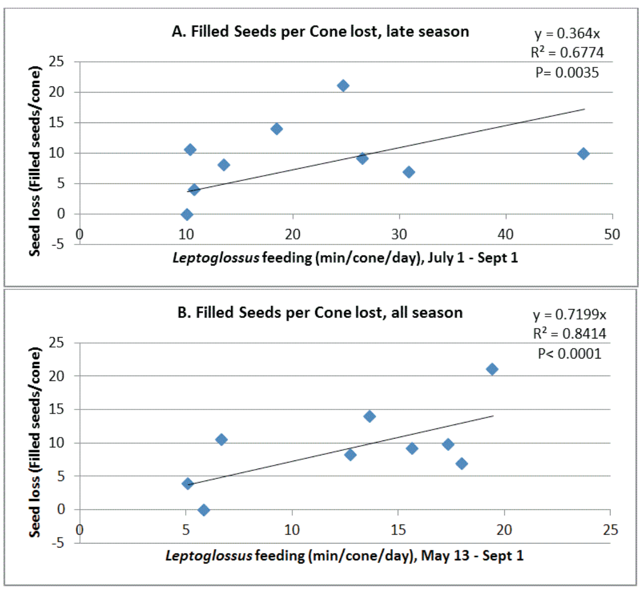

Figure 13. Seeds lost per hour of seedbug feeding. Feeding is combined adults and myphs, feeding on clusters of 3 or 4 cones. For Filled Seeds per Cone Lost, feeding from July 15-Aug30 only is included, since feeding prior to this reduces total seeds, not filled seeds. For the same reason, feeding for % Filled Seeds Lost was season-long: total seeds are used to calculate % filled seeds, so early-season feeding was included.

Early-season feeding has been shown in the past to reduce total seeds by causing the ovules or undeveloped seeds to flatten and fuse to the seed scale, thereby becoming unextractable (Bates et al. 2000).

This experiment conclusively proves that neither temperature nor relative humidity are the reason that enclosing 2nd-year Pli cones in mesh bags increases seedset. Rather, the increased seedset is certainly due in large part to protection from feeding by seedbugs.

seed loss. For Filled Seeds per Cone Lost, late season feeding was used, since feeding prior to this reduces total seeds, not filled seeds. For % Filled Seeds Lost, season-long feeding was used: total seeds are used to calculate % filled seeds, so early-season feeding was included.

Increasing feeding in early season caused an increasing loss in total seeds per cone (Figure 14). Early-season feeding has been shown in the past to reduce total seeds by causing the ovules or undeveloped seeds to flatten and fuse to the seed scale, thereby becoming unextractable (Bates et al. 2000). These data confirm that the more early-season feeding, the more seeds are lost.

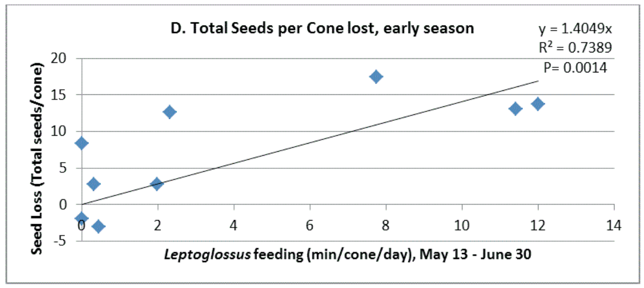

Figure 14. Total Seeds per cone lost per hour of Leptoglossus feeding. Early-season feeding reduces Total Seeds per Cone, feeding until June 30 only was included.

Conclusions

This experiment conclusively proves that neither temperature nor relative humidity are the reason that enclosing 2nd-year lodgepole pine (Pli) cones in mesh bags increases seedset. Rather, the increased seedset is certainly due in large part to protection from feeding by seedbugs. There may be other minor factors associated with the mesh bags, such as direct insolation on the cones, reduced evaporative water loss from cones or nearby needles, or a combination of local factors that protect against whole-tree stress. However, the physiological mechanisms underlying any of these theories are unclear, and there is no evidence to even build a testable hypothesis based on these mechanisms. On the other hand, there is abundant and conclusive evidence that seedbugs are responsible for the prevention of seed loss by mesh bags.

This study confirms many other research projects conducted in BC since 1996, that seedbugs cause seed loss in Pli. In my opinion, we do not need to spend more time and money trying to find out if seedbugs cause seed loss; this fact is thoroughly investigated and proven. Rather, we need to figure out how to manage seedbugs in order to prevent seed loss. Despite the years of research, we still have no efficient means of monitoring, no traps, no novel control tactics, and no registered pesticide. Orchardists sometimes apply Sevin XLR® (carbaryl) against mountain pine beetles or pine sawflies, with poorly studied effects on seedbugs. A new pesticide (Matador®, lambda-cyhalothrin) is currently undergoing registration under the User-Requested Minor-Use Label program of the Pest Management Regulatory Agency. This and a related pesticide are the main products used to control seedbugs in the USA, therefore it may help us manage seed loss due to seedbugs.

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All images by Dr. Ward Strong.

Results of a pesticide trial targeting European pine shoot moth attacks on young ramets in Kalamalka lodgepole pine orchard 230

submitted by Nancy van der Laan, Faye Klassen, Karen Meggait, Gary Giampa, Jim Corrigan

Since 2011, Kalamalka lodgepole pine Orchard 230 has been upgraded by planting approximately 640 small, newly grafted ramets into it. Each ramet consisted of a rootstock sapling to which a single shoot of scion material had been grafted (one year prior to being planted – Figure 1). Given that the 'business end' of each of these future production ramets consisted of a single grafted shoot, they were particularly vulnerable to attack by *Rhyacionia buolina*, the European pine shoot moth (EPSM). One EPSM larvae could kill the graft, effectively destroying this ramet for future cone and seed production.

Figure 1. A recently grafted lodgepole pine ramet showing extent of scion material (the shoot on the left) just prior to being transplanted into Orchard 230. Photo by Nancy van der Laan.

The life cycle of the European pine shoot moth is somewhat complex. Winters are passed as third instar larvae inside mined out buds (Figure 2). In the spring, the EPSM

Figure 2. European pine shoot moth (EPSM) overwintering sites in lodgepole pine buds (left) and three overwintering EPSM larvae removed from another bud (right). Photo by Jim Corrigan.

larvae leave their overwintering buds and bore into newly elongating shoots. The larvae complete their feeding and larval development inside these shoots, thereby killing them. The insects pupate inside the shoots hollowed out by their larval feeding, and the adults emerge from them. Peak adult flights occur from mid-June into mid-July in the Okanagan Valley. Adults lay small inconspicuous eggs on needle fascicles, bark and at the base of buds. On hatching, the larvae bore through the fascicle sheaths and feed by mining inside the needles (Figure 3). Later in the summer, EPSM larvae leave the needles and bore into terminal buds, where they will overwinter. There is one generation per year.

The life cycle of the European pine shoot moth is somewhat complex.

Pheromone traps have been developed for this pest and timing of sprays can be made by monitoring the adult flight.

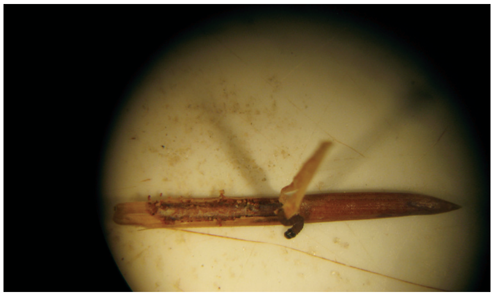

Figure 3. Second instar European pine shoot moth larvae found in mine on a lodgepole pine needle. Photo by Jim Corrigan.

Before the summer of 2013, EPSM attacks on young pine ramets were being managed by physically removing the larvae from their overwintering buds before they could enter the grafts. This job was done biannually in the spring and fall, and each sweep of the orchard required several days of labour by a crew of 2-3 people.

Using information about chemical control options for EPSM in Christmas tree production (Shetlar, 2002), a trial was initiated in 2013 in a section of Pli 230 entirely populated by newly planted ramets. Two rows of young ramets in Kalamalka Pli 230 were sprayed by Karen Meggait on June 27 with the systemic insecticide Dimethoate at a 2% rate. Karen treated two other rows with Malathion (a non-systemic insecticide) at a 0.7% rate on July 18, 2013. Both pesticides were applied with a backpack sprayer and every ramet was treated to runoff. The efficacy of both treatments was compared with two rows of small ramets that were not treated with any pesticide.

The timing of the Malathion treatment was critical. This non-systemic pesticide can only kill EPSM larvae during the time when they are exposed on the outer surfaces of the ramets as they move from needle mining to their overwintering sites inside buds. The timing of application for the Malathion treatment was based on information coming from a website from The Ohio State University (Shetlar, 2002). The pertinent advice was (quote, emphasis mine):

"Pheromone traps have been developed for this pest and timing of sprays can be made by monitoring the adult flight. ***Spray susceptible trees about 10 days after the peak adult catch has occurred.****"*

During mid-October of 2013, and again in the middle of May of 2014, Nancy van der Laan and Faye Klassen conducted surveys of all ramets used in this trial. They recorded the presence and viability of all EPSM larvae found and removed the live larvae from the ramets. Differences between the fall and winter surveys for the numbers of ramets surveyed per treatment (Table 1) were due to mortality and replacement of ramets that took place between the times when the fall and spring surveys were done.

Timing of Observations	Dimethoate treatment	Malathion treatment	Untreated
Fall 2013	N = 72: No EPSM larvae seen 68 Dead larvae 3 Live larvae 1	N = 66: No EPSM larvae seen 64 Dead larvae 2 Live larvae 0	N = 68: No EPSM larvae seen 41 Dead larvae 3 Live larvae 24
Spring 2014	N = 76: No EPSM larvae seen 60 Dead larvae 5 Live larvae 11	N = 69: No EPSM larvae seen 66 Dead larvae 1 Live larvae 2	N = 65: No EPSM larvae seen 15 Dead larvae 2 Live larvae 48

Table 1. Number of ramets observed with European pine shoot moth larvae.

The fall surveys showed that both pesticide treatments had been extremely effective, reducing the number of live EPSM larvae found on treated ramets to virtually zero (Table 1). No evidence of EPSM activity was seen on the majority of the ramets in the four treated rows in October of 2013, while over 35% of the ramets in the untreated rows contained live EPSM larvae at that time. Follow-up surveys conducted in the spring of 2014 reinforced the observations made the previous fall. In particular, very low numbers of live EPSM larvae were found in the rows that had been treated with Malathion during the summer of 2013. This seasonal carry-over effect was expected, as there was no opportunity for EPSM to re-attack ramets between the October 2013 survey and the one done in the spring of 2014. The increased numbers of EPSM larvae observed in the spring surveys in both the Dimethoate and the untreated rows may be because the surveyors were finding EPSM larvae that had not yet moved to overwintering sites in the buds at the time when the October surveys were done. That said, the majority of the ramets treated with pesticides were free of EPSM larvae in the spring of 2014, while approximately 75% of the untreated ramets were hosting live EPSM larvae at that time.

Conclusions

While it was shown to be quite effective, Dimethoate is both expensive and highly toxic to non-target organisms when compared with Malathion. We feel that Malathion treatments can be effective in significantly reducing shoot mortality on newly planted lodgepole pine ramets. The use of Malathion treatments to protect the scion material on young ramets should be less expensive and require less staff time than the existing management option, that being bi-annual physical removal of the EPSM larvae. It is expected that carefully timed Malathion treatments will form an important component of the management plan to control EPSM attacks on newly grafted lodgepole pine ramets. As well, it is expected that Malathion treatments will be applied to control EPSM populations occurring on mature ramets in lodgepole, western white and ponderosa pine seed orchards at the Kalamalka and Bailey Road seed orchards in future growing seasons.

Acknowledgements

The authors would like to thank the entire Kalamalka work crew for their ongoing work to maintain Pli Orchard 230.

Reference

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Megastigmus seed parasitism of North American Cupressaceae

submitted by Jean-Noel Candau and Ashley Dickey

***Megastigmus* seed insects pose issues as native pests, greatly impacting seed production and thereby affecting seed orchard operations and, in some cases, forest sustainability.**

As native pests, *Megastigmus* seed insects pose a variety of forest health issues, greatly impacting seed production and thereby seed orchard operations and, in some cases, forest sustainability. Moreover, international seed trade has introduced several species of this genus in various countries where they became successful invaders. Worldwide, 15 species of *Megastigmus* are known to infest Cupressaceae seeds. Most of these species originate from Western Europe (Figure 1). Surprisingly, only one species (i.e., *Megastigmus thyoides* [Turgeon et al., 1994]) has been reported in the Nearctic where it affects only one host (i.e., *Chamaecyparis thyoides*) although a quarter (33 out of 133) of the Cupressaceae species are native of this region. Similarly, whereas host switching among Cupressaceae species seems to occur in Europe, as described for *M. amicorum* commonly found on *Juniperus* in France but also on *Cupressus* species introduced from California, it has never been reported in North America.

From a pest management point of view, the distribution of this species raises the question of the invasibility of North American Cupressaceae with regards to introduced *Megastigmus* as well as the invasive capacity of these insects. This question was addressed as part of an international research project "*Megastigmus* and Conifers: The Biology of Invasion" (MACBI) which had bases in France and Canada. Since *Megastigmus* seed parasites have a particularly cryptic life cycle and few studies have been devoted to sampling this genus in North America, its distribution in the Neartic needed first to be confirmed.

The first step in this process was to conduct an extensive search for all published material relevant to *Megastigmus* infestation on Cupressaceae species. The analysis of this material did not reveal previous accounts of *Megastigmus* on Cupressaceae in the Neartic region except for *M. thyoides* as previously mentioned.

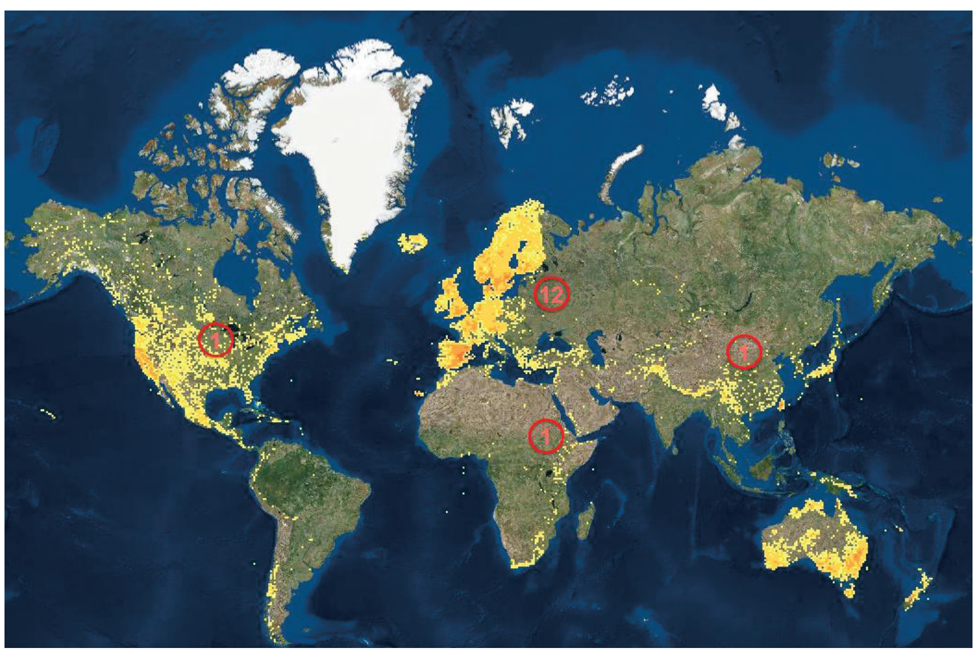

Figure 1. Worldwide distribution of Cupressaceae species (yellow shades) based on occurrence records available through the GBIF network (may not represent the entire distribution) and number of native *Megastigmus* species infesting native Cupressaceae seeds (red numbers).

Simultaneously, a collection of Cupressaceae seeds was organized in North America. Arboreta, seed orchards, botanical gardens and tree seed centers were contacted to provide cones or seed samples (Table 1). Some sampling was also done by the authors. The objective was to sample as many native and introduced Cupressaceae species as possible to test for the possible introduction of non-native *Megastigmus* species.

Collections were made in the summer and fall of 2011, and in the fall of 2012. The sampling protocol consisted in sampling 3 trees per species and location, 10-15 cones per tree when the cone crop was sufficient enough. All the seeds were extracted from the cones and x-rayed to detect the presence of larvae (a sign of possible infestation by *Megastigmus*). Seeds that were identified as potentially infested on the x-rays were drawn from the samples and put in rearing in emergence boxes in the Great Lakes Forestry Centre insectarium in Sault Ste Marie, Ontario. When no emergence had occurred after 2 years, potentially infested seeds were dissected. All larvae found were put in alcohol for genetic analysis.

Over this 2-year study, we extracted and x-rayed more than 100,000 seeds from 50 locations and 47 species (Table 1). We confirmed seed infestation in 3 species of Cupressaceae. Infested seeds of *Chamaecyparis thyoides* were found in cones from the North Carolina Botanical Gardens (Chapel Hill, NC) and the Longwood Gardens (Kennett Square, PA). Both locations had low infestation rates (< 3%). One larva collected in North Carolina was sent for DNA analysis (COI and Cyt b). The comparison of the sequences with a reference sample identified as *M. thyoides* indicated that the larva found in our sample was indeed *M. thyoides*. *M. thyoides* was first described from samples collected in 1994 in North Carolina (Turgeon et al., 1997). The emergence of some females in the Longwood Gardens sample confirmed the presence of *M. thyoides* (identification performed by J. Turgeon). *Chamaecyparis obtusa* seeds collected at the Arnold Arboretum and the Morris Arboretum were infested (8% and 19.5% respectively). Samples from the New York botanical garden had no infestation. *Megastigmus chamaecyparidis* and *Megastigmus cryptomeriae* are known to infest *C. obtusa* in Japan but to our knowledge, these species have never been recorded in North America. The analysis of larvae DNA (COI) showed that the samples from Massachusetts (Arnold) and Pennsylvania (Morris) are of the same species (sequences are identical) and that this species was neither *M. thyoides* nor *M. cryptomeriae.* The comparison of DNA sequences to existing phylogenies and GenBank blast did not return any positive result. However, it is worth mentioning that *M. chamaecyparidis* was not present in these databases, so it is not possible at this point to confirm that the species found on *C. obtusa* is indeed *M. chamaecyparidis*. Unfortunately, after 2 years of rearing, nothing has emerged from the seeds so it has not been possible to identify the species morphologically. We have put a request to our Japanese colleagues to obtain adult *M. chamaecyparidis* so we can perform additional DNA analyses in an attempt to identify the species found in North America. Finally, *Cryptomeria japonica* seed samples collected at the Morris arboretum (PA) and the New York Botanical Garden (NY) showed infestation rates of less than 1% and up to 15% respectively. *Cryptomeria japonica* is infested by a species of *Megastigmus* (*M. cryptomeriae*) in its native Japan and in China, but this species has never been recorded in North America. The DNA analysis of a sample collected at the Morris arboretum indicates that the species is very likely *M. cryptomeriae*. Incidentally, the analysis of the samples revealed that *Juniperus communis* and *J. virginiana* collected at the Shorts Creek Canyon (BC) and the New York Botanical Garden respectively, were both infested by the Juniper seed chalcid, *Eurytoma juniperina*.

A collection of Cupressaceae seeds was organized in North America. Arboreta, seed orchards, botanical gardens and tree seed centers were contacted to provide cones or seed samples.

Two species of parasitoids were also found in our samples: a *Torymus* species identified as *Torymus bedeguaris* found on *Thuja plicata* at the Saanich Forestry Centre (BC), and *Aprostocetus* spp. collected from *Juniperus communis/horizontalis* at Shorts Creek, BC.

According to our survey, *Megastigmus* seed insects parasitize only 3 out of 47 species of Cupressaceae tested in North America.

Callitropsis nootkatensis	*Cupressus bakeri*	*Cupressus sempervirens*	*Juniperus rigida*	*Sequoia sempervirens*
Calocedrus decurrens	*Cupressus chengiana*	*Juniperus ashei*	*Juniperus sabina*	*Taxodium disticum*
Chamaecyparis lawsoniana	*Cupressus duclouxiana*	*Juniperus bermudiana*	*Juniperus scopulorum*	*Thuja occidentalis*
Chamaecyparis nookatensis	*Cupressus himalaica*	*Juniperus chinensis*	*Juniperus squamata*	*Thuja plicata*
Chamaecyparis obtusa	*Cupressus forbesii*	*Juniperus communis*	*Juniperus virginiana*	*Thuja standishii*
Chamaecyparis pisifera	*Cupressus formosana*	*Juniperus formosana*	*Juniperus xpfitzeriana*	*Thujopsis dolabrata*
Chamaecyparis thyoides	*Cupressus glabra*	*Juniperus horizontalis*	*Metasequoia glyptostroboides*	*Xanthrocyparis nootkatensis*
Cunninghamia lanceolata	*Cupressus goveniana*	*Juniperus occidentalis*	*Platycladus orientalis*	
Cryptomeria japonica	*Cupressus macnabiana*	*Juniperus phoenicea*	*Sciadopitys verticillata*	
Cupressus arizonica	*Cupressus nootkatensis*	*Juniperus pingii*	*Sequoiadendron giganteum*	

Table 1. List of Cupressaceae species sampled for seed insect damage in 2011 and 2012 in North America (native species are underlined).

In conclusion, according to our survey, *Megastigmus* seed insects parasitize only 3 species of Cupressaceae out of 47 tested in North America. We confirmed that *Chamaecyparis thyoides* is the only native species affected by a native seed insect, *Megastigmus thyoides*. The infestation of two Cupressaceae species introduced from Asia (i.e. *Chamaecyparis obtusa* and *Cryptomeria japonica*) is a new finding. Despite a fairly extensive survey, we have not been able to detect any host switching from native to introduced host species or vice versa. At least 3 hypotheses could explain the relative scarcity of Cupressaceae seed infestation in North America. In the first hypothesis, Cupressaceae seed feeders related to Nearctic ancestors of *Megastigmus* existed but disappeared. This hypothesis is supported by the presence of at least one native *Megastigmus* on Cupressaceae in the Nearctic. The second hypothesis suggests that the separation of Nearctic and Palearctic Cupressaceae occurred before the appearance of the Chalcidoidae family as we know it. This hypothesis is supported by a recent phylogeny of Cupressus (Little 2006) showing that the genus is split in 2 clades corresponding to New World and Old World. The third hypothesis is based on a recent phylogeny of *Megastigmus* that puts *M. thyoides* in the same group as the species infesting Pinaceae as opposed to the group infesting Cupressaceae (Auger-Rozenberg et al. 2006). This finding suggests that the only native *Megastigmus* infesting Cupressaceae in the Neartic was originally on Pinaceae. A better understanding of the mechanisms involved in the distribution of these insects will require additional work to complete and compare the phylogenies of both the hosts and the parasites.

Finally, the relative low number of introduced *Megastigmus* species may reflect that Cupressaceae are not as commercially important in North America as other tree families, so slower trade could have held back an invasion of *Megastigmus*. Most imported or introduced tree species also do not arrive as adults, but as seeds or seedlings. If *Megastigmus* is introduced in seeds brought to North America, it would have to find a suitable host upon emergence. As it is not likely to find its original host, another suitable host would have to be close by and the insect would have to be non-host specific, that is having the ability to recognize a different, but similar Cupressaceae species as a host and be sufficiently compatible with it. In the case of Cupressaceae, the difficulty is compounded by the wide variation in cone morphology and phenology within this family. However, further increase in global tree seed trade, including Cupressaceae, is likely. As more introduced species mature into cone-bearing individuals and as the number of imports increases, the risk of *Megastigmus* species managing to survive importation, find suitable hosts, and establish populations inevitably grows, despite the efforts of import regulation bodies.

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Disease-Resistance Screening Is Key To Saving Whitebark Pine (Pa)

submitted by Michael Murray, Jun-Jun Liu and Charlie Cartwright

During the past several years, demand for disease resistant whitebark pine (*Pinus albicaulis*) seedlings has grown steeply in Canada.

In 2012, whitebark pine was designated as a federally endangered species in Canada.

During the past several years, demand for disease resistant whitebark pine (*Pinus albicaulis*) seedlings has grown steeply in Canada. Seedlings are used for restoration by Parks, mines, and First Nations. Burned, disturbed, and harvested Crown land (public acreage) is increasingly being re-planted with whitebark pine. In 2012, whitebark pine was designated as a federally endangered species in Canada. With a federal recovery strategy being drafted now, it is likely that the promotion of disease-resistant planting stock will be a key component of the strategy.

Whitebark pine occurs at high elevations and often provides a keystone role for sustaining wildlife, mountain scenery, and hydrologic balance. Its federal endangered status is due primarily to impacts from the introduced white pine blister rust disease. The development of seedlings able to survive the disease is crucial for the pine's future in BC. Fortunately, the quest for identifying disease-resistant whitebark pine trees has been bolstered recently. There are at least three tandem efforts occurring in BC: genomics testing, field screening, and controlled inoculations. These projects are receiving partial funding from Genetic Conservation Technical Advisory Committee (GCTAC) of the Forest Genetics Council of BC.

Genomics

Genomics research is being conducted by Jun-Jun Liu (Canadian Forest Service) and Richard Hamelin (Univ. of BC) who are investigating transferability of western white pine genetic markers into whitebark pine. So far, we have verified more than 200 western white pine markers. Dr. Liu believes that at least 50% of them would work in whitebark pine. In addition, we hope to verify some markers in the whitebark pine populations.

We have extracted genomic DNA from 11 Kootenay BC seedlots and some Oregon and Washington seed-lots. The next step is to figure out how many markers and how many seedlings will be put into SNP genotyping. Hopefully, we can get some insight into whitebark pine genetic diversity first this year and resistance association later in coming years.

Controlled Inoculations

Inoculations of whitebark pine families in BC took place last August (2013) at the Kalamalka Forestry Centre in Vernon. This effort has focused on 40 families from the Kootenay region with results (i.e. identification of disease-resistant families) expected over the next five years. Meanwhile, demand continues for further screening for other regions in BC. Thankfully, new funding through the GCTAC will permit work to continue. In February, the US Forest Service Coeur d'Alene Nursery provided us with cuttings of *Ribes nigrum* ('Blackdown' black currant) to enhance our capabilities. Our plan is to inoculate 40 additional families per year for the next three years. Seedlings will be collected by multiple jurisdictions such as national and provincial parks and possibly mining companies who have expressed an interest in using whitebark pine to rehabilitate their high-elevation impacts. The coordinators for controlled inoculations are Michael Murray and Ward Strong (MFLNRO).

Field Screening

Our field screening project is a comprehensive parent tree testing and rust resistance screening effort. The goal is to test 500 parent trees collected from 50 populations from throughout the range of whitebark pine in BC and the United States. Eight long-term field trials will be established to assess family level resistance to white pine blister rust. The result for this project will be the identification of parent trees with high levels of resistance which can be used for restoration efforts. Charlie Cartwright (MFLNRO) is the lead coordinator.

All our work has benefited through the close collaboration with our friends in the US Forest Service who have shared technical knowledge, *Ribes*, and whitebark pine families (for comparing results): Dorena Genetic Resource Center, Oregon, Institute of Forest Genetics, Placerville, California, and Coeur d'Alene Nursery, Idaho. Our efforts are on-going. No operational funding (e.g. base funding) has been readily available. However, these multi-year projects are expected to continue with a steady stream of soft funds already earmarked through 2019 or longer.

Figure 1. Blister rust often kills tree tops first, thus reducing cones available for regeneration and wildlife foraging.

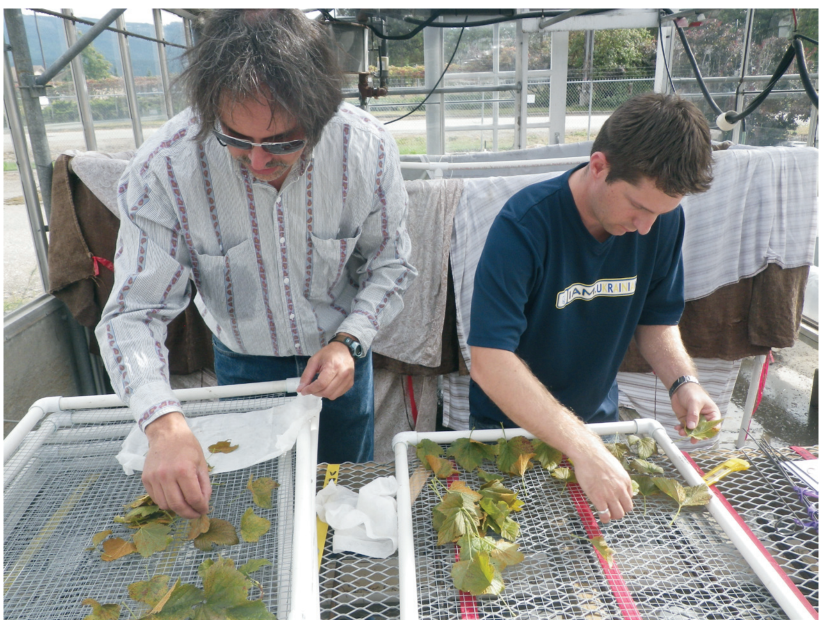

Figure 2. Michael Murray and Nick Ukrainetz placing *Ribes* leaves (with inoculum) over whitebark pine seedlings for controlled inoculation at Kalamalka Forestry Centre, 2013.

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Screening Whitebark Pine for Blister Rust Resistance

submitted by Charlie Cartwright, Nick Ukrainetz and Michael Murray

The primary factor considered in site selection will be the presence of blister rust based on the occurrence of the alternate host and history of past infection in the surrounding stand.

Whitebark pine is a slow growing, shade intolerant tree of the high Coastal and Rocky Mountains. It generally occurs in upper reaches of the Mountain Hemlock and Engelmann Spruce Subalpine Fir zones, as well as into the alpine as krummholz. Though its slow growth and wind swept form result in a tree with little timber value, it is classified as a keystone species because of its complex and vital interactions with other biota, and its importance in forming forest communities where otherwise none would exist. It has become a conservation concern experiencing catastrophic population declines over much of its range due largely to decimation by white pine blister rust (*Cronartium ribicola*), but also mountain pine beetle (*Dendroctonus ponderosae).* Human activities such as wildfire suppression, mineral extraction and recreational development have also had negative impacts.

In 2012, as a result of high mortality whitebark pine was listed as an endangered species under the federal Species at Risk Act (SARA) on the recommendation of a federal committee that predicted that it would be reduced to as little as a quarter of its original range without action. Listing has direct consequences for federal lands, including developing of a recovery plan, but several clauses of the SARA make it incumbent on the provinces to support the national action. 56% of the species range is in Canada, with 47% of that occurring in BC with the rest in Alberta. Alberta already has its own recovery plan in place while in BC whitebark is blue listed through the BC Conservation Data Centre of the Ministry of Environment making it incumbent on land managers to foster its preservation. The federal plan is at the draft stage, but has already stressed that identifying trees resistant to blister rust for restoration efforts is a key component for recovery.

Finding white pines with resistance has been approached in two basic ways. The first is to apply a well-calibrated spore load in a controlled environment and hold seedlings for observation for several years, remarking spotting on leaves due to infection, development of cankers and survival. The alternate to this is to plant seedlings out in trials in the wild, assuming that the disease is pervasive and that creating a disease garden is unnecessary. Field testing of provenances with family structure on a broad array of test sites across the province has the additional value of elucidating species genetic architecture and patterns of adaptation to site. As well, long term trials are also necessary to gauge the durability of rust resistance over time and responses to climate change.

Given the limited resources currently available, it was decided field trials, where most tasks are done on contract, would be an appropriate supplement for limited controlled inoculation runs. Field screening was also selected based on lower cost, though an exchange with USDA Region 6 permits some families to be intensively tested in America, and controlled environment screened parents of theirs to be included in our field trials. Our own controlled environment rust screening with a subset of parents has already commenced at the FLNRO Kalamalka Forestry Centre.

The proposal for funding of the field trials was presented to the Genetic Conservation Technical Advisory Committee (GCTAC) of the Forest Genetics Council of BC (FGC), and a scaled down version was eventually funded; (field testing is a departure from previous activities and priorities for spending are gravely considered). The plan entails 2 series of 4 test sites each with 250 parent trees having the goal of identifying resistant provenances and parents from which seed could be collected in the future. From studies by the USDA Forest Service it was found that rust resistance was more common in whitebark pine than other white pines. A selection proportion of 1 in 10 trees might provide the required level of rust tolerance to allow progeny to survive on the landscape. From other studies with the species it was found that geographically based variability is limited or at most moderately common, so that one or two seed zones for BC are likely to suffice.

Currently open-pollinated seed has been collected from 474 individual trees, representing 44 populations. Parent trees were tagged in the field and geographic coordinates and health information collected. The seeds of each tree are assessed for quality by x-ray, and the number sown adjusted on that basis. Procedures for stratification of seed is one of the most complex amongst all conifers with a soak of seed in mesh bags in a sanitizing peroxide solution for 1 to 2 hours, followed by 2 to 4 days imbibition in running water with extra aeration added by an aquarium pump. The bags of seed are then packed in sterilized sand and held at warm temperatures for a month, followed by 3 months at 2 to 4^{O} C. Prior to sowing, seed are scarified which involves nicking the end of the seed from which the radicle will emerge. The seed are sown into 2 styro blocks with 77 cavities from which assumed 80 plants can be extracted. Seedlings will be grown for two seasons and will be hot-lifted for summer planting if test site soil moisture permits, but otherwise fall planting will be undertaken.

The first series of tests will be established in 2015 with the second series being planted two years later. Control seed lots with known levels of resistance will be used as reference markers across sites and a group of 20 to 30 common families will be used in both series of tests to allow results to be standardized. The primary factor considered in site selection will be the presence of blister rust based on the occurrence of the alternate host and history of past infection in the surrounding stand. Secondary factors include

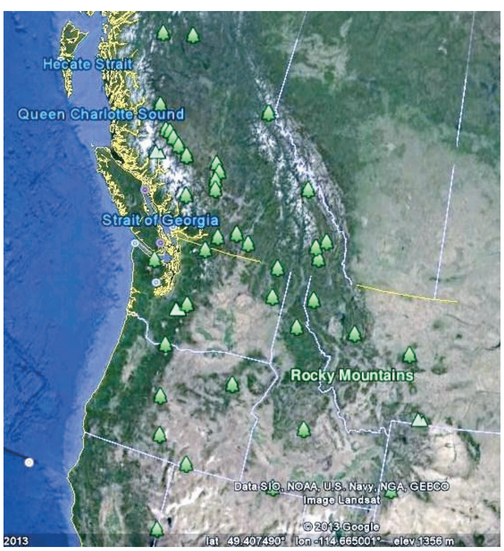

Figure 1. Populations represented in the first series of trials.

access, uniformity, and climatic separation. This is to ensure that resistance is durable across the range of conditions in which the species occurs; similarly seed sources are wide spread to assure provenance variation in rust resistance is captured. Single tree plots using a randomized incomplete block (alpha) design with eight sets of 30 to 32 families per set and 20 replications will mean each test site is about a hectare given 1 x 1.5 m spacing. Close spacing is used in anticipation of high mortality. It is hoped that half to 3 quarters of plants will survive which should suffice given moderately high family heritability for resistance. Backward parental selections will be based on estimated rust resistance breeding values that are stable across sites. As well, heights will be measured to assess vigour.

To date 240 families were sown in March (2014) representing 30 populations (Figure 1). Germination by family has averaged about 50% but ranged widely by seed source and family (Figure 2). Nursery height growth will be assessed in the fall and again when growth ceases at the end of the second summer. Individual trees will be tagged at that point and packaged for shipping to planting sites. Survival checks will be made annually as well as test maintenance as required. About 5 years after out-planting, it is expected that rust resistance may be estimated and improved seed for restoration projects can be collected from the parent trees in the wild. Scion will also be collected from those plants so that they may be preserved. As well, a better idea of seed transfer limits will be available and action can be taken to preserve this valuable species.

Figure 2. Whitebark pine seedlings in early development.

Field trials for whitebark pine entails 2 series of 4 test sites each with 250 parent trees having the goal of identifying resistant provenances and parents from which seed could be collected in the future.

Whitetail Lake Whitebark Pine Seed Production Area

submitted by Don Pigott, Randy Moody and Michael Murray

Assessing stand health and collecting seed from whitebark pine trees that may be resistant to white pine blister rust can improve the chances that restoration in high elevation habitats will succeed.

Background

Whitebark pine (*Pinus albicaulis*) is an uncommon five-needle pine growing at higher elevations in western North America from California to British Columbia. At its upper elevation limit it is generally considered to be a short, slow growing species, but at lower elevations it can attain commercial dimensions.

Currently, interest in the status, preservation, and restoration of this species has intensified due to increasing mortality and lack of regeneration as a result of the mountain pine beetle epidemic, white pine blister rust, and its displacement by more shade-tolerant species. The British Columbia Conservation Data Centre lists the conservation status of whitebark pine as "Blue" (special concern). Blue-listed species are those which are not immediately threatened with extinction, but are of concern because of characteristics that make them particularly sensitive to human activities or natural events. Whitebark pine is a Threatened species in Alberta, and has also been added to Schedule 1 (Endangered) under the Federal Species at Risk Act because of the rapid decline in populations over the past several decades, and a Federal Recovery Strategy is currently being drafted. Whitebark pine is considered to be a keystone or foundation species in subalpine ecosystems because a large number of other plant and wildlife depend upon its existence, and it plays an important role in retaining snow and water on site, reducing erosion and influencing stream headwater hydrology.

The Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) has surveyed some whitebark pine stands across its range in BC to quantify levels of white pine blister rust infection, and possibly identify resistant trees.

Seed collections have been made throughout its range in British Columbia for *ex situ* gene conservation, although only a few collections have been made between Cranbrook and Golden in the East Kootenays due to infrequent cone crops, and the absence of easily accessible stands. This area has been severely impacted by both mountain pine beetle and white pine blister rust, and whitebark pine is often harvested together with target forestry crop species, such as lodgepole pine, despite its low commercial value.

Although seed has been collected for *ex situ* conservation, and possibly provenance research at some future date, little seed has been available for *in situ* conservation projects due to the high cost of collections. There is also a significant demand for forestry, mining reclamation, and restoration projects.

Many stands which are currently of cone bearing age (40 years+) may be impacted by mountain pine beetle and white pine blister rust, which may kill these mature trees. Disease-resistant seed sources are valuable for reforestation initiatives since many seedlings die from white pine blister rust. Assessing stand health and collecting seed from trees that may be resistant to this disease can improve the chances that restoration in high elevation habitats will succeed. The USDA Forest Service has had great success in their research and breeding programs to produce whitebark pine seedlings with heritable disease resistance.

In order to maintain a healthy, diverse, and resilient forest ecosystem at higher elevations it is essential to ensure that keystone species such as whitebark pine continue to be well represented. It is generally accepted that a diverse mix of species adapted to the site is essential to buffer the possible negative impacts of climate change. This can be partially achieved through conservation projects that maintain or improve the current status of whitebark pine, or ensure that seed is available for *in situ* projects such as restoration planting.

In the Findlay River area, east of Canal Flats there is a 60 hectare vigorous 20-30 year old stand of mixed whitebark and lodgepole pines. The stand was harvested in 1992 and lodgepole pine was planted in 1993. There is a mature stand adjacent to the young stand which consists of lodgepole pine, subalpine fir, Engelmann spruce, and whitebark pine. The MFLNRO has a permanent forest health monitoring plot in this mature stand. In the summer of 2010, while visiting the forest health plot, we observed male flowers on several of the trees in the adjacent young stand which is somewhat precocious for whitebark pine.

A seed production area (SPA) is defined as a stand of better than average quality that is upgraded and opened up by removal of undesirable trees, and then cultured for early and abundant seed production. In BC, the establishment of seed production areas by both the BC Forest Service, and some forest companies began in 1957 due to an increasing planting program, and the need to provide seed of know provenances, and better genetic quality than had been available previously. These SPAs were established in 20-40 year old natural stands (cone–bearing age) in representative areas in many regions. The SPAs established for coastal Douglas-fir proved to be the most successful, but were generally abandoned as seed orchard seed became available.

In July 2012, with the cooperation of Tembec (now Canfor) two hectares of the stand was pre-commercially thinned (spaced) to remove all species other than whitebark pine, and any whitebark pine of poor phenotype, or with obviously terminal blister rust cankers. The spacing contractor had many years of experience with western white pine, pruning branches to eliminate infected branches and reducing the chances of infection, as well as excising stem cankers. As there will undoubtedly be more infections develop over time, the minimum target spacing was 1x1 metres to allow for continual rogueing. The remaining trees are well-spaced so that full crowns develop to encourage more abundant flowering. Various standard cone induction treatments may be applied including fertilization, girdling and possibly the application of flower inducing gibberellin plant hormones. The success or

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Figure 1. Young whitebark pine stand after spacing in 2012. Mature stand in background.

failure of these trials will be useful should seed orchards with tested material ever be established.

Hopefully by removing the whitebark pine trees that are badly infected by white pine blister rust, the level of resistance in the seed produced will increase, since more susceptible parents will be eliminated.

This project also provides an opportunity to monitor the development and health of a young whitebark pine stand over a long period of time, and serve the needs of *in situ* whitebark pine conservation in this area. It will also provide useful growth and yield information. The adjacent un-treated portion of the stand will serve as a control.

Shortly after thinning, a health transect showed approximately 13.5% infection in the treated area while the sample in the un-treated area was 14%. A survey of the mature whitebark pine in the adjacent mature stand indicated 21%.

In August 2014, three 3.99 metre plots were randomly established to assess the status of the trees. Ninety-two percent of the trees had no sign of white pine blister rust. Two percent

The random and singular distribution of most of the trees suggests that the trees originated primarily from natural seed-fall, albeit many clumps likely originated from either squirrel or nutcracker caches.

had branch infections, and 6 percent had stem infections. The average dbh was 3 cm with a range of 1- 4.5cm. The average height was 182 cm with a range of 40 - 330 cm. The 2012 growth increment averaged 8 cm with a range between 0 and 18cm.

The average stocking for the three plots was 3300 stems per hectare. Five whitebark pine trees were cut down as close to the ground as possible, in the un-spaced control. As suspected all five trees were established prior to the harvest of the previous mature stand. They ranged in age from 26-32 years old at a stump height of between 2 and 5 cm.

The random and singular distribution of most of the trees suggests that the trees originated primarily from natural seed-fall, albeit many clumps likely originated from either squirrel or nutcracker caches. Unfortunately, data on the species composition of the original stand is not available, but it was probably similar to the existing mature stand which has approximately 20% whitebark pine.

Overall the stand appears healthy and robust. There were no observed negative effects such as sun scald, chlorosis, or reduction in increment as a result of the spacing.

Currently there are two separate pilot initiatives to screen putatively resistant selections for white pine blister rust. Hopefully one day enough parents will be available to establish a seed orchard to provide resistant material for operations. This seed production area could provide valuable insight into seed orchard management techniques, as well as being an example *in situ* genetic conservation, and perhaps be an interim source of seed for the region.

Whitebark Pine Seed Reserves

submitted by Dave Kolotelo

The provincial government seed bank of whitebark pine resides at the Provincial Tree Seed Centre in Surrey, BC. Some of the collections have been donated, but funds for the sourcing and caging, collecting, and processing of the majority of these valuable crops have been provided through the Genetic Conservation Technical Advisory Committee (GCTAC) of the Forest Genetics Council of BC. Funding was provided for crops collected in 1999, 2007, 2010, 2011, 2012, and 2013 with no appreciable crop identified this past year. This seed bank is composed primarily of individual tree collections to allow for the identification of blister rust resistant individuals, to conduct population genetics or other studies on individual trees and to enable one to customize seed for sowing based on new selection criteria. The seed bank is composed of 562 individual tree collections distributed across 37 populations (Figure 1). The total inventory equates to over 54 kilograms of seed which is equivalent to over half a million seeds. Most populations are composed of ten parent trees with Mt Sidney Williams being represented by the maximum of 37. The highest priority for additional collections lies within the Rocky mountain portion of the range north of Kicking Horse pass.

The seed bank is composed of 562 individual tree collections distributed across 37 populations.

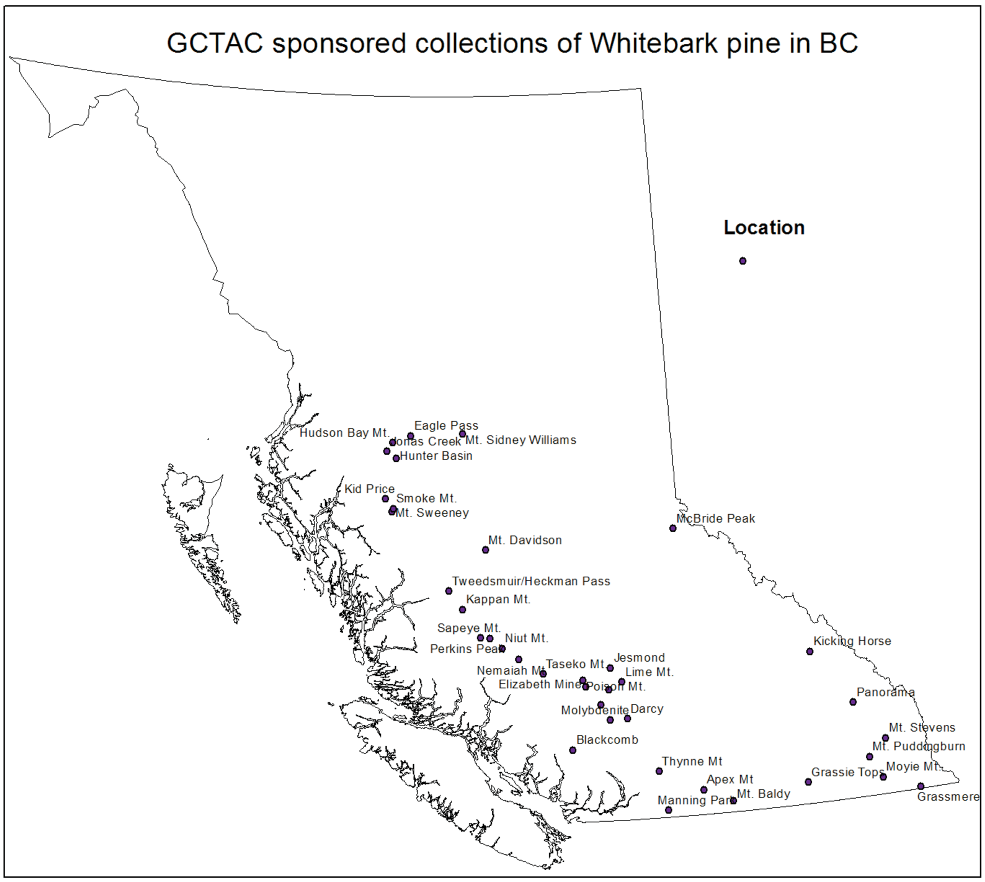

Figure 1. Populations of whitebark pine in the provincial genetic conservation seed bank. (Figure courtesy of Dr. Tongli Wang and the UBC Centre for Forest Conservation Genetics)

Two current ongoing activities with these collections are i) continuing to determine non-destructively through water activity measurement that the seed is dry enough for freezer storage and ii) estimating the viability and relative embryo length through digital x-ray analysis.

Sources from BC populations range over almost six degrees of latitude, 12.5 degrees of longitude and over 1300 m in elevation (Table 1). These basic co-ordinates for each of population were entered into ClimateBC version 5.04 (http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateBC) to produce a wide variety of climatic variables, a few of which are displayed in Table 1. These variables indicate the severity of the climate this species exists in, but also the large range of some of these variables exhibited in natural populations of whitebark pine. The ability for the species to survive in cold, harsh environments is clear with a mean annual temperature (MAT) of -0.2°C and an average of only 67 days or just over two months without frost. This frost-free period ranged from a high of 110 days on Grassie Tops to a low of 40 days on Sapeye Mt. The average minimum temperature over the past 30 years for these 37 populations is -40.5°C.

Precipitation averaged 1061 mm and ranged from a high of 1826 to 504 mm. The distribution of precipitation was generally about one-third during the growing season and two-thirds snow in the winter. At the extremes, summer precipitation accounted for 50% of the total at Mt. Stevens (also the coldest site) and only 18.9% at the Taseko Mt. site. The largest proportion of precipitation as snow (74.2%) was at the Kicking Horse site and the minimum (53.8%) at the Lime Mt. site.

	Longitude (°)	Latitude (°)	Elevation (m)	MAT[1] (°C)	FFP (days)	MAP (mm)	P % in Summer	P% as Snow
AVERAGE	51.57	-122.37	1858	**-0.2**	**67**	**1061**	**30.5**	**64.6**
MAXIMUM	54.91	-114.94	2340	1.8	110	1826	50.0	74.2
MINIMUM	49.02	-127.43	1004	-1.8	40	504	18.9	53.8
RANGE	5.88	12.49	1336	3.6	70	1322	31.1	20.4

Table 1. Geographic and climate variables describing the location and climatic mean and range of the 37 whitebark pine populations in the provincial seed bank.

Two current ongoing activities with these collections are i) continuing to determine non-destructively through water activity measurement that the seed is dry enough for freezer storage and ii) estimating the viability and relative embryo length through digital x-ray analysis. With these small and valuable samples it does not make sense to germination test and consume this valuable seed to estimate the germination capacity as single-seed sowing or transplanting are common techniques used with this valuable seed. There is currently no standard test regime for whitebark pine (in progress), although commonly one month of warm stratification and three to four months of cold stratification have been used. Recent work by Lindsay Robb from Alberta indicates that an extended warm treatment may also improve germination and the exact duration may be something that is informed by the degree of embryo elongation provided by x-ray analysis.

The summary focuses on seed that is part of the provincial seed bank, but we are also storing about 26 kg of seed for other agencies including Parks Canada, BC Parks, the Bulkley Valley Research Centre, the Wetzin'Kwa native band, New Gold and BC Timber Sales. Some of these collections will become registered seedlots for use on crown land. For information on the availability of whitebark pine seed for research or restoration activities, please contact me directly as each request is evaluated individually based on its own merits and probability of success.

[1]MAT= Mean Annual Temperature; FFP=Frost Free Period; MAP=Mean Annual precipitation; P=Precipitation

British Columbia Seed Orchard Association Meeting, Salmon Arm, BC June 17-18, 2014

submitted by Tia Wagner

The BC Seed Orchard Association (BCSOA) hosted its biennial meeting in Salmon Arm from June 17 – 18, 2014. This was a joint meeting with delegates from the Northwest Seed Orchard Manager's Association (NWSOMA, USA) and the Alberta (AB) Tree Improvement community in attendance. There were a total of 95 people who attended, some from as far away as Norway and Florida, resulting in a diverse knowledge and experience base.

The first day of the meeting was dedicated to field tours at Skimikin Nursery Ltd. and Skimikin Seed Orchards (Ministry of Forests, Lands and Natural Resource Operations - MFLNRO) located just outside of Salmon Arm. The focus of the meeting was the technical aspect of the seed orchard business; therefore many of the field tour talks were geared towards field technicians and innovative ways to accomplish orchard maintenance tasks. Due to the variety of participants there were many ideas and thoughts shared. In addition, an overview of the breeding program in BC, pest management in orchards, growing A-class seed in the nursery, and the assisted migration trials were presented.

The following day was full of informative presentations on tree improvement and seed orchard management with delegates from BC, AB, and NWSOMA speaking. Participants got an overview of the future of tree improvement in BC, in terms of supply and demand, climate impacts, and growing A-class seedlings on the landscape. Speakers from AB and NWSOMA gave excellent presentations on tree improvement in their areas and initiatives they are taking to increase gain and improve crop yields. The highlight for many was an interactive presentation on nutrient deficiencies in conifer plants with a group exercise on diagnosing tree health based on visual cues and nutrient analysis reports.

In addition to presentations, a delegate from the NWSOMA facilitated a round table discussion where participants could ask for advice on various orchard management issues and share successes or innovations occurring at their site. This allowed for some interesting topics and discussions as well as a general transfer of knowledge and ideas.

The organizing committee would like to give a big thank you to the employees from Skimikin Seed Orchards, Kalamalka Seed Orchards, PRT Growing Services, and Vernon Seed Orchard Company for making this meeting a success. It was a great opportunity to network with other site managers and technicians to exchange experiences and gain knowledge. The next meeting will be held in the Vancouver area in 2016.

It was a great opportunity to network with other site managers and technicians to exchange experiences and gain knowledge.

Figure 1. BCSOA 2014 attendees at Skimikin Seed Orchards.

Saanich Forestry Centre features the oldest seed orchard in Canada, established in 1964, which produces seeds selected to ensure healthy, resilient trees for the future.

MILESTONES

Saanich Forestry Centre 50th Anniversary

submitted by Amy Spencer and Annette van Niejenhuis

The Saanich Forestry Centre, Western Forest Products Inc. (WFP) celebrated its 50th anniversary on September 9, 2014. For fifty years, the Centre has supported a coastal tree breeding program that has significantly enhanced reforestation on the B.C. coast.

The event highlighted the history of the Centre, Western's dedication to sustainable forest management, and the company's ongoing capital investments in timberlands and manufacturing operations. Western is the only forest company on the coast to own, operate, and continually invest in a seed orchard, tree nursery, harvesting operations, and sawmills.

The Centre features the oldest seed orchard in Canada, established in 1964, which produces seeds selected to ensure healthy, resilient trees for the future. Cone-bearing trees supply superior tree seed for Douglas-fir, western red cedar, hemlock and sitka spruce, as well as cuttings for yellow cypress.

It also has a nursery that grows 3.3 million seedlings per year for replanting. The Centre's nursery has produced 89 million seedlings since it began production in 1981. These seedlings have contributed to new forest stands that are more productive, and more resilient.

WFP Chief Foresters past and present; members of local, provincial and federal government; Government of BC forestry staff; First Nations representatives; and WFP staff attended the anniversary event.

The Honourable Steve Thomson, Minister of Forests, Lands and Natural Resource Operations (FLNRO) toured the facility, and thanked Western for its contributions to sustainable forest management.

Western's CEO Don Demens made the following statement at the event:

> "Our mission is to create a globally competitive, sustainable business that operates profitably through business cycles, for the benefit of shareholders, employees and the communities in which we operate.
>
> The fifty years of sustainable management of our coastal forests, and the ongoing investments we make in our timberlands and manufacturing, demonstrates our commitment to B.C."

Western also celebrated its history of making investments in B.C. In the past three years alone, the company has invested more than $165 million in the business, primarily to upgrade facilities and increase competitiveness.

The Saanich Forestry Centre supports healthy and resilient forests, which supports local communities and citizens, and the forestry industry's future growth and prosperity.

Figure 1. FLNRO Minister Steve Thomson in WFP seedling nursery.

Figure 2. WFP CEO Don Demens and FLNRO Minister Steve Thomson.

Vernon Seed Orchard Company (VSOC)[1] celebrates 25 years

submitted by Dan Gaudet

It seems like yesterday for me that I started at VSOC, yet as I stood at the company's 25th year luncheon and looked around, I could not help but think of all the people I have met over the years who have been involved in tree improvement and have gone unnoticed or left us too soon.

The word 'family' was used often by the speakers that day and it reminded me of the joy of working with Ministry staff on a daily basis, always with the same goals and successes.

The tireless work ethic from Seed Orchard staff, tree breeders, and Tree Seed Center representatives within these past 25 years has made all of us at VSOC proud.

Research scientist Barry Jaquish said it well when he reminded us of how intricate Ron Pearson was when gridding out our first rows for orchards; he knew then we were serious about the task we had been given.

Tim Lee and I often discussed at length on long road trips that being in this business was the best job in the world. We both agreed that we had never once dreaded coming to work.

We have traveled from China, New Zealand, Sweden, and Southern US, and can easily state that British Columbia, Canada has the best tree breeding programs, the best Tree Improvement staff, and the best tree seed extraction facility, bar none, across the world.

Myself and the rest of us at VSOC recognize that none of this could have been possible without the efforts of the founders of Tree Improvement and all who have been involved in this great business.

As I move into my 26th year at VSOC I can only hope to continue to be engaged with the future Tree Improvement staff, knowing that the next 25 years will be even greater than the first.

Figure 1. Aerial view of Vernon Seed Orchard Company.

[1]Vernon Seed Orchard Company (VSOC) is a joint venture company owned by Canadian Forest Products Ltd., Winton Global Lumber Ltd. and West Fraser Mills Ltd. Our objective is to provide quality seed to all licensees in the Seed Planning Units (SPU) for the Northern and Central Interior. Seed is available for the three main harvest species: white spruce, lodgepole pine and Douglas-fir. Our thirteen orchards are located on a large parcel of land overlooking the City of Vernon at the northern end of the Okanagan Valley in B.C. This site has many benefits, most importantly the soil, climate and availability of the city spray irrigation program. These all have positive effects on the supply of seed for the interior Seed Planning Zones. VSOC has a second site located in Quesnel B.C. This site is in the process of being re-established as a lodgepole pine seed orchard. As the home region of the lodgepole pine selection, Quesnel has the desired climate for this particular species.

AWARDS

Dr. Sally Aitken awarded the IUFRO Scientific Achievement Award at IUFRO World Congress, 2014 in Salt Lake City, Utah

Dr. Sally Aitken was awarded the IUFRO Scientific Achievement Award in recognition of her distinguished scientific achievements in the field of forest conservation genetics. Dr. Aitken is a professor in the Department of Forest and Conservation Sciences and Director of the Centre for Forest Conservation Genetics at the University of British Columbia.

She leads a broadly-based research program that ranges from investigating basic scientific questions around how forest-tree populations adapt to local climatic conditions and how rapidly they can adapt to new climates, to applied research about how the diversity of native tree species is best managed to ensure planted forests are both productive and resilient to environmental perturbations. As leader of the multi-disciplinary AdapTree project, Dr. Aitken is bridging genetics, climate modelling and socio-economic studies to understand and predict the adaptive responses of trees to climate change.

Dr. Sally Aitken is able to link original and creative research to issues that have important social and economic implications both in western Canada and world-wide.

Working with other scientists worldwide and with the associates and students in her lab, Dr. Aitken is adding to a comprehensive body of theoretical knowledge on the evolutionary biology and adaptation of trees species, and applying this knowledge to the development of methods and tools that allow better decision making in applied forest management. At the present time, the AdapTree genomics project is linking new developments in genomics with climate modelling, evolutionary biology, and economic analysis. This integrated work is bringing together disparate disciplines such as genomics and climate science in order to extend the theoretical base and address the issues facing the forest industry and provincial agencies with responsibilities for massive annual reforestation programs that are part of a key industry and socio-economic driver.

This research will lead to unique solutions and methods for the assisted migration of reforestation stock to address the increasing genetic maladaptation of reforestation stock in western Canada due to climate change. The project has drawn the interest, participation, and funding support of the provincial Ministry of Forests, Lands and Natural Resource Operations and forest companies.

Figure 1. Dr. Sally Aitken receiving the IUFRO Scientific Achievement Award in Salt Lake City, Utah.

Figure 2. Dr. Sally Aitken.

Dr. Michael Carlson awarded the Queen's Diamond Jubilee Medal and the Forest Genetics Council of BC Achievement Award

Dr. Michael Carlson, emeritus scientist with the Ministry of Forests, Lands and Natural Resource Operations, has been awarded the **Queen's Diamond Jubilee Medal.**

The medal, which commemorates the 60th year of Queen Elizabeth II's reign, was presented to Carlson by Forests, Lands and Natural Resource Operations Minister Steve Thomson in a ceremony at the Kalamalka Forestry Centre, Vernon, BC.

The Jubilee Medal recognizes people who have dedicated themselves to serving their community, their country and their fellow Canadians.

Carlson started working for government in 1982, eventually leading a lodgepole pine genetics research program that has had a major positive impact on reforestation in the province. He retired in 2010 but continues to work in forestry as a volunteer emeritus scientist.

In 2000, Dr. Michael Carlson received the Forest Excellence Award from Forest Renewal BC for "Community Forestry".

He has been a member of the Board of Directors for the Allan Brookes Nature Centre in Vernon for 12 years and is an active volunteer. He has been involved with many tree and shrub planting and riparian habitat restoration projects programs including the Regional District of North Okanagan (RDNO) and other municipal organizations.

He has arranged and lead student and professional tours with colleagues at the Kalamalka Forestry Centre in Vernon for over 20 years on "Tree Breeding, Bugs, Dirt and Adaptation". He is an active member of the BC Big Tree Registry committee.

Minister of Forests, Lands and Natural Resource Operations Steve Thomson stated:

"The Queen has chosen the theme of service for this milestone year, and no one is more deserving of recognition than Dr. Carlson. His work has been of tremendous service to the people of the province, and has had a lasting impact on forest genetics and forestry in British Columbia."

Figure 1. Dr. Carlson receiving the Queen's Jubilee Medal from the Honourable Steve Thomson.

Dr. Michael Carlson also received the **Forest Genetics Council of BC Achievement Award in January, 2013.**

The award was presented by Dave Peterson, Provincial Chief Forester.

The award was presented for outstanding contributions to Genetic Resource Management in British Columbia through leadership in tree breeding, chairing the Interior Technical Advisory Committee, and exceptional communication and collaboration with stakeholders and colleagues.

Figure 2. Provincial Chief Forester Dave Peterson presenting Dr. Michael Carlson with the Forest Genetics Council of BC Achievement Award.

Tim Lee awarded the Forest Genetics Council of BC Achievement Award

Tim Lee received the FGC Achievement Award posthumously for his exemplary service to Council as an Orchard Manager, and for extraordinary leadership and communication of genetic resource management in BC.

Tim Lee championed Genetic Resource Management (GRM) throughout his years with the Vernon Seed Orchard Company (VSOC). In particular, he advocated for the use of select seed with industry foresters from companies affiliated with VSOC and greatly increased the awareness of the importance of GRM and select seed use.

Continual improvement and discovering solutions were key to Tim's management of the VSOC orchards. He facilitated and supported research on site, and cooperated with the science community to acquire new tools for the orchard management toolbox. At Vernon Seed Orchard Company, Tim Lee mentored numerous staff, some of whom are now leaders in the seed orchard community. Tim also supported non-VSOC employees and encouraged their career development and contributions.

Tim Lee has served as ITAC chair and an FGC member from May, 2009 until July 2013, and was an engaged member of the Tree Improvement community of practice since 1999. He demonstrated leadership in these roles by engaging the interior forest regeneration community in ITAC meetings and helped garner industry support for broader provincial GRM initiatives. He hosted and offered the resources of the Vernon Seed Orchard Company for numerous FGC and subcommittee meetings, workshops, and extension events.

Tim engaged interior stakeholders in the FGC program and was a strong advocate for communication with people outside the GRM community of practice, including local politicians, industry leaders, and the general public.

Tim Lee has collaborated with others and facilitated cooperation that has been instrumental in the advancement of seed orchard programs and seed production in all interior orchards. In addition, Tim competently led the VSOC operation, the largest single orchard site in BC, to provide seed for large planting operations in central BC.

Figure 1. Brian Barber and Larry Gardner, co-chairs of the Forest Genetics Council presented the Forest Genetics Award to Tim Lee posthumously. Shown above (from left to right) are Larry Gardner (West Fraser Mills), Heidi Lee (Tim's daughter), Brian Barber, Karen Lee (Tim's wife), and Rollen Lee (Tim's son).

Annette van Niejenhuis awarded the Jim Rodney Memorial Volunteer of the Year Award for 2013 by the Association of BC Forest Professionals (ABCFP)

The Association of BC Forest Professionals (ABCFP) presented the Jim Rodney Memorial Volunteer of the Year Award for 2013 to Annette van Niejenhuis who was heralded for her volunteerism.

Annette van Neijenhuis, RPF, works for Western Forest Products in Saanichton where she is a forester specializing in forest genetics and incremental silviculture. Her contributions to the community do not stop with her paid employment. She is an avid volunteer with several organizations including the Vancouver Island Section of the Canadian Institute of Forestry, the ABCFP's Network of Forest Professionals, the Marble River Fish Hatchery, and the North Island Invasive Species Partnership.

In 2013, Annette was a key part of a province-wide task force dedicated to increasing the profile of National Forest Week in BC. Additionally, she was instrumental in organizing National Forest Week activities for the people of Campbell River.

Annette is a councillor with the Forest Genetics Council of BC (FGC) and chairs the Coastal Technical Advisory Committee. She is involved with related committees.

Figure 1. Annette receiving her award from past president Christine Gelowitz, RPF at the ABCFP annual meeting in Kelowna in 2013.

Dr. Robb Bennett a Fellow of the Entomological Society of Canada (2012)

Dr Robb Bennett is exemplary in his scientific contributions and dedicated service to entomology in Canada. As an entomologist with the British Columbia Ministry of Forests, Lands and Natural Resource Operations (1992-2010), he created and expanded a major research program in cone and seed pest management that had international collaborative spread and influence. His successful lobbying for provincial support garnered annual funding and the establishment of the Pest Management Technical Advisory Committee (PMTAC) of the Forest Genetics Council of BC, which he initially chaired (2003-2010). During this period, his participation was critical for ground-breaking research that produced the first ever description of a cecidomyiid fly pheromone (named "Bennettin" in recognition of his work), and the use of infrared radiation by a herbivore in host-finding (*Leptoglossus occidentalis*).

Dr. Bennett is highly respected as one of Canada's leading spider systematists, and has shared this expertise through volunteer curation of the spider collections at the Royal British Columbia Museum in Victoria, where he is a Research Associate, and the Canadian National Collection of Insects, Arachnids and Nematodes (Ottawa) (CNC).

The results of his scientific efforts are 45 peer-reviewed papers, 44 technical publications, 3 on-line arthropod identification guides, and the mentoring of many undergraduate and graduate students. He also has been an active advocate in conservation entomology where he has volunteered on various committees as a Specialist, Member or Chair: for example, B.C. Ministry of Environment Invertebrates-at-Risk Team (2001- 06), Committee on the Status of Endangered Wildlife in Canada, and Arthropods Specialists Subcommittee (2006-present).

Of particular note have been his contributions to the Entomological Society of Canada, for which he has served on several committees starting in 1998 and as Editor-in-Chief of *The Canadian Entomologist* (*TCE*) (2007-11). In the latter role, he is to be commended especially for elevating the quality of the journal, thereby setting a solid stage for its move to electronic publication and a new publisher. (Bulletin of the Entomological Society of Canada, Vol. 44 (3) September, 2012)

And a Blues connoisseur too ... a renaissance man!

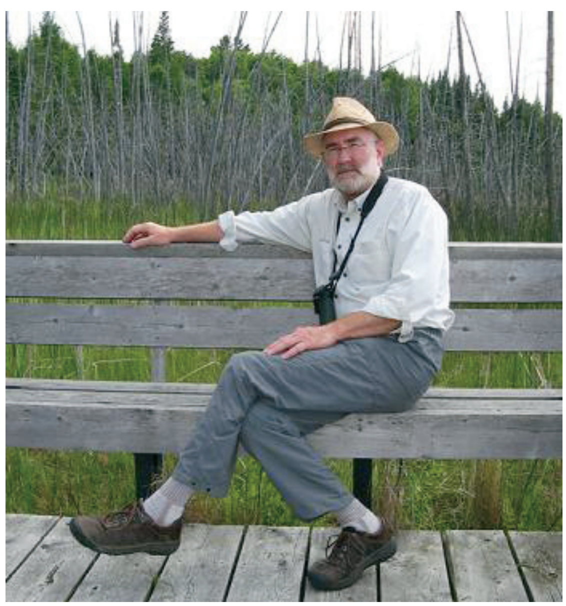

Figure 1. Dr. Robb Bennett by at the Purdon Conservation Area in northern Lanark County, Ontario. Photo by Jenny Terpenning.

Forsite Consultants Ltd. and FLNRO Tree Improvement Branch receive Award of Excellence from Esri (Environmental Systems Research Inc.)

Kelowna, Esri Canada User Conference – May 14, 2014 – Forsite Consultants Ltd. and British Columbia's Tree Improvement Branch (TIB), Ministry of Forests, Lands and Natural Resource Operations were presented today with an Award of Excellence by Esri Canada for developing a new mapping program which supports the conservation and growth of BC's future forests. By leveraging Esri's geographic information system (GIS) solutions to review climate-based seed transfer science, complex spatial data is transformed into visually appealing, easy to understand dynamic maps.

"We have data on the growth of various BC tree species from many seed sources, planted in provenances across BC, that has been analyzed in conjunction with climate change model data. Our scientific working group needed an effective way to display and review this information," said Susan Zedel, Seed Resource Specialist, Tree Improvement Branch. "Lacking GIS expertise within the Branch, we tasked Forsite to create a system where we can evaluate options for a climate-based tree seed transfer system to replace the current geographic-based system and to incorporate assisted migration."

With several diverse biogeoclimatic zones ranging from coastal to mountains, British Columbia's landscape provides unique challenges in reforestation, with approximately 240 million seedlings planted per year. Using climate criteria for seed deployment will improve adaptation of planted trees in the future, thereby maximizing growth and pest resistance. Forsite used ArcGIS as a platform to build an easy to use and interactive Web map which is accessed through ArcGIS Online, a cloud-based solution that can be used by TIB personnel without any specialized GIS training.

"Using TIB's data, we developed a new approach of providing dynamic access to this information," added Stephen Smyrl, GIS Analyst, Forsite Consultants Ltd. "Simple, yet powerful, query tools have proven to be extremely valuable in making key decisions. Intricate matrices are seamlessly integrated into the platform and parameters can be easily changed to create updated maps."
"This initiative demonstrates the power of GIS as a pervasive and transformative technology," noted Alex Miller, president, Esri Canada. "By using ArcGIS Online, TIB has an integrated solution for data management, analysis and visualization that allows them to review forest genetic and climate change science and develop options that will inform future seed transfer legislation and policy."

IN MEMORIUM

Tim Lee championed Genetic Resource Management (GRM) throughout his years with the Vernon Seed Orchard Company.

Tim Lee

Timothy Eugene Lee
March 19, 1955 (Outlook, SK) – July 7, 2013 (Vernon, BC)

Tim was born in Outlook, SK. He trained with the RCMP in 1974 and was posted in Pincher Creek and Medicine Hat, AB until 1978 when he and his family moved to Vernon.

Tim married Karen Reinhardt and they have four children: Rollen, Logan, Ehren and Heidi and six grandchildren.

Tim worked in reforestation serving as orchard supervisor with Vernon Seed Orchard starting in 1990 and as manager from 2003 to 2013. Tim was very active in various provincial committees, contributing to Tree Improvement in BC. He is missed for his positive outlook, patience and wisdom.

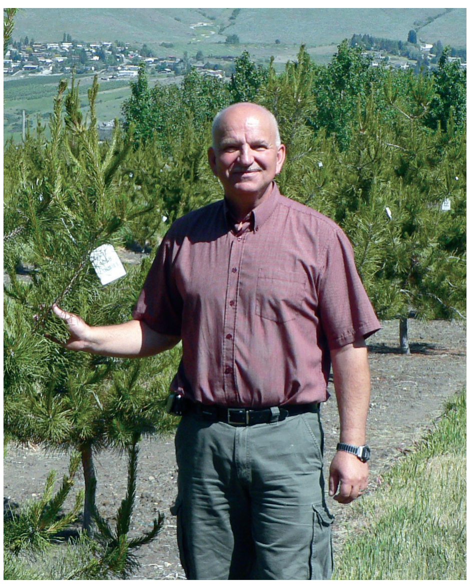

Figure 1. Tim Lee at Vernon Seed Orchard.

Joe Toth

Joseph Reginald Toth
February 28, 1971 (Quesnel, BC) – October 21, 2013 (Prince George, BC)

Joe worked at Prince George Tree Improvement Station as an equipment operator from 2001 to 2013. His mechanical inclination was well suited to the job and he enjoyed inventing new contraptions to get the job done. One of his best achievements was the design of a pesticide sprayer to protect the pine orchards from the mountain pine beetle onslaught in 2007.

Joe enjoyed mountain biking, dirt biking, gold panning, fishing and camping with his son Cale.

Figure 2. Joe Toth on the beach by the Fraser River looking for a good gold panning spot.

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