Tree Seed Working Group News Bulletin

Canadian Forest Genetics Association
l'Association canadienne de génétique forestière

67
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Featured in this issue:

Banner photo of *Pinus strobus* (Eastern white pine) seedlings on downed woody debris, during a Tree Marking Level 1 course for the Great Lakes-St. Lawrence Forest in Ontario. Photo by Melissa Spearing, September 2018.

Armchair Report No. 67

It's looking like a bumper cone crop year for many BC species with large crops of Douglas-fir, interior spruce, western redcedar, yellow cypress and western larch visible. Lack of available cone collecting labour is a common theme for many in the cone collecting business in BC and beyond. This past year we have sown seed to produce over 275 million seedlings in BC, of which 60% are derived from seed orchards. Looking at our top reforestation species the following are the seedling totals and percentage of seed orchard seed being used in the province for 2018 sowing:

- *Pinus contorta* var. *latifolia* (Pli = 103.8 M. 28%)
- *Picea glauca* x *engelmannii* complex (Sx = 101.0 M, 95%)
- *Pseudotsuga menziesii* var. *glauca* (Fdi = 25.0 M, 40%);
- *Pseudotsuga menziesii* var. *menziesii* (Fdc = 13.4 M, 91%);
- *Thuja plicata* (Cw = 11.4 M, 57%)
- *Larix occidentalis* (Lw = 8.4 M, 99%)

The above species account for 96% of our reforestation in BC.

In BC, we are transitioning from our Geographically Based Seed Transfer (GBST) system to a Climate Based Seed Transfer (CBST) system that has been developed over the past decade. Margot provides an overview of the system and although seedling deployment will have a transition period, all new seedlots registered after August 6, 2018 will only be registered for use via the CBST system. Additional genetic trait codes (primarily for pest resistance) are also being added to seedlots as we test and quantify traits that move BC to the goal of 50% of seed sown having some degree of pest resistance by 2035. It's an exciting time for genetic resource management in BC and I'm sure you'll be hearing more about developments in future News Bulletins.

In support of CBST and our 2018 bumper cone crop, there was a one-day joint wild stand cone collection/CBST workshop hosted at

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

All issues of the News Bulletin are freely available here.

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

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

four locations (Nanaimo, Vernon, Castlegar, and Prince George) to a total of 145 participants – see the summary article and links to the presentations provided. We also just had our biennial BC Seed Orchard Association meeting in Penticton, BC, which attracted about 67 people. Kudos to the organizing committee for a great meeting and more details can be found in the enclosed summary article. About 30% of the attendees were from the USA and many had kind words regarding the News Bulletin. Thank you – not fishing for compliments, but I often wonder who reads it – always good to hear it is serving a useful role.

There is a report from Jack Woods and Ward Strong on pesticide trials to control *Leptoglossus occidentalis* (Lepto), which we refrained from shortening too much as the details on increasing filled seeds per cone will likely be useful to many.

A summary of our fungal assay program is included and we are contemplating changes to the program. The largest impediment is getting real-life feedback on disease issues – whether this is due to a lack of extension staff, us being too close to the nursery rating system or just a general introversion within the industry – nursery pest problems are poorly quantified provincially. Changes being considered are:

- Dropping the *Sirococcus conigenus* assay (is this still a problem for anyone?);
- Dropping companion fungi identification (non-pathogen identification that is not being used) and,
- Redirecting energies to pursue identification of *Fusarium* contamination to the species level vs. the current genus level only.

In terms of significant retirements, Jack Woods is 'officially' retired and celebrations occurred on the coast and interior since the last News Bulletin. Jack has made huge contributions to BC tree breeding, genetic resource management and tree improvement program management and his breadth, knowledge and fearless questions will be missed. I'd also like to wish a happy retirement to Jim Corrigan who has left BC and is now fishing up a storm in the Miramichi area of New Brunswick. Our new Seed Orchard Pest and Plant Health Biologist is Geoff Bradley. Geoff is originally from the East Kootenays, (Kimberley, BC), but comes to us from Maple Ridge, BC. Geoff did his BSc in Plant Biology at UBC and followed that with a MSc in Plant Pathology from Simon Fraser University. For his MSc, he studied biocontrol of fungal pathogens. Geoff is joining us from the Canadian Food Inspection Agency where he has spent the past nine years working in various roles with the Plant Protection branch of CFIA.

In terms of retirements we are also facing facilities 'retiring' and for some activities there does not seem to be a succession strategy . The Ontario Ministry of Natural Resources and Forestry's plan to close the Angus Seed plant seems to be moving forward with the September 2018 closure despite a review process this summer after the Ontario provincial election. The plant

Jack Woods (formerly SelectSeed Ltd) at his interior retirement celebration with Dave Kolotelo (BC Tree Seed Centre).

started in 1923, so 95 years of service to reforestation and conservation. It was also announced that the Pineland Forest Nursery (Hadashville, Manitoba) which also provides seed extraction and cleaning services, seed storage and a testing facility will be closing its doors on December 31, 2018. The facility has been producing seedlings since 1954 and processing cones and seed since 1964. I send my Thank you's to the Angus and Pineland staff for their contributions to reforestation and conservation in their jurisdictions. I'm saddened to hear that these facilities will no longer be contributing to forest stewardship activities.

You may also remember that over a year ago George Edwards had a stroke and has been in the hospital since. I visited George this summer and although restricted to a wheel chair, he was cheerful and aware. He continues with physical therapy and appears to be progressing in regaining some of his movement. If you'd like to send George a note he can be reached at this e-mail address: de4757@telus.net

Though come and gone during the course of publishing this News Bulletin, I am looking forward to the International Society for Seed Science meeting in Fort Collins, Colorado. It seems appropriate to visit the USDA "seed bank" in association with a workshop on Seed Longevity. I look forward to seeing old and new friends at this important meeting. At the BC Tree Seed Centre, we are celebrating our 60th anniversary as a provincial facility and planning a few functions. During National Forestry Week (September 23–29) we will have an open house and Ministers' visit. We will also host a Seed Use Efficiency II meeting (October 16–17) and a smaller more hands-on whitebark pine workshop scheduled for October 23rd.

I wish you all the best with your cone, seed and seedling crops!

Dave Kolotelo
TSWG Chairperson

Editor's Notes

Happy fall and welcome new subscribers! I take full responsibility for the delay on the summer issue as wearing too many hats was compounded by family health issues. My enthusiasm for this Bulletin has not waned, merely the number of hours with which I could find to effectively concentrate. Thank you to everyone who contributed articles but primarily to Dave for his understanding and support. This issue may seem West Coast focused, but topics such as cone physiology, evaluating pest control efficacy in seed orchards, managing light cone crops and crops when there is excess seed in storage should be universally applicable.

Of major forest research milestones, it's worth noting the Petawawa Research Forest, Chalk River, Ontario celebrated it's 100th anniversary this year. Here's hoping for another 100.

I started to pen several of my own articles but will save them for the next issue, especially as the situation for seed policy and supply in the Great Lakes region continues to evolve. The void left by the Ontario Tree Seed Plant continues to occupy my and many others' time. The three Ontario FGRM associations are working to ensure our members' needs and existing policy requirements are met, as well as considering the implications of future policy changes since last summer's Seed Transfer Policy Workshop. I commend this Bulletin for a quick study in the development of climate-based seed transfer science and the risks of not considering it. But changing operational status quo of what and whose seeds to use where without a provincial inventory management system will be the true challenge.

In that spirit, please save the date for next summer's CFGA conference August 19–23, 2019 at Le Manoir du Lac Delage, Québec, where the theme is "Applied Forest Genetics: Where Do We Want to Be in 2049?" More information will be included in the June 2019 issue.

Until then, please keep the TSWG Bulletin's health in your thoughts and let us know what you and the squirrels are up to. We can't let Ben down!

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Transitioning British Columbia to Climate Based Seed Transfer

This note was first published in the 2018 May/June issue of *BC Forest Professional.*

Introduction

Based on the knowledge that trees are genetically best adapted to the environment and climate in which they evolved, establishment of seed transfer limits has long been a fundamental component of reforestation. With British Columbia warming an average of 1.4°C per century between 1900 and 2013 (BC Ministry of Environment 2016), trees have been unable to move or adapt fast enough to find their optimal climate niches.

In pursuit of adapting to and mitigating the impacts of climate change while achieving the goals of forest ecosystem resilience, health and productivity, the Forest Improvement and Research Management Branch (FIRM), has been working towards a climate based seed transfer (CBST) system for over a decade. The CBST system improves the match between seed and plantation climates through assisted migration. The approach, developed by FIRM staff with assistance from Dr. Tongli Wang at UBC, was published in 2017 (O'Neill et al. 2017).

Science Overview

The Province's existing seed transfer system uses a geography based methodology that limits seed transfers on the basis of longitude, latitude, elevation and biogeoclimatic zone. The new climate based seed transfer system matches the climate and latitude of a seed source, as represented by a Biogeoclimatic Ecosystem Classification (BEC) subzone/variant, with the current and near-future climate of a planting site. The nine variables used include[1]:

- latitude
- mean annual temperature
- mean cold month temperature
- summer–winter temperature differential
- mean annual precipitation
- mean summer precipitation
- degree days above 5°C
- extreme maximum temperature
- precipitation as snow

BC's approach to assisted migration in CBST is conservative. Most of the migration distance accounts for past climate change (1940s–2016), or "adaptation lag"; future climate change is projected for only 15 years on the coast and 20 years in the interior (representing a quarter of a typical harvest rotation). This balances adaptation for ongoing climate change without compromising plantation establishment. Another way to look at this is that we are currently planting into sites that are too warm for the seed. With CBST, we will be planting into sites that are colder than the best climate match – in anticipation of ongoing climate change. This approach to migrating seed sources is combined with provenance data to determine an acceptable transfer distance that results in a BEC variant matrix which is the foundation of the CBST transfer standards.

Species Selection and Seed Selection

Under FRPA, the tree species selected to reforest each site are specified in a Forest Stewardship Plan (FSP)[2] and a seedlot is subsequently selected to achieve the *Chief Forester's Standards for Seed Use*. Given this approach, assisted migration under CBST will not move seed outside of its current species range, unless policy is also developed to

[1] Precipitation as snow was added as a result of genomics information provided through the AdapTree genomics project led by Dr. Sally Aitken, at the University of British Columbia.
[2] The Reference Guide for Forest Development Stocking Standards provides information to assist in tree species selection.

apply assisted migration to tree species selection in the FSP.

FLNRORD (Forests, Lands, Natural Resource Operations and Rural Development) Research Ecologists are currently developing an approach to climate change informed species selection (CCISS)[1]. This project is quantifying potential shifts in tree species suitability caused by climate change, and interpreting these results at the BEC site series (stand) and landscape levels. The model and decision aids are currently undergoing refinement and review. Collaboration efforts between the CBST project and the CCISS project will continue to ensure integration and consistency between decision tools and policy realms.

CBST Policy Development and Implementation

As part of CBST policy development, FIRM worked with GIS consultants to develop a tool to demonstrate shifts to areas of use for seed of each species in each BEC variant.

The parameters and science behind the CBST tool were recently incorporated into the FLNRORD's Seed Planning and Registry System (SPAR), to align with the amendment to the *Chief Foresters Standards for Seed Use*. This amendment is being timed to enable optional use of CBST transfer limits starting with the 2019 seedling request season (August, 2018). Initially, seed users will be able to use the current (geographically based) transfer standards, the CBST standards, or a mix of both. The option to use the current transfer standards will be discontinued at the end of the "transition period".

Further impact assessment and gap analysis, as well as stakeholder engagement, is needed to help determine the most appropriate length for the transition period. At this time, a two year period is planned, subject to results of the impact assessment, gap analysis and further engagement.

The adaptive policy development approach used for CBST will be ongoing. FIRM will be hosting future training and information sharing sessions to support the planned phased implementation of CBST over the next number of years. More information, including training opportunities, is posted at www.gov.bc.ca/climatebasedseedtransfer

Climate Based Seed Transfer and Risk

- Doing nothing about climate change is high risk.
- CBST is a climate change adaptation strategy intended to reduce the risk associated with climate change impacts.
- CBST takes a conservative approach – focusing on catching up with climate change that has already occurred, rather than projecting too far into the future; this is intended to balance establishment risk with the risk of maladaptation and loss of productivity.
- BC's network of forest genetic provenance trials has allowed scientists to use space in place of time to measure impacts of potential seed movements and advance the CBST project.
- There is no risk-free approach to addressing climate change; all future climates are projections.

Literature Cited

Indicators of Climate Change for BC, Ministry of the Environment, 2002 (2016 update). URL here.

O'Neill, G, T. Wang, N. Ukrainetz, L. Charleson, L. McAuley, A. Yanchuk, and S. Zedel, 2017. A proposed climate-based seed transfer system for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 099. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr099.htm

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[1]Initiative led by Will Mackenzie, Provincial Ecologist, North Area; and Pamela Dykstra, Research Leader, Forest Ecology Interpretations, Resource Practices Branch, Office of the Chief Forester. http://www.fgcouncil.bc.ca/CCISS-Pam-Dykstra-ITAC-2018.pdf

Wildstand Cone Collection Workshops in BC

In BC, we are seeing a bumper cone crop for many species and we will also be introducing Climate Based Seed Transfer (CBST) as the only method available for seedlot registration. This resulted in the desire to put on a Wildstand Cone Collection Workshop that focused on cone, seed and insect biology, cone collection best practices, and a review of BC tree seed regulations, tools available to assist with seedlot registration and CBST. The agenda for the workshop is presented below with the presenters varying at some of the locations:

- **Forest Genetics: Tree Seed Regulations and Seed Planning** – Brian Barber / Margot Spence
- **Climate Based Seed Transfer** – Margot Spence / Susan Zedel
- **Seed Planning and Registry System** –Susan Zedel / Margot Spence
- **Seed Biology and Tree Seed Centre Services** – Dave Kolotelo
- **Cone and Seed Pests** – Dave Kolotelo
- **Cone Collections** – Don Pigott

The workshop was held at four locations: Nanaimo (June 12); Vernon (June 21); Castlegar (June 26) and Prince George (June 28) with a total of 145 people attending one of the workshops. The Powerpoint presentations from the workshop are available at the following link: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/seed-planning-use/cone-collection-workshop.

I'll discuss just a few overarching themes from the workshop here. With CBST, the biogeoclimatic ecosystem classification (BEC) variant will be the unit helping define seed transfer as well as the area that can be registered under one seedlot. Previously it was only a requirement to collect within a biogeoclimatic zone (with latitude, longitude and elevation restrictions), but new seedlots must be collected from the same zone, subzone and variant (if one exists). Areas that previously were able to have cone crops registered may now need to be split if they cross BEC unit boundaries. The tougher decisions involve predicting seed use through a CBST lens and this is something seed owners or those with reforestation responsibilities needs to review based on their existing seed inventories, planting programs and access to seed orchard seed. To help answer these questions a new seedlot selection tool (https://maps.forsite.ca/204/SeedTransfer/CBST_v2.html) was constructed to assist with seed planning initiatives with a CBST lens. Additional information on CBST can be found on the dedicated weblink: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/seed-planning-use/climate-based-seed-transfer.

In terms of best cone collection practices there were two key messages – collecting cones at the appropriate maturity level and secondly ensuring that you provide good interim storage conditions that protect your investment prior to shipping your cones to the extractory. Those items cannot be emphasized enough. Good luck with your 2018 cone collections!

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BC Seed Orchard Association (BCSOA) Meeting 2018

The biennial meeting of the BCSOA meeting took place in Penticton, BC on June 19 and 20, 2018. Kudos to the organizing committee for putting together a great meeting: Mike Brown, Gary Giampa, Penny May, Robert Taylor and Tia Wagner. The program booklet and the presentations from this and a few past meetings can be found at this link: http://www.fgcouncil.bc.ca/bcsoa/past-meetings.html.

I'll touch on a few meeting highlights with the biggest BC highlight being the bumper crops forecasted for most non-serotinous species. An area which I think is filled with opportunities is in the area of water, soil and nutrition management in seed orchards. At this meeting Chuck Bulmer (Ministry Soil Scientist) presented the concept of 'precision agriculture' and its application to seed orchards. Advances in various remote sensing technologies allow for the ability to better understand variability within orchards and increase the efficiency of various inputs. To assist with watering regimes, Andrew Peterson (BC Ministry of Agriculture, Water Management Specialist) spoke on evapotranspiration tables and the various factors involved in increasing irrigation efficiency. The water, nutrition and soil concept was also expanded on by Clare Kooistra at the 2016 BCSOA meeting and for those interested in the topic, his presentation is worth looking at. Clare continues to work on increasing orchard efficiency through investigations into water and nutrition needs in addition to working with Chuck on the soil aspect. Clare was unavailable to provide an update at the 2018 meeting, but we look forward to hearing about his findings and recommendations in the future.

Spray technology was an emphasized area through an entertaining and passionate presentation by Kim Blagborne who is the owner of Slimline Manufacturing (http://www.slimlinemfg.com/company/). Slimline manufactures turbo mist sprayers used extensively in agriculture, horticulture and the seed orchard business. The manufacturing facility is in Penticton, BC, so in addition to hearing about the many considerations for increasing spray efficiency we also got to see the production plant, gain additional insights and have time for questions.

The organizing committee chose Penticton to enable the meeting to feature and learn from some of the practices used in the BC wine belt. We visited a large scale (Red Rooster) and a small scale (Tightrop) winery to obtain different perspectives on crop management from the viticulture industry. Although different from seed orchard crops, advances in orchard and crop monitoring systems are reasonably simple to transfer to our business. The other tour stop was a visit to the Summerland Research and Development Station which was established in 1914 and is focused on building resilient and profitable horticultural production systems. We had presentations from a variety of researchers ranging from soil ecology to germplasm development to tools available for plant physiology measures.

The next BCSOA will be in 2020 on the coast and you'll hear more about location and theme as we approach that date.

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Impact of Surround®, Pounce®, and Matador® on Lodgepole Pine Filled Seed Production in Southern Interior BC Seed Orchards: 2017 Trial

Introduction

This is the third in a series of reports on cooperative projects that evaluated the impact of commercially-available pesticides on lodgepole pine seed production when used to control western conifer seed bug (*Leptoglossus occidentalis*) populations (affectionately called "Lepto"). This project builds on earlier projects reported by Woods et al. (2015), Woods and Strong (2016), and Giampa (2016 pers. communication). Specifically, this trial is designed to evaluate the efficacy of Surround in combination with Matador, and of Pounce, a permethrin-based pesticide, relative to Matador alone and to a non-treated control. Seed set (filled seeds per cone) is the primary variable of interest.

The production of filled seed in many lodgepole pine seed orchards located in the North Okanagan of British Columbia has long been below levels considered adequate to meet objectives of the Forest Genetics Council of BC (FGC 2015) and to allow orchard businesses to operate at a financially sustaining level of production and sales. Results from the 2014 Matador trial implemented in four seed orchards showed an increase in operational filled seed production of from 82% to 200% for treated blocks relative to non-treated control blocks (Woods et al. 2015). A 2015 trial with both Matador and Delegate showed that both improved filled seed production relative to an untreated control, but the improvement was less dramatic than in the 2014 trial (14% to 53% for Matador and 3% to 41% for Delegate). The lower success rate in 2015 is thought to be due to lower Lepto populations than in 2014. The 2015 trial also showed that Lepto control prior to harvest reduces seed losses during August, a critical period during which cone harvest is taking place.

A trial implemented by Gary Giampa in 2015 tested the effect of Surround (a kaolin clay product used in agriculture) on filled seed production in a single orchard. A primary objective of this trial was to provide lodgepole pine trees planted in the warm conditions of the Okanagan valley with a cooling effect from the light-coloured clay covering foliage and reflecting some sunlight. Surround is also marketed as a pesticide, as the gritty clay particles can interfere with the exoskeleton function of some insects. The 2015 trial showed an increase in filled seed production of 22% relative to a non-treated control.

The importance of treatment timing

Previous work by Strong (2015) on the timing of Leptos emergence and feeding suggests two key periods for control; late May through June when overwintering Lepto begin to feed on developing ovules in maturing cones (early season), and early July through to September (late season) when newly hatched nymphs begin to feed on developing seeds and mature to adults. There is abundant evidence (Bates et al 2000, Strong 2006, Strong 2013, Woods et al. 2015) that the early feeding kills ovules and limits seed development, resulting in a reduction in the total formed seeds (filled and empty) in a cone (TSPC). The later feeding reduces the number of filled and viable seeds (FSPC) that develop in the immature seeds that remain following the first feeding. This later feeding appears to take place for a longer period than the first feeding. The 2014 trial results suggested that filled-seed losses were about equally caused by early- and late-season predation. The 2015 trials (Woods and Strong 2016) showed that a late July treatment of Matador or Delegate resulted in less seed loss during the critical August and early September period when cone harvest is taking place. The trials reported here attempted to implement pesticide treatments to reduce Lepto populations at the beginning of both the early and late feeding periods (approximately late May and early June).

Questions addressed

Does Pounce increase seed set relative to no treatment, and is it as effective as Matador? The hypothesis for this question is: *there is no difference in the effectiveness of Matador and Pounce.*

Does Surround increase seed set beyond that achieved with Matador alone? If excessive heat is impacting seed set and if Surround is providing a cooling effect, then using Matador and Surround together are expected to have an additive effect and seed set should be higher than with using either alone. However, if Surround is increasing seed set due to its acting as an insecticide, then the use of Matador and Surround together are expected to have a similar impact on seed set as Matador alone. This assumes that Matador effectively eliminates Lepto following spraying, so there would be no Lepto remaining for Surround to impact. The hypothesis for this question is: *Surround effects are additive to Matador effects.*

Methods

Orchards

Eight orchards located on four sites in south-central British Columbia participated in this trial (Table 1). Two sites (Grandview, and Vernon Seed Orchard Company) are central to the North Okanagan area where problems with filled seed production in lodgepole pine have been most prevalent. Sorrento is in a somewhat cooler ecosystem, but Lepto has historically been a problem on the site. Kettle River is in a cooler ecosystem than Sorrento, and Lepto have been less of a problem than at the other three sites.

To address the key questions, the following treatments were used:

1. Control – no pesticide application
2. Matador
3. Pounce
4. Matador followed immediately with a treatment of Surround (Matador + Surround)

Each orchard was divided into from two to four blocks (Table 2). Smaller orchards were divided into only two or three blocks due to the need for a large block size to properly simulate whole-orchard treatment and to reduce the rate at which Lepto migrate back into a block following treatment. Block assignments to each orchard were structured to simplify spray applications, with consideration to the logistics of how a tractor-puller sprayer can be utilized and turned on the edges of each block.

Pesticides and pesticide application

Matador 120EC is a is a photostable, synthetic pyrethroid insecticide that is registered for use on many pests, including the apple brown bug in apple orchards and the tarnished plant bug in peach orchards. The application rate recommended on the label for the tarnished plant bug is 104 ml of product per hectare, delivered through an air-blast sprayer. This rate was used for these trials. Re-entry is 24 hours after treatment.

Pounce is a permethrin insecticide commonly used in agriculture. Other very similar permethrin products are

Table 1. Site location and climatic information for the eight lodgepole pine seed orchards participating in the study.

Orchard No.	Seed Planning Unit (SPU)	Site	Latitude	Elevation (m).	Mean annual temp (°C)	Mean annual precip. (mm)	Mean summer precip. (mm)
237	Prince George	Kettle River	49°13	636	6.7	453	185
238	Central Plateau	Kettle River	49°13	636	6.7	453	185
337	Nelson low elev.	Grandview	50°23	483	7.1	481	209
338	Thompson Ok. low elev.	Grandview	50°23	483	7.1	481	209
240	Bulkley Valley	Sorrento	50°52	521	6.8	585	248
241	Central Plateau	Sorrento	50°52	521	6.8	585	248
234	Bulkley Valley	VSOC	50°14	495	7.2	536	240
236	Prince George	VSOC	50°14	495	7.2	536	240

Temperature and precipitation data from ClimateWNA (Wang et al., 2012). UBC Center for Forest Conservation Genetics online model.

Table 2. Number of ramets per treatment block.

			Number of Ramets per Treatment			
Orchard No.	Location	SPU	Control	Matador	Pounce	Matador + Surround
237	Kettle River orchards	PG low	896	536	2491	551
238	Kettle River orchards	CP low	492	572	1257	624
337	PRT Armstrong	NE low	–	436	555	–
338	PRT Armstrong	TO low	539	1201	2208	734
240	Sorrento Nurseries	BV low	–	686	1703	697
241	Sorrento Nurseries	CP low	609	907	483	–
234	Vernon Seed Orchard Co.	BV low	534	431	1453	449
236	Vernon Seed Orchard Co.	PG low	643	779	1996	789
Totals			3713	5548	12146	3844

Perm-Up and Ambush. Pounce is registered for use in seed orchards (Seeding Trees Reforestation Areas on the label) and for some conifers, including pine trees. Some restrictions apply. The application rate is 175 ml of product per ha applied as a ground spray. Pounce is a broad-spectrum insecticide with unknown control and residual effects on Lepto. It has a 12-hour re-entry period. Re-entry is allowed once the product has dried on foliage.

Surround is a kaolin clay product that forms a barrier to sunlight and thereby has a cooling effect that may reduce tree stress during hotter periods. In addition, the gritty clay particles are a deterrent to many insects. Because of this deterrent property, Surround is sometimes used as a method to control insect populations in agricultural crops. There are no re-entry limitations.

Matador and Pounce were applied to label specifications on the dates shown in Table 3. Surround was applied at the rate of 25 kg per hectare, as recommended by Gary Giampa and Mark French from Kalamalka Seed Orchards. All sites used an airblast tank sprayer pulled by a tractor. Nozzles were low and set to spray the pesticide mix up into the crowns of orchard trees. Tree heights are under five meters (with very few exceptions) and spray reached above the crowns and settled back onto the crowns.

Table 3. Pesticide application dates by site.

Orchard No.	Site	1st Application Date	2nd Application Date
237	Kettle River	June 4–6	July 28
238	Kettle River	June 4–6	July 28
337	Grandview	May 19	June 29
338	Grandview	May 19	June 29
240	Sorrento	June 6, 7	July 13, 14
241	Sorrento	June 6, 7	July 13, 14
234	VSOC	June 6	July 14
236	VSOC	June 6	July 14

A notable difference between how Surround was applied in this trial and how it was applied in trials done at Kalamalka is the nozzle heights for the sprayer. Kalamalka has a lift system that allows spray from nozzles set much higher, allowing spray directly onto the upper crown. It was noted that the amount of Surround visible on ramets at each site in this study was less than what was observed at the Bailey Road orchard. However, all orchard blocks treated in this trial had a clearly visible whitish hue from the Surround treatment. Likely due to the low height of the airblast sprayer nozzles, the lower crowns of the ramets treated in this trial appeared to have more Surround coverage than the upper crowns.

Cone and seed sampling

Within each treatment block, a central area was designated for cone sampling that was separated from the edge of the block by at least four orchard rows to reduce edge effects. A single sample of 80 cones was collected from each treatment block. Where possible, no more than two cones were collected from each orchard clone to ensure a broad and representative sample of parental clones. In some cases, cones were not found on 40 different clones, so the sample of 80 cones was made on fewer than 40 clones. In no instance were more than two cones sampled from a single ramet.

Eighty-cone samples from each treatment block in each orchard were bulked to a single sample and placed in appropriately-labeled paper bags. Cones from all samples were dried in ambient conditions at the Kalamalka Forestry Center for about two months, and then kiln-dried to open the cones. Seeds were manually removed from the cones using standard Center protocols. All formed (non-flat) seeds extracted from the cones in each of the labeled bags were counted. The number of cones from each treatment sample was recorded (80 in all cases). Seeds were X-rayed to allow counts of the number of filled seeds among the formed seed that were extracted. For each of the 28 samples, data were tabulated for the number of cones, the number of formed seeds, and the number of filled seeds. Statistics of interest were calculated from these data, including the total formed seeds per cone (TSPC), filled seeds per cone (FSPC), and the percent filled seed per cone (%FSPC = FSPC/TSPC).

Lepto surveys

Surveys for Lepto populations were conducted weekly on all sites using a timed 20-minute walk through each orchard or treatment block and recording the number of Lepto observed. Prior to the first spray, most sites did a single survey of the whole orchard. Following the first treatments, the 20-minute surveys were done weekly within each treatment block.

Data analysis

Means were calculated for TSPC, FSPC and, %FSPC by treatment and orchard. Statistical significance was tested with an analysis of variance using the following model:

Analysis of variance model to evaluate the relative effects and significance of treatments and orchards.

Variable	df	SS	MS	F
Orchards	7	SSo	SSo/7	MSo/MSe
Treatments	3	SSt	SSt/3	MSt/MSe
Error	21	SSe	SSe/21	
Total	31	SStot		

Comparisons among treatments were done using a Holm correction test (stepdown Bonferroni).

Results and discussion

Lepto surveys

Lepto surveys were, in most cases, done by the same person on each site, but different people across sites. Observational skills will differ by surveyor, but these skill differences cannot be separated from site differences in Lepto numbers. Site managers attempted to conduct surveys during dry warm periods when Lepto are more active. However, weather differences occurred between weeks on each site, as well as between sites for a given week. These sources of error in Lepto counts can't be adjusted or properly evaluated among sites and must, therefore, be used only as a broad indicator of the actual Lepto populations at the time of a survey (Table 5).

Prior to the first treatments, some surveys were done at the whole-orchard level rather than by treatment block. Following the first treatments, all surveys were done by treatment block. No surveys were conducted following the collection of cone samples.

Total seeds per cone

Seeds that were successfully pollinated the previous year will expand to fully formed seeds in the early spring period if no events, such as insect predation, stop development (Owens 2006). Therefore, TSPC is a measure of the number of pollinated seeds that were healthy and still had the potential to become filled seeds at the time seed coat development and formation is complete in approximately late May to mid-June. TSPC includes both filled seeds which have complete

Table 5. Counts of Lepto by week, location, and treatment block. Prior to the first spray treatments, most sites conducted a single survey for the orchard rather than surveys by treatment block. All surveys were done with 20-minute visual walk-through. Dates of sample collections are shown. n/a indicates that no survey was conducted. Orange-filled cells indicate approximate spray dates.

Orch. #	Site	SPU	Treatment	April 24	May 1	May 8	May 15	May 22	May 29	June 5	June 12	June 19	June 26	July 4	July 10	July 17	July 24	July 31	Aug. 7
237	Kettle	PG	Control	n/a	0	0	0	0	0	1	0	0	0	0	1	0	0	n/a	Collect samples
237	Kettle	PG	Matador							0	0	0	0	0	3	0	0	n/a	
237	Kettle	PG	Matador + Surround							0	0	0	0	0	0	0	1	n/a	
237	Kettle	PG	Pounce							0	0	0	0	0	4	3	3	n/a	
238	Kettle	CP	Control	n/a	0	0	0	0	0	n/a	0	0	0	0	0	0	0	n/a	
238	Kettle	CP	Matador							n/a	0	0	0	0	2	0	0	n/a	
238	Kettle	CP	Matador + Surround							n/a	0	0	0	0	1	0	0	n/a	
238	Kettle	CP	Pounce							n/a	0	0	0	0	2	0	0	n/a	
337	Grndv.	NE	Matador	n/a	0	n/a	n/a	0	3	3	n/a	14	n/a	0	0	0	0	2	
337	Grndv.	NE	Pounce			n/a	n/a	1	3	3	n/a	13	n/a	0	0	0	0	1	
338	Grndv.	TO	Control	n/a	0	n/a	7	1	4	4	n/a	6	n/a	0	2	2	11	1	
338	Grndv.	TO	Matador			n/a		0	0	3	n/a	9	n/a	0	0	0	0	0	
338	Grndv.	TO	Matador + Surround			n/a		0	0	0	n/a	n/a	n/a	0	0	0	0	0	
338	Grndv.	TO	Pounce			n/a		3	8	9	n/a	20	n/a	0	1	1	0	3	
240	Sorrento	BV	Matador	n/a	0	0	0	n/a	5	2	0	0	2	3	2	0	0	Collect samples	
240	Sorrento	BV	Matador + Surround								0	0	1	1	0	0	0		
240	Sorrento	BV	Pounce								0	0	5	0	7	1	0		
241	Sorrento	CP	Control	n/a	0	0	0	n/a	3	0	3	3	7	2	5	10	2		
241	Sorrento	CP	Matador							0	0	0	1	2	2	0	0		
241	Sorrento	CP	Pounce							0	1	1	4	0	2	1	0		
234	VSOC	PG	Control	0	0	0	0	5	3	1	2	3	0	0	Sprayed - no survey	n/a	Collect samples		
234	VSOC	PG	Matador					5	6	0	0	0	0	0		n/a			
234	VSOC	PG	Matador + Surround					5	10	0	0	0	0	1		n/a			
234	VSOC	PG	Pounce					12	6	0	0	2	1	0		n/a			
236	VSOC	PG	Control	0	0	0	0	12	9	2	2	0	0	0		n/a			
236	VSOC	PG	Matador					18	7	0	0	0	0	0		n/a			
236	VSOC	PG	Matador + Surround					10	8	0	0	0	0	0		n/a			
236	VSOC	PG	Pounce					8	4	0	0	2	0	0		n/a			

embryo and megagametophyte development (FSPC), and non-viable empty seeds that were pollinated and healthy until an abortion-causing event during the spring. In a 2014 study (Woods et al. 2015) about half of the total loss in FSPC to Lepto predation was attributed to early feeding that eliminated potential seeds before a seed coat fully formed (i.e. reduced TSPC). The remaining loss of FSPC were due to later-season predation that reduced the number of filled seeds among the already formed seeds.

TSPC treatment means are shown in Table 6. Based on an ANOVA these differences are not significantly different ($p>0.22$). Orchard effects are significant, however ($p<0.04$). Review of Lepto survey data and knowledge of the sites and phenological stages suggests that the timing of the first pesticide-treatment at Grandview was early enough to control high Lepto populations before substantial feeding of over-wintering Lepto. At Kettle, almost no Lepto were observed through most of the summer, so it's likely that the first treatment had little effect on TSPC. At VSOC, Lepto survey counts were high for at least two weeks prior to the first spray application. At Sorrento, surveys were not applied in a consistent manner, but it is likely that Lepto populations were reasonably high for at least two weeks prior to the first treatment. Orchard mean TSPC for VSOC and Sorrento orchards (first treatment applied after Lepto observed for two or three weeks) are much lower than for Grandview and Kettle orchards where Lepto were controlled (or not present) in mid-to-late May. These differences among sites with and without May Lepto control are significant ($p<0.001$) and account for a confounding of orchard differences in TSPC with pesticide treatment differences in the mixed-model ANOVA used because most of the reduction to TSPC at VSOC and Sorrento likely took place before the first treatment. In addition, due to small orchard size and some treatments not being applied (missing cells in Table 6), the sample size for the comparison of the control treatment with the three pesticide treatments on a site with Lepto pressure is reduced to a single sample (orchard 338).

Filled seeds per cone

Filled seeds result when a potential seed successfully completes fertilization, followed by embryo and megagametophyte development that is uninterrupted to the time of seed maturity and sampling. Filled-seed counts in these trials are based on X-ray photographs, and are assumed to correlate strongly with actual viable seed production.

FSPC results by orchard and treatment are shown in Table 7. Based on ANOVA, these results show highly significant ($p<0.01$) treatment and orchard effects. All pesticide treatments result in a significant ($p<0.05$) increase in FSPC relative to the non-treated control blocks. Differences among pesticide treatments are not significant ($p>0.6$). Both the Matador and the Matador+Surround treatments resulted in greater FSPC than the Pounce treatment, as well a more favorable probability that they are significantly better than the control. However, based on these data there are no strong indicators that any differences exist among the three pesticide treatments used.

Percent filled seeds per cone

The percentage of FSPC relative to TSPC (%FSPC) is a good measure of seed losses during the late summer in seeds that were successfully fertilized and remained healthy long enough to develop a formed seed coat. Based on ANOVA of %FSPC data, treatment effects were highly significant ($p<0.001$).

As with FSPC, multiple comparisons using a Holm correction shows a highly significant difference ($p<0.002$) between the non-treated control and both the Matador and the Matador+Surround treatment. The difference between the Control and the Pounce treatment is also significant ($p<0.02$), but less favorable. Differences among the three pesticide treatments are not significant ($p>0.39$).

Discussion

These trials show that the control of Lepto populations increases filled seed production in lodgepole pine and support the results from previous trials undertaken in 2014 and 2015. The first hypothesis these trials set out to test (there is no difference in the effectiveness of Matador and Pounce) is accepted, as no significant differences were noted in the FSPC production between the two pesticides. However, the lower overall FSPC and %FSPC result obtained for Pounce relative to the other treatments and the lower level of significance for differences between the Pounce and control treatments are indicators that Matador may be more effective than Pounce. If Pounce is less effective than Matador, the experimental design used did not clearly demonstrate this. Further investigation is warranted to further test the relative efficacy of these two pesticides.

Table 6. TSPC by orchard and treatment. Based on ANOVA across all sites, differences between treatments are not significant (p>0.05). Blank cells indicate no data.

			Treatment				
Orchard No.	Location	SPU	Control	Matador	Pounce	Matador + Surround	Orchard Mean
237	Kettle River	PG low	26.4	25.7	26.6		26.6
238	Kettle River	CP low	15.5	29.9	22.8	20.3	22.2
337	Grandview	NE low		21.0	19.7		20.3
338	Grandview	TO low	16.6	22.9	17.3	26.3	20.8
240	Sorrento	BV low		9.4	7.1	9.8	8.8
241	Sorrento	CP low	7.0	6.5	7.3		6.9
234	VSOC	BV low	11.3	13.6	13.7	11.3	12.5
236	VSOC	PG low	12.4	11.5	14.7	12.1	12.7
Treatment Mean			14.9	17.6	16.1	17.9	
Increase (%) over Control				18	9	21	

Table 7. FSPC by orchard and treatment. Probabilities that treatments are different from the control are based on ANOVA and multiple comparisons using a Holm correction. Blank cells indicate no data.

			Treatment				
Orchard No.	Location	SPU	Control	Matador	Pounce	Matador + Surround	Orchard Mean
237	Kettle River	PG low	10.9	14.3	12.3	18.5	14.0
238	Kettle River	CP low	6.7	15.8	13.8	12.4	12.2
337	Grandview	NE low		8.3	6.7		7.5
338	Grandview	TO low	3.7	11.6	8.0	12.1	8.9
240	Sorrento	BV low		4.9	2.2	4.1	3.7
241	Sorrento	CP low	1.8	3.0	2.9		2.6
234	VSOC	BV low	6.3	7.5	8.4	6.7	7.2
236	VSOC	PG low	3.7	5.1	7.7	6.2	5.7
Treatment Mean			5.5	8.8	7.7	10.0	
Increase (%) over Control				60	41	81	
Probability difference over Control				0.007	0.044	0.007	

Table 8. %FSPC by orchard and treatment. Probabilities that treatments are different from the control are based on ANOVA and multiple comparisons using a Holm correction. Blank cells indicate no data.

			Treatment				
Orchard No.	Location	SPU	Control	Matador	Pounce	Matador + Surround	Orchard Mean
237	Kettle River	PG low	41	56	46	67	53
238	Kettle River	CP low	43	53	61	61	54
337	Grandview	NE low		40	34		37
338	Grandview	TO low	22	51	46	46	41
240	Sorrento	BV low		52	30	42	41
241	Sorrento	CP low	26	46	39		37
234	VSOC	BV low	55	55	61	59	58
236	VSOC	PG low	30	45	52	51	44
Treatment Mean			36	50	46	54	
Increase (%) over Control				37	28	49	
Probability difference over Control				0.002	0.011	0.001	

The second hypothesis (Surround effects are additive to Matador) is rejected, as no significant differences were found in FSPC production following an additional treatment with Surround in a Matador-sprayed block, relative to treatment with Matador alone. As discussed previously, Surround may impact filled-seed production through a cooling effect that could result in less stress, or through a pesticide effect due to the gritty kaolin clay particles impacting insects. As there was no significant improvement in filled seed production when Surround was used after Matador relative to using Matador alone, it is likely that previously observed modest improvements in filled seed production at Kalamalka in 2015 (22%) was due more to a pesticide effect than to cooling. However, this assertion should be further tested, as the applications of Surround in the trials reported here likely resulted in a less complete coverage of the product on foliage than was achieved in the Kalamalka trial. Also, it is likely that most of the orchards in this trial are under less physiological stress than the orchard used for the 2015 Kalamalka trial.

Data here support conclusions of Strong (2015) and Woods et al. (2015) that about half of the loss in filled seed is due to Lepto predation by over-wintering adults feeding on developing seeds from about mid-May to mid-June. Losses during this period reduce TSPC and the number of viable seeds in a cone that can develop during the late spring and early summer. The remaining losses appear to take place from mid-July through to late September (Woods and Strong 2016). For operational control of Lepto feeding, a first pesticide spray in mid-to-late-May to reduce over-wintering Lepto populations is likely the most critical treatment as it has a large impact on the potential number of seeds available for development through the remainder of the spring and summer. Furthermore, if uncontrolled, these adults give rise to progeny that consume seeds later in the summer. A second spray in late-June to mid-July can be undertaken based on observed Lepto populations. Quick harvest beginning about the last week of July or the first week of August will help avoid Lepto predation from developing nymphs and adults during the August and September feeding period.

Recommendations

1. Trials to further compare the efficacy of Pounce relative to Matador are warranted.

2. Comparison of Matador with Surround on more stressful sites such as Bailey Road, Kalamalka, and VSOC would help to determine if Surround is improving seed set because of cooling and associated stress reduction or because of a pesticide effect. These trials should include blocks with Matador, Surround,

and Matador+Surround.

3. Pesticide treatments to control Lepto should be applied in mid to late May on north Okanagan sites and as soon as possible after surveys detect any Lepto.

4. Summer pesticide treatments to control Lepto should be applied based on surveys.

5. Early and quick cone harvest should be carried out beginning in late July or the first week in August, as is the current practice on most sites.

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Managing a Cone Crop in an Orchard with Excessive Seed in Storage

This is a problem that orchard managers will encounter as our original first generation seed orchards reach the end of their operational lives. These mature orchards can be extremely productive but there is often a huge inventory of seed in storage for the seed planning zones they are intended to service.

We had to deal with this situation at Kalamalka Seed Orchard in 2018. First generation Sx orchard 306 (Nelson High seed planning unit) delivered a bumper crop. Clients in this SPU use about 2 million seedlings annually. There is approximately 25.7 years' worth of Class – A seed in storage.

Obviously collecting the bumper 2018 cone crop would just exacerbate the over-supply situation.

Why not just leave the cones on the trees?

Leaving a large amount of cones in the orchard is a sure way to develop insect problems. Pests will complete their life cycles in these unmanaged cones and emerge the following year to prey on the next crop.

Sanitation picking (removing all the cones from the orchard before the insects can complete their life cycles) is an option but this is costly and time consuming – especially with a large cone crop.

What did we do?

Haley Walsh (Kalamalka seed orchard supervisor) and I stepped back and considered all the angles. First, some background on orchard 306:

- This orchard is capable of producing seedlots in the 25% GW range (Genetic Worth = % gain in volume expected at rotation).
- There are about 51 million potential seedlings in storage for this SPU.
- However, most of the stored material is fairly low gain and will probably never be used (our clients prefer the highest GW seedlots available).
- Only about 5.0 million seedlings in storage are GW 18% or better.
- The trees in 306 are generally quite old and tall (many of them are 6 – 8 meters in height). The cones are usually high in the crown.

Haley and I decided it would be appropriate to create a small, high value seedlot from orchard 306. This was our approach:

- Haley surveyed the orchard. Cones were counted on each tree and the trees were categorized according to picking efficiencies ("money tree" rating system).
- We selected trees from the 12 highest ranking clones that had major cone loads. We used the cone estimate survey to ensure that we collected roughly the same number of cones from each of these high ranking clones
- This will allow us to deliver a 25% GW seedlot with an effective population size of +10.

What about cones that did not get picked?

Orchard 306 contains 34 clones. We did not plan on harvesting crops from 22 of these clones. This would be a significant number of cones to leave behind.

The decision was made to top the unmanaged trees and remove the tops from the orchard before the cones matured. This crown management activity served three purposes:

1. The majority of the unpicked cones were removed from the orchard when we topped the trees. This effectively cut off insect life cycles mid-stream so the pests could not develop. This could be considered another (less labour intensive) form of sanitation.
2. The trees were getting too tall and hard to manage, crown height needed to be corrected anyways.
3. With the possible exception of the high ranking clones seed from this orchard is not in demand. Reducing crown size on the lower ranking clones should discourage the production of large crops from the lower ranking clones for a few years.

Conclusion

We feel the strategy we applied to orchard 306 was an effective way of managing the situation. However, this whole issue could have been avoided if we had planned better in the past.

Seed inventory management is something we need to pay more attention to. Once an orchard has an adequate supply of seed in storage the management focus should shift from production to gain. Upgrading and / or downsizing strategies should be employed to produce smaller high gain seedlots once basic seed needs for the SPU have been safely met.

In the case of orchard 306 old low gain seedlots should be decommissioned and removed from the books. Including old lots that will probably never be used in our inventories falsely inflates seed supply figures. Please note that orchard capacity decisions are influenced by seed inventory information.

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Managing Borderline Cone Crops

Deciding whether or not to manage a borderline cone crop is something every seed orchard manager is going to have to deal with at some point. An orchard will produce a marginal cone crop and the decision has to be made – should we manage this crop or walk away?

Managers are under a lot of pressure to produce seed from their orchards. Seed orchard operating budgets are often dependent on seed sales. There is the perception that not harvesting a crop and leaving seed behind in the orchard is a failure. However, in some cases deciding not to manage a borderline crop is the right call. First of all let us define a couple of issues:

What is a borderline or marginal cone crop?

Generally speaking we are referring to a situation where revenue from seed sales may not cover the costs of managing the crop.

In a perfect world most of the trees in an orchard will have a reasonable amount of cones on them and collecting the crop is an obvious decision. The reality is that there will be times when an orchard has a very light crop. Sometimes only certain clones produce cones and the majority of the trees in the orchard have little or no crop.

At this point the manager has to decide if the quantity and quality of the seed that the orchard can potentially deliver justifies the effort and expense of harvesting the crop.

What is crop management?

If one decides to manage a cone crop you are committing to a series of events and expenses we will refer to as crop management. These activities may include:

- Crop assessments, including flower surveys and phenology assessments.
- SMP (supplemental mass pollination) if appropriate.
- Insect surveys and pest management (and you will definitely be battling insects if it is a light crop).
- Cultural activities that promote cone and seed health such as increased irrigation and additional fertilizer.
- Cone harvest and related logistics including hiring picking crews, organizing equipment, co-ordinating with the cone processing facility, post-harvest care and storage, cone shipping, seedlot reporting.

Here are some points that should be considered when trying to decide if you should manage a borderline crop:

Is the seed from the orchard in high demand?

- How badly do your clients need the seed from this orchard? If seed is in short supply it might be worth accepting the additional effort, expense and risk managing a marginal crop will require? In BC managers can refer to the latest FGC business plan for information on “estimated years of class-A seed in storage”.
- Consider seed lot genetic worth or pest resistance. A very high quality seedlot may be worth managing?

Think about costs

Due to “economy of scale” it is going to cost a lot more to manage a light crop.

- A marginal cone crop will often require SMP because of light pollen loads. This is a cost that may not be incurred in a normal crop year.
- Picking costs will increase. Trees are generally carrying fewer cones and crop trees are further apart so efficiencies are reduced.

- Spray costs may be higher. Extra insecticide applications are often required to protect a light crop.
- Despite best efforts to protect the cones light crops often have high levels of insect damage. Cones that are infested with insects slow down the pickers (pickers will be forced to decide if damaged cones are worth harvesting).
- Processing insect damaged seed lots requires more effort and expense at the processing facility.
- Always remember that managing a borderline crop is a risk. Despite your best efforts you may not have a successful outcome. You may have to make the decision to walk away from a light crop once you have already made an investment (after SMPing for instance).

Chances of producing a successful seed crop:

- Pest surveys may be required to predict pest loads. In general pest pressures are heavier on a light crop.
- It is difficult to protect a crop from high pest loads. If pest loads are extremely high it is unlikely that even repeated sprays will deliver total control. In other words, expect to lose a percentage of the already marginal crop to insects. These anticipated losses must be factored into your decision making process.
- Big crop – small crop ecology. Here is what Kalamalka Pest Biologist Jim Corrigan has to say about this situation in addition to Figure 1:

  In normal years, the pest population takes a small proportion of the crop. The mast crop overwhelms the pest populations' abilities to exploit a large volume of host material, but all the pests find cones for reproduction. In the post-mast year, unusually large pest populations are attacking an unusually small cone crop. While this crop will be devastated, the small number of cones available for attack in the post-mast year reduces the pest populations to very low levels for the next growing season.

  The message here is that you should look back at the previous crop season to determine if the big crop – small crop ecology issue applies to the crop you are trying to manage.

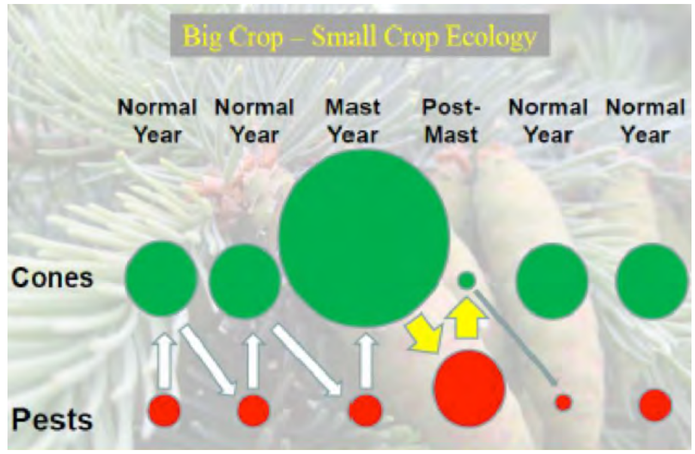

Figure 1. Relationship between cone crop size and pest cycles. Slide provided by Jim Corrigan.

- Seed set is often lower in a light crop year. This is probably due to two factors. Increased insect pressure and decreased pollen supply. If there is a light cone crop there is usually a light pollen crop. Not only are you spending more time / effort to collect fewer cones, you are likely to yield less seed as well. Seed set can be estimated with a half cut survey prior to harvest.
- A marginal crop may have a reduced effective population size. In most light crop years it is only a subset of the orchard clones that are contributing to the crop (personal observation). In certain cases it may be difficult to meet minimum *Ne* requirements? A crop tree survey or cone count should be conducted to determine if this is the situation.

Other considerations

- What else do you have going on? Will dealing with the marginal crop draw resources (people, equipment, etc) away from other more important tasks?
- Be aware that when managing a borderline crop you are dealing with an unstable situation. The volume of potential cones can decrease suddenly due to conelet abortion from lack of pollen, insect predation and many other factors. A marginal crop must be assessed on a regular basis to make sure the number of cones has not dropped below minimum requirements.
- Most insecticide sprays will reduce beneficial insect populations – which could have repercussions the following year. Pesticides can also have a negative impact on tree health.

- The bottom line is that you have to think ahead. Is it really worth protecting a borderline crop if you are going to jeopardize plant health and future crops.

Conclusion

Every situation is different and a manger must consider all angles when trying to decide if a borderline crop is worth managing. Just remember that in some cases deciding to walk away from a crop can be the best decision.

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Opening Coniferous Cones

Conifer cones can be described as hydrophilic (having an affinity for water) and this affinity may be realized through direct absorption of liquid water (i.e. soaking cones) or through gaseous water when cones are placed in an environment with a higher relative humidity than the cones have equilibrated to. The cells of mature cones are predominately dead and water uptake or loss is a passive process that can go through repeated cycles of cone opening when dry and closing when wet. Cones have also been referred to as hygromorphs as they respond to environmental humidity by changing their shape (Reyssat and Mahadevan 2009). These physical properties allow cones to be used as a hygrometer. You can find many articles and videos on the topic, but I'm including the link to Robert Krampf's (The Happy Scientist) version.

The most in depth studies of the conifer cone opening mechanism were done in 1964 illustrating the differential anatomical construction and shrinkage properties between the upper (adaxial) and lower (abaxial) portions of the ovuliferous scale (Allen and Wardrop 1964; Harlow et al 1964). The mechanism appears to have been present for millions of years based on coalified cones exhibiting similar characteristics (Poppinga et al 2017). The upper surface of the ovuliferous scale contains the vascular tissues (primarily tracheids) and the lower surface composed primarily of sclereids, characterized by thick lignified cell walls (Dawson et al 1997) (Figure 1). These cells are all dead at cone maturity and prior to cone opening the flow of water from the tree is halted through the blockage of the tracheid cells by the secretion of resin at the base of the cone axis.

More recent literature and interest on cone opening mechanisms has been found in the engineering literature as cones are a common example used to demonstrate passive systems to induce movement (actuation). In Figure 2, a closed and open cone as well as the significant differences in cell anatomy are displayed. The flexing or bending of the cone scale is due to the difference in the cellulose microfibril angle in the middle secondary cell wall between the tracheids (low angle = resists elongation) and the thick walled sclereids (high angle = allows elongation when damp). The ovuliferous scale has been described as being similar to a bimetallic strip, although it is differences in humidity vs. temperature that cause the movement to occur.

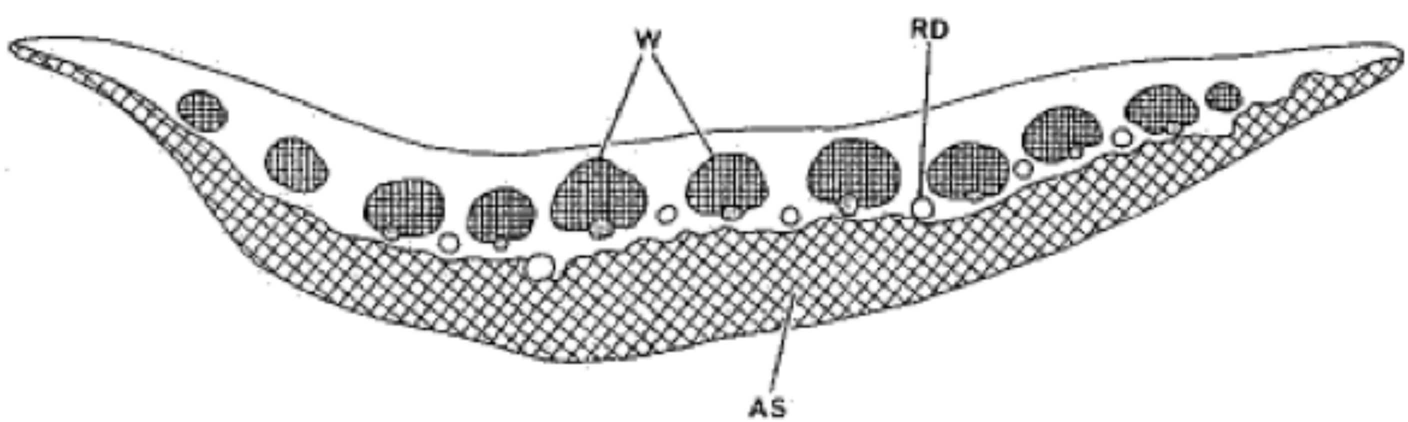

Figure 1. Cross section drawing of a pine cone scale. AS = abaxial sclerified tissue; W = adaxial tracheids; and RD = resin ducts. Illustration from Fahn and Werker (1972) based on the photograph in Harlow et al 1964.

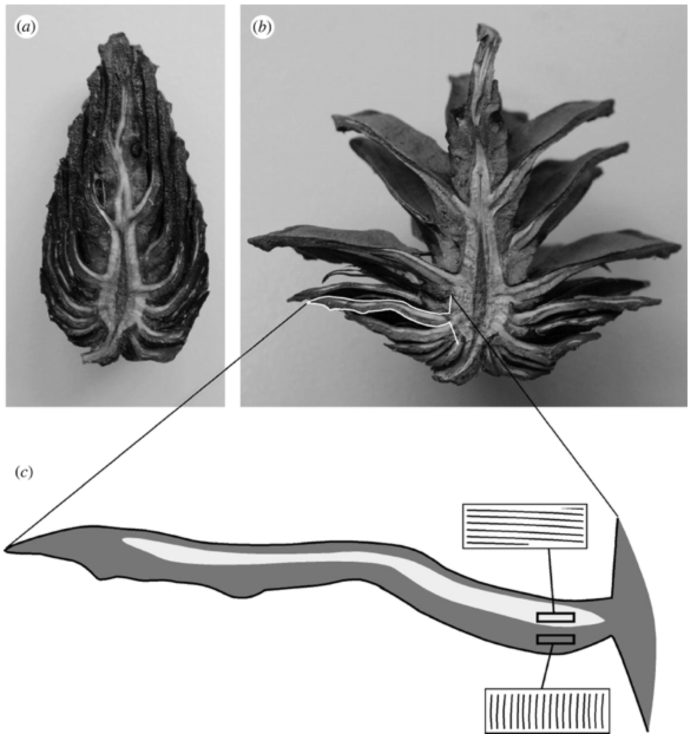

Figure 2. A comparison between two cone halves with a) being wet and b) being dry. The diagram illustrates the differential secondary cell wall structure (cellulose microfibril angle) of the two faces of the ovuliferous scale that results in cone scale opening and closing. Figure supplied from Burgert and Fratzl (2009).

Following the cone scale movement after soaking it was obvious that most of the scale motion occurred at the distal portions of the scale (Song et al 2015). Species differences in scale elongation, and deflection of cone scales, was compared among spruce, pine and larch cones. The difficulty in extracting *Larix* seeds was attributed to the restricted amount of scale elongation at the proximal end and resulting narrow scale angle of 30% while spruce scales may be 50% (Aniszewska 2010). A comparison of five pine species indicated that elongation of scales ranged from 10.6% in *Pinus palustris* to 31.6% in *Pinus sabiniana* after a 24-hour soak (Harlow et al 1964).

This passive mechanism of dead cells allows the ovuliferous scale to open and close in response to liquid or gaseous water. The mechanism causes maximal opening to occur under the driest conditions which would most easily allow the seeds to be dislodged and travel the farthest. Under moist conditions, when seed dispersal distances would be less, the cones close.

Most of the work on cone opening has been based solely on pine species, but there is no evidence to indicate that this general model does not apply to the majority of conifers. There are couple of adaptations to cone opening namely cone serotiny and the progression from easily removed ovuliferous scales (i.e. *Pinus albicaulis*) to full abscission (i.e. *Abies* spp.) as the normal process and these will be discussed in a future article. I'm always interested in additional references on the topic, so if you are aware of any, please forward them to me.

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Fungal Assay Results of BC Tree Species

This article is an update to fungal assay information presented in a 2010 extension poster to summarize results, increase program awareness and help with interpretation of the results. The original poster can be viewed at this link in a full page format and large scale posters were also produced and distributed to BC nurseries at that time: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-seed/tree-seed-centre/tsc_fungal_assay_poster_2010.pdf

That poster is still a good, brief source of information regarding the program, its history and how to interpret results. The specific pathogen results for each seedlot are available on our BC Seed Planning and Registry (SPAR) system which includes seedlot registration information, test information and also acts as a means for entering seedling requests. This summary is also timely as it coincides with the retirement of Michael Peterson who has conducted the vast majority of our fungal assays to date over the last 25 years. Thank you Michael for all the assistance you have provided to the BC reforestation program! The fungal assay program of tree seeds will continue under a Memorandum of Understanding (MOU) with the Plant Health Unit within the BC Ministry of Agriculture.

Table 1 provides an update on the testing program with the respective sample sizes by species (not provided in the initial poster due to size restrictions). Over the past 25 year there were 6,920 tests performed with 64% being for *Fusarium* spp., 21% being for *Caloscypha fulgens* and 15% for *Sirococcus conigenus*. The emphasis on referring to the results as an infection (occurring inside the seed) or contamination (on the surface of the seed) is important to understand respective options for disease control. With *Fusarium* as a contaminant any surface sanitation technique (hydrogen peroxide, bleach, running water soaks) will result in a decrease in seed-borne contaminants, but will not have an effect on infected seeds. In *Caloscypha fulgens*, seeds are killed by the pathogen and in *Sirococcus conigenus* the pathogen causes a blight – often on an alternate species. More details on the pathogens, testing and control methods can be found in the *Seed Handling Guidebook* (https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-seed/tree-seed-publications/seed_handling_guidebook_hi.pdf).

It is worthwhile reviewing the statistics presented and their interpretation and as an example I will use *Larix occidentalis* and *Fusarium* spp. This combination had tests performed on 259 seedlots and a contamination probability of 62.2% was estimated meaning 161 out of the 259 tests had a result greater than 0.0%. Of those 161 tests with results greater than 0.0 the average contamination is 2.3% and the maximum seedlot result obtained was 43.2%. It is believed those are the most useful statistics, but if you prefer the Average contamination be based on all tests, not just those greater than 0.0, then in this example simply multiply 161 × 2.3% and then divide by 259 resulting in an overall average of 1.4%.

The presented results indicate the total scope of the testing program to provide 'reasonable' estimates for infection and contamination estimates when seedlot specific results are unavailable. The estimates include seedlots that have been fully consumed and no longer part of the inventory. A reassuring part of the program is that the maximum test results have not changed from the 2010 poster indicating that those very high pathogen levels are not reflective of new seedlots, but a legacy of our past collections.

The transition to a new program provider have brought with it a review of past practices and a refocusing on the most critical items. Here are a few thoughts on our potential changes and I'm interested in feedback from BC and other jurisdictions.

1. Discontinue testing samples for the Sirococcus shoot blight (*Sirococcus conigenus*). This is simply due to the perception that this is not a problem in the forest tree nurseries based on discussion with a variety of growers. The fact is that we don't currently have a good feedback

Table 1. The results of the BC fungal assay testing program (1992-2017) by tree species[1] and pathogen.

	Fusarium spp. Contamination (%)				*Caloscypha fulgens* Infection (%)			
Species Code	Sample Size	Contamination Probability	Average Contamination	Maximum Contamination	Sample Size	Infection Probability	Average Infection	Maximum Infection
Ba	265	31.3	1.1	12.1	199	14.1	3.9	22.0
Bg	58	41.4	1.6	7.0	42	14.3	5.1	12.4
Bl	245	33.9	0.8	14.0	204	34.8	4.9	32.8
Bp	23	52.2	1.0	2.0	23	4.3	2.0	2.0
Cw	331	48.3	1.4	20.4	11	0.0	0.0	0.0
Fdc	517	57.6	3.2	84.0	61	1.6	0.4	0.4
Fdi	687	57.9	1.7	42.0	158	8.2	1.4	4.4
Hm	30	13.3	0.2	0.2	8	0.0	0.0	0.0
Hw	176	30.1	0.8	4.8	55	7.3	0.4	0.4
Lw	251	61.8	2.1	43.2	17	0.0	0.0	0.0
Plc	4	25.0	0.1	0.1	5	0.0	0.0	0.0
Pli	548	6.6	0.4	1.2	53	0.0	0.0	0.0
Pw	150	64.0	2.4	29.0	110	5.5	1.6	4.8
Py	230	51.3	2.1	35.8	27	7.4	5.2	10.0
Sb	5	0.0	0.0	0.0				
SS	96	22.9	1.3	6.4	85	9.4	7.8	37.6
Sx	717	25.2	1.6	39.8	383	11.2	2.5	16.0
SxS	36	13.9	0.8	2.8	38	21.1	1.9	9.2
Yc	28	25.0	0.4	0.8	7	0.0	0.0	0.0
Total	4402				1486			

[1] Tree species codes: Ba = Abies amabilis; Bg = Abies grandis; Bl = Abies lasiocarpa; Bp = Abies procera; Cw = Thuja plicata; Fdc = Pseudotsuga menziesii var. menziesii; Fdi = Pseudotsuga menziesii var. glauca; Hm = Tsuga mertensiana; Hw = Tsuga hetetrophylla; Lw = Larix occidentalis; Plc = Pinus contorta var. contorta; Pli = Pinus contorta var. latifolia; Pw = Pinus monticola; Py = Pinus ponderosa; Sb = Picea mariana;

loop to inform the fungal assay program, but no one has directly complained about *Sirococcus* for well over a decade, so an easy gain in efficiency if it truly is not an issue. Please let me know if you are experiencing Sirococcus shoot blight with your spruce or pine crops.

2. A pathogen that we have been hearing more about is *Fusarium* caused problems with coastal Douglas-fir. It is unclear whether the pathogen is introduced via the seed, but some seedlots do have high levels of the *Fusarium* genus. Although there has been past work on identifying *Fusarium* to the species level, this was not considered cost-effective. It is generally believed that we would be much better served with assays to the species level as pathogenicity can vary greatly between species. With advances in molecular biology, reduction in cost and greater availability of equipment this may now be a realistic option. There is still work to do, but this is a primary focus area – anyone else interested? We don't want to recreate the wheel.

3. Discontinue quantification of companion fungi. The identification of fungal species other than the target has been a part of our historical program. This adds to the workload without providing any additional useful information to the grower. This information has not been used and removing it as a deliverable will greatly increase program efficiency.

Table 1 continued.

Species Code	*Sirococcus conigenus* Infection (%) Sample Size	Infection Probability	Average Infection	Maximum Infection
Ba				
Bg	1	0.0	0.0	0.0
Bl				
Bp				
Cw				
Fdc	4	0.0	0.0	0.0
Fdi	6	0.0	0.0	0.0
Hm				
Hw	82	8.5	0.3	0.5
Lw	44	18.2	0.5	1.4
Plc	7	0.0	0.0	0.0
Pli	23	0.0	0.0	0.0
Pw	3	33.3	0.9	0.9
Py				
Sb	1	0.0	0.0	0.0
SS	97	18.6	0.3	1.5
Sx	734	14.2	0.7	7.8
SxS	28	25.0	0.6	1.4
Yc				
Total	1032			

I welcome any feedback on our fungal assay program and our pathway to the future.

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National Tree Seed Centre Update

If there is a period of down time at the NTSC I have yet to discover when that might be! The fringes between seasons seem too blur and just when we think that we might be catching up, another headwind comes in.

Over the late winter and spring of 2018 the NTSC was fortunate to have three new technicians join our staff. Roger Graves, Sarah McLean and Katie Burgess joined Peter Moreland and myself for the better part of three months as we cleared away the backlog of 2017 collections that needed to be processed and cataloged. We also used this extra help to get an early start to our 2018 testing on stored seed lots. As a result of her strong performance during this time we feel very fortunate that Katie Burgess has been assigned to us until March 2019.

During this time we also updated the capacities of the NTSC by installing our new seed cleaner (Figure 1) which we estimate will cut our processing/cleaning time for ash and maple seed by 50–75 percent. In addition all nine of our germinators have been equipped with data loggers so we can monitor them remotely for changes in temperature, humidity, light and CO_2. We have also been working with our IT group to revamp the interface with the NTSC database, making it more intuitive and easier to navigate

Figure 1. *Fraxinus americana* seed before and after two × 30 second cycles in the Westrup seed cleaner.

for data queries.

Over the past winter an R&D knowledge transfer agreement was signed with Viridis Terra Innovations out of Quebec to advise them on setting up a seed collection and processing facility for tree species, of interested, for land reclamation. The species we are assisting them with are those not readily available at high vigor levels from private nurseries, specifically *Salix* spp. and *Populus* spp. Dr. Evgéniya Smirnova joined us for five days of knowledge transfer which resulted 55 new collections of these species this spring.

The NTSC is also happy to welcome UNB master's student Rob Vaugh to the mix. Rob will be studying the affects of projected climate change scenarios on seed germination and early seedling growth. He is to officially start September 2018, but is already spending time at the NTSC in preparation!

With Emerald ash borer (EAB) being positively identified in the Maritimes in the spring of 2018 the NTSC continues to build and expand upon our collaborative efforts with the Invasive Species Centre and Forest Gene Conservation Association in Ontario and to expand our citizen science network throughout eastern Canada. Collaboration with First Nations and Provincial Rangers have been extremely helpful for early forecasting. Initial indications in the Maritimes are showing a bumper crop for seed collections in 2018, but not much anywhere else.

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Upcoming Meetings

ISTA ATC Workshop on Seed Image Analysis
November 26–30, 2018
Registration dead October 26, 2018
Piracicaba, Brazil
https://www.seedtest.org/en/event-detail---0--0--0--102.html

4th World Congress on Agroforestry
May 20–22, 2019
Montpellier, France
https://agroforestry2019.cirad.fr/

Opportunities & Issues in Re-Wilding
May 22–23, 2019
Sheffield Hallam University, Sheffield, United Kingdom
https://www.ukeconet.org/opportunities_issues.html

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

Recent Publications

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