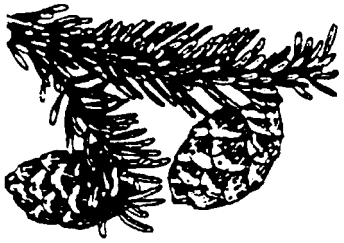
CANADIAN FOREST GENETICS ASSOCIATION
ASSOCIATION CANADIENNE DE GÉNÉTIQUE FORESTIÈRE



Tree Seed Working Group

NEWS BULLETIN

No. 63 June 2016

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CHAIR'S 'ARMCHAIR' REPORT

Hello! In BC we just finished putting on our BC Seed Orchard Association (BCSOA) meeting in Langley, BC in which our Tree Seed Centre was a focal point and one of the afternoon tours. The agenda is included in the News Bulletin and we will be putting the pdf versions of all presentations up on a webpage in the near future and will include that link in the next News Bulletin (or contact me if you can't wait that long ☺). I'm still coming down from that rush of meeting activities, but the most lasting impression is the passion that individuals have for their part in the delivery of genetic gain to the landscape. It's a great community of practice to be a part of.

A consistent theme in our community of practice is succession and upcoming retirements. Looking at our facility one year from now, there will be new faces in six of our thirteen permanent staffing positions, so it's a time of intense change. I encourage anyone who is interested in opportunities at the BC Tree Seed Centre to contact Heather Rooke, our Manager, (Heather.Rooke@gov.bc.ca) for additional information. A significant change in Ontario is the retirement of Al Foley who managed the provincial tree seed plant in Angus. Al was a frequent contributor to the News Bulletin and our workshops and he will be missed by many. There are a couple historical articles in this News Bulletin that focus on the people and facilities that have been involved with tree seed collection, production, and use. It's a good way to leave a little legacy or memory to those people and organizations that have brought us to where we are today. In this Edition, we also have a reappearance of George Edwards who contributes his own unique version of passion to a topic that he has thought long and hard about. On a more sombre note, Bob Dobbs passed away on May 23, 2016 at

80 years of age. Bob worked for many years with the Canadaian Forest Service and ended his career as Manager of the Seed Services section of the BC Ministry of Forests. A memorial service will be held on Friday July 29th, 2016 at the First Unitarian Church of Victoria.

Reforestation efforts in BC are in full swing as we continue to recover from the effects of the mountain pine beetle epidemic. Over 260 million seedlings will be planted in BC this year with over 55% coming from seed orchards. Highlights include about 80 million seedlings of interior spruce (white (*Picea glauca*), Engelmann (*P. engelamnnii*), and hybrid swarms) being produced from seed orchards, equivalent to about 86% of the provincial need for this species group. Lodgepole pine (*Pinus contorta*), our most planted species in BC, continues to challenge us in meeting our needs with only 28 million seedlings being produced from seed orchards, an additional 21 million being produced from superior provenances and the remaining 58 million coming from standard wild stand collections. These two species account for 77% of the requested seedlings. Other species programs are indicated below as millions of seedlings produced (and % of orchard seed use in brackets): western white pine (*Pinus monticola*) – 1.8 M (100%); western larch (*Larix occidentalis*) – 8.1 M (93%); coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) – 11.7 M (87%); interior Douglas-fir (*P. menziesii var. glauca*) – 6.8 M (38%); and western red cedar (*Thuja plicata*) – 5.8 M (54%). Genetic worth (GW) for growth of seed orchard crops averaged across species was 15% indicating that is the increased volume expectation at harvest compared to using local, wild seed. Several programs have seedlots with a GW above 25 – interior spruce, interior Douglas-fir, western larch, and red alder (*Alnus rubra*).

In terms of upcoming meetings, next year's Canadian Forest Genetics Association meeting will be in Edmonton with the Tree Seed Working Group workshop being handled as a conference session vs. a separate meeting. More details will be brought to you in the December News Bulletin, but never too early to express interest to your supervisors. Next summer, we will also see the International Seed Testing Association (ISTA) have its annual meeting in Denver, Colorado which may make it a reasonable destination for some to attend. I'm sure there are many upcoming meetings and I welcome you to contribute announcements or summaries to future News Bulletins. Have a fun and safe summer.

Dave Kolotelo

EDITOR'S NOTES

Welcome to another edition of the Tree Seed News Bulletin. This issue offers a wide variety of articles. Michele Fullarton starts by illustrating the use of growing degree days to time cone collection in seed orchards. Dave Kolotelo provides a summary of the BC Seed Orchard Association meeting. George Edwards has written a detailed treatise on pure seed definitions and why they need to be changed. Don Pigott submitted an article about Frank Barnard outlining his contributions to the seed industry in British Columbia. Fabienne Colas and her collaborators provide an interesting perspective on the impact of temperature on equilibrium relative humidity. Melissa Spearing also talks about equilibrium relative humidity and drying seed. Peter Hellenius provides a historical perspective of his former seed company. Barb Boysen and Melissa Spearing write about various projects and activities of the Ontario Forest Gene Conservation Association. Dave Kolotelo reports results from a study on natural cone drying following collection. Ward Strong provides an update on new pesticide registrations for seed orchards. Katri Himanen volunteered an article about variation in full seed among Norway spruce trees and clones.

I hope that you all have a great summer enjoying nature's beauty. Until the next Bulletin ...

Dale Simpson
Editor

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Comments, suggestions, and contributions for the News Bulletin are welcomed by the Chair and Editor.

All issues of the News Bulletin are available at: http://www2.gov.bc.ca/gov/topic.page?id=4E4651B3A01448FAB6F39ACAD1C348C1

USING GROWING DEGREE DAYS FOR SEED ORCHARD CONE COLLECTION

Cone collection at the DNR Tree Improvement Unit is an important component of our annual work planning, and the reforestation nursery relies on a high quality, reliable source of seed for their production. Cone collection in our orchards began in the late 1980's, and continued as we changed from using seedling seed orchards to clonal orchards exclusively by the late 1990's. Over the years, we have recorded the dates that cone collection started and, since the year 2000, the corresponding growing degree days (GDD). GDD provide a guide to when cones are ripe and embryos sufficiently developed. We use a web-site called FARMZONE (http://www.farmzone.com/) which records local weather conditions. For GDD, the mean temperature for the day is calculated and 5 is subtracted. If the number is negative, there is no GDD. However, if it is positive, this value is used. The cumulative value for the current year is used, but in the case of the pines, the cumulative value over 2 years is used. In addition, we also do a cut test of the cones in the field to evaluate embryo development.

Table 1 summarizes collection dates and GDD for various species over the past 16 years. White spruce (*Picea glauca*) cones collected in 2000 did not yield good seed as they were collected too early. We have since found that white spruce needs a minimum of 1000 GDD before collections begin. Also the black spruce (*Picea mariana*) cones will start to open in the fall if we get hot, dry weather, although that is not typical. We have not collected any jack pine (*Pinus banksiana*) seed since 2007 due to reduced sowing in the nursery, and in the past 2 years there has been no jack pine seed used. We have a large inventory that is periodically re-tested. The Norway spruce (*Picea abies*) orchard yielded its first small crop in 2015, but the cones were scattered throughout the orchard. The cones were all collected from squirrel caches in the orchard, so it required extra drying time on benches in one of our empty greenhouses. This ensured the cones dried properly, as they tend to absorb a lot of moisture when piled in caches.

We have had great success with our collections over the years and find that timing is one of the many important factors in order to maximize seed yields from the collection. With changing climate and weather conditions, it is important to keep a close eye on all the factors affecting cone development and ripening.

In conclusion, it would be interesting to know how our GDD values compare with those from other provinces in the country with the same species.

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Table 1. Cone collection dates and corresponding Growing Degree Days for collections made in NBDNR seed orchards over 16 years.

	2000		2001		2002		2003		2004		2005		2006		2007	
Abies balsamea					13-Aug	**1112**			11-Aug	**1104**			14-Aug	**1370**		
Picea glauca	1-Aug	**707**							9-Aug	**1075**			14-Aug	**1370**		
Picea mariana	28-Aug	**865**	30-Aug	**1507**	21-Aug	**1259**	26-Aug	**1445**	12-Aug	**1120**	29-Aug	**1413**	21-Aug	**1465**	20-Aug	**1272**
***Pinus banksiana* (2 yrs)**	13-Sep	**na**	13-Aug	**2202**	22-Aug	**3252**	18-Aug	**3094**	13-Aug	**3087**					6-Sep	**3482**
Picea rubens									13-Sep	**1500**			6-Sep	**1616**		

	2008		2009		2010		2011		2012		2013		2014		2015	
Abies balsamea							11-Aug	**1090**								
Picea glauca			10-Aug	**1150**			8-Aug	**1065**			6-Aug	**1116**	11-Aug	**1179**	17-Aug	**1184**
Picea mariana	25-Aug	**1434**	17-Aug	**1257**			31-Aug	**1271**	13-Aug	**1269**			2-Sep	**1459**		
***Pinus banksiana* (2 yrs)**																
Picea rubens			28-Aug	**1445**			16-Sep	**1451**	27-Aug	**1451**	22-Aug	**1277**	28-Aug	**1412**	9-Sep	**1545**
***Pinus strobus* (2 yrs)**	16-Sep	**3582**	21-Sep	**3585**			12-Sep	**3299**			27-Aug	**3292**	29-Aug	**3219**	8-Sep	**3407**
Thuja occidentalis	25-Sep	**1736**	24-Sep	**1664**			16-Sep	**1451**							11-Sep	**1576**
Picea abies															13-Oct	**1827**

BC SEED ORCHARD ASSOCIATION (BCSOA) 2016 MEETING

The following is the agenda for our recent BCSOA meeting that took place in Langley, BC on June 21 and 22, 2016. A set of pdf`s of the speakers' presentations will be placed on a dedicated webpage in the near future. We had about 45 people attend the meeting. The organization hosts a meeting every two years and it is anticipated that the 2018 meeting will be in association with the Northwest Seed Orchard Managers Association (NWSOMA). They meet each year, so it's a bit early for them, and us, to be planning for 2018. It's a good meeting opportunity for those managing seed orchards as the meeting is planned to occur in the years between the Canadian Forest Genetics Association conferences.

Tuesday June 21

Session 1 History

Dave Brownstein – The Surprising Origins of Coastal British Columbia Reforestation Efforts, 1914–1939

Don Pigott – Reflections on the Past - From Seed Production Areas to Seed Orchards in Coasta BC

Session 2 Cone Production and Care

Patrick von Aderkas – How to Adorn Trees With More Cones: A Lesson in Patience

Dave Kolotelo – Cone Handling, Monitoring and Tree Seed Centre Overview

The afternoon was spent at the provincial Tree Seed Centre (TSC). The group was divided into two with half initially receiving a TSC tour and the other half receiving a safety session by AgSafe BC on tractor and folklift safety (including a mobile app for simplifying the inspection process), respirator safety, and New Worker Orientation. The two groups then alternated to receive the other session. There was an evening banquet that featured the local Madflower band that got virtually all, young and not so, up and dancing.

Wednesday June 22

Session 3 Orchard and Cone Crop maintenance

Clare Kooistra – Revisiting and Rethinking Water, Soil and Nutrition in Seed Orchards

Ward Strong – New pesticide registrations for Seed Orchards

Screening Trees for Pest Resistance

Session 4 Seed Orchard Updates/Round table

3 to 5 minutes oral presentation by orchard site emphasizing Advances and Challenges
Round table Discussion

Session 5 The Future

Jack Woods – Seed Orchards as a Business

Richard Reich – Managing Foliar Disease in Unpredictable Climatic Conditions

Nick Ukrainetz – Challenges with Future Seed Orchard Composition: Multiple traits and Climate Based Seed Transfer

Following the afternoon session some of the attendees visited the Pacific Regeneration Technology (PRT) Hybrid nursery facility for a tour hosted by Jody Branter. This year`s meeting was unique in that we did not actually tour a seed orchard and focused on the subsequent steps of processing, testing, pretreatment, and the actual use of seed in producing seedlings for reforestation. The organizing committee tried to keep registration costs low by using car-pooling for the afternoon tours and it worked well for the size of the meeting and relatively short travel distances.

Dave Kolotelo

PIECES OF FOREST TREE SEEDS... PIECES OF UNSCIENTIFIC NONSENSE IN THE ISTA RULES

Quite some time after retiring from tree seed testing at the Canadian Forest Service's Pacific Forestry Centre I was surprised to receive an invitation from the International Seed Testing Association (ISTA) to review Pure Seed Definitions (PSDs) for tree seeds. Without too much delay I submitted my ideas for one PSD, only to be told in very strong terms that my revision was unacceptable because I had omitted the provision that "pieces of seed units larger than one-half their original size with a portion of the testa attached, as found in the working sample, are to be considered to be pure seeds".

While this was something I faintly recalled from previous ISTA Rules requirements, it was not a matter that had played a major role in our official testing (we were ISTA-Accredited lab CAN07).

Very reluctantly I agreed to the "correction", but was stimulated to investigate this matter further. Rereading the Rules (Anon. 2009) I discovered that all PSDs for tree seeds, plus other seeds, then included what I identified as Rule 3.2.1.1.2 (Chapter 3 in the Rules is devoted to Pure Seeds). This led me further into the history of the Rules and how this matter had been introduced, and by whom. My research led me to writing a critical review of the piece of seed issue, especially for forest tree seeds; the bulk of this review can be accessed on my web site http://ftb.ca/pieces/; (I recommend including "pieces" because other items are to be found there). This article is a shortened version of this review.

Users of the ISTA Rules will know (need to be reminded?) that the first page of the Introduction states:
(i) The test methods used must be based on scientific knowledge and the accumulated experience of those working in seed testing and quality control. [In this the word "must" is vital.]
(ii) The primary aim of the ISTA Rules is to provide testing methods for seed designated for growing of crops or production of plants. [In this the words "growing" and "plants" are vital.]

Having completed my review I claimed that there is abundant evidence to demonstrate that as far as Rule 3.2.1.1.2 and forest tree seeds are concerned, these claims are patently untrue. That they are, in fact, scientifically bankrupt.

Ashton (2000), an agricultural seed expert, pointed out that Rule 3.2.1.1.2 does not define how to measure "one-half": only seed length, or all dimensions, i.e., seed mass (see Gorian et al. 2006). Actual measurements do not give more accurate results because the appearance of the missing fragment can only be estimated. Also, seeds "exactly one half of their original size are classified as inert matter" (Ashton 2000). This latter is Rule 3.2.3.3. In my review, only seed length is to be considered even though forest tree seeds are usually asymmetrical.

My website version covers several dictionary definitions of the word "**pure**": prominent among these are definitions "uncorrupted; faultless; genuine article; free from alteration; free from anything debasing or deteriorating; unadulterated". "Unadulterated" is a significant word in this context: it means the opposite of "adulterated" which is the opposite of "spurious" or "counterfeit". Are not broken seeds adulterated? They are definitely not the *genuine article*. ISTA should consider stepping outside the pure seed definition box to provide its definitions of the words "pure" and "inert" as they are applied to seeds in general, taking into account such dictionary definitions.

One really important part is **Rule 3.2.3 Inert Matter** which covers 8 provisions; no. 5 states that Inert Matter is to include "pieces of broken or damaged seed units half or less than half of the original size": also "seeds of the (Leguminosae) with separated cotyledons", [irrespective of whether or not the radicle-plumule axis retaining more than one half of the testa is still attached.]

As with the word "**pure**", most definitions of the word "**inert**" speak to the "lack of power to move", but do not state that this "lack of power" is permanent. In a human context, a person may fall to the ground and lie "*inert*", that is, "*without the power to move or act"* until medical help arrives. The person is then *revived* and recovers the power to move. Even intact, fully-developed forest tree seeds are "*without the power to move or act*", that is, they are ***inert*** while they are **dormant.** Dormant seeds do not move, they do not grow/germinate because the power to do so is not available in their dormant state, in which they may remain for months to several years (Bonner 2008).

Thus, based on official English-language definitions, *intact*, *fully developed*, *mature*, *dormant* tree seeds would be classifiable as both "*pure seed*" and "*inert matter*". That is, **inert, pure seed**. As listed in my website version, seeds of a Protoaceae (*Leucospermum* spp.) and two legumes (*Liparia* spp. and *Acacia* spp.) that were collected in the early 1800s were germinated 150 years later: supported by carbon-dating, other seeds have survived for over 200 years (Daws et al. 2007) because not only had they remained **intact,** they remained **inert.** (See also Porsild (1967) for seeds known to have remained inert – not dead – for several thousand years). The ISTA Rules should cease using the term "*inert matter*" in preference to **Impurities.**

Is ISTA (and other seed testing agencies such as Association of Official Seed Analysts) using the correct term in describing forest tree seed units from which the seed coats have been entirely removed as "inert matter" (Rule 3.2.3.5)? Such seed units are not "inert" as defined above. They are dead as can be quickly assuaged with a tetrazolium test (Rule 6). As dead as any chaff, stems, leaves, cone scales, wings, bark, soil particles, sand or stones, as stipulated in Rule 3.2.3.7. They should be referred to more correctly as inanimate. Again, and better still, as *Impurities.*

Another detail that needs attention. All PSDs (11, 47, 49, 50, 51) for the 17 gymnosperm genera

state that *pieces of seed units larger than one-half of their original size* (Rule 3.2.1.1.2) *are to be considered as "pure seed", provided a portion of the testa remains attached*. No explanation is given as to whether this must be a small or large portion of the testa. Eleven of the 14 PSDs (10, 11, 12, 48, 50, 52, 55, 56, 57, 58, 60) to which 28 angiosperm genera are assigned allow that pieces of seed units more than one-half their original size are to be recognized as "pure seed" even if no pericarp or testa remains attached. That is, completely naked seeds are to be recognized as "pure seed" provided they are larger than one-half their original size. Hair splitting at its finest. This ISTA idea makes it clear that "pure seed" means something entirely different from that of seed users – the farmer, the forester, the horticulturist.

The early Rules (roughly 80 years ago) were formulated to deal with the quality of agricultural crop seeds. Forest tree seeds were not introduced until some 50 years ago. So, the provision for piece (or pieces) of seed/seed units that were larger than one-half the original size to be recognized as pure seeds was already contained in the 10 PSDs to which some tree seeds were assigned. For the bulk of other forest tree seed genera 9 new PSDs had to be written. Each and every one of these PSDs included **Rule 3.2.1.1.2**. That is, although certain tree seed genera were shoe-horned into existing definitions, all tree seeds were expected to comply with the existing piece/pieces provision without exception. That is, no consideration was given to the scientific knowledge of forest tree seeds, despite the claim on page 1 of the Rules.

To illustrate what damage a broken tree seed suffers, the excellent line drawings published in Schopmeyer's (1974) "Seeds of Woody Plants in the United States" are used. These have been modified, using Photoshop, by adding check marks to the vertical scale to show proportions of 25%, 50%, and 75% of the overall (i.e., original) size, either from the chalazal (cotyledonary) or micropylar end. Portions of the line drawings have been erased and a dashed line added to indicate the position of each inferred break. For the present discussion, the drawings of a larch (*Larix laricina*) seed are presented; other genera are illustrated on the website version in Appendices I and II. The larch seed drawing was chosen because this particular illustration provides not only an internal impression of the seed structures, as if by x-ray, but also an exterior, adaxial view of a complete seed representing the view that the purity analyst would have. This is shown in Fig. 1.

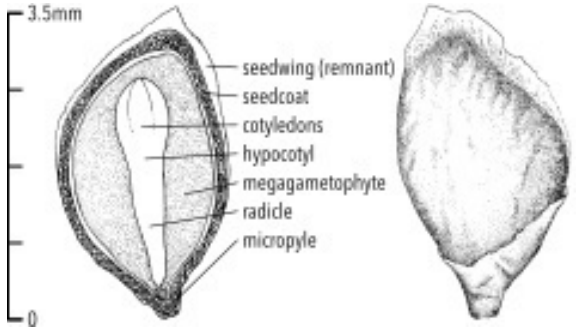

Figure 1. Line drawing of an intact *Larix laricina* seed. On the left is shown the internal structures, on the right is an external adaxial view.

The piece of seed shown in Fig. 2 is approximately 55% of the original length as measured from the chalazal end. Thus, it is larger than one-half of the original, so an analyst must classify it as a "pure seed". The view of the internal structures (left) shows it has lost its embryonic root meristem from which the radicle would develop. It should be clear that this piece of seed (more than one-half the original size) with a full compliment of seed (or testa) represents the same condition, *viz.* **separated cotyledons,** for which seeds of the Fabaceae (Leguminosae) would be classified as "inert matter". Why do **separated cotyledons** not apply to seeds of the Cupressaceae, Pinaceae, Taxaceae or Taxodiaceae? Something appears to be amiss here.

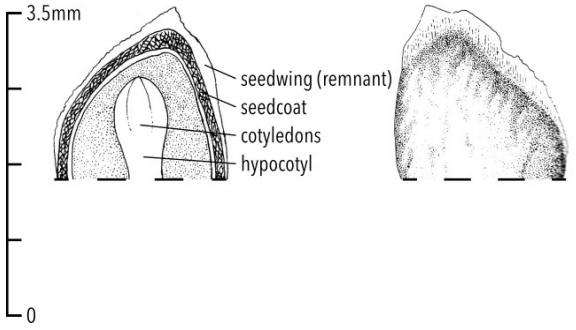

Figure 2. Line drawing of a *Larix laricina* seed broken at approximately 55% of its original length as measured from the chalazal (cotyledon) end.

Even if this piece of seed was sown, or included in a germination test, it would be impossible to form a primary root. All gymnospermous seeds exhibit

epigeal germination so this piece of seed has zero possibility of forming a new plant. The drawing of the external view shows that it would be easily recognizable for what it is to a purity analyst, but it must be classified as a "pure seed" according to **Rule 3.2.1.1.2.** If a **tetrazolium test (Rule 6)** was performed on such a seed, if staining occurred how would it be interpreted (Rule 6.5.2.A.4) for an **incomplete embryo?** Does this not mean that the TTZ test is contradicting the Purity Test?

Similarly, Fig. 3 shows a piece of a larch seed approximately 55% of the original size as measured from the micropylar end: that is, more than one-half the original size so the analyst must classify it as a "pure seed". Yet it is clear from the internal view that it lacks the embryonic cotyledons and its apical meristem. If sown or included in a germination test, the embryo-remnant would swell and the broken surface of the embryo may extrude beyond the megagametophyte surface. Because there is no chalazal end, the elongating embryo-remnant would meet no resistance and would not emerge via the micropyle (epigeal germination). Even if the radicle were to penetrate the micropyle, the lack of cotyledons means that this seed is doomed. The cotyledons are the organs that absorb the energy (mainly sugars) for growth from the megagametophyte, and in their absence the seed will be unable to grow. Yet it must be classified as a "pure seed" according to **Rule 3.2.1.1.2**. If a tetrazolium test was performed on such a piece of seed, how would the staining pattern (if one occurred) be interpreted (Rule 6.5.2.A.4) for an **incomplete embryo**? Another contradiction.

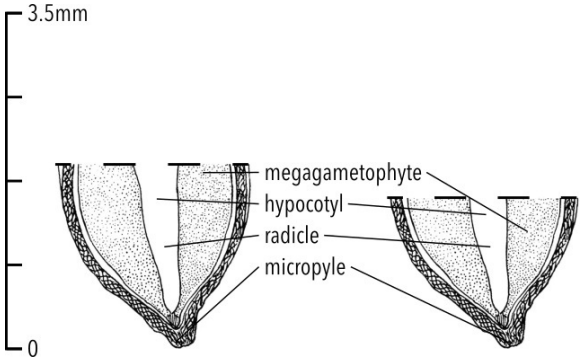

Figure 3. Line drawing of a *Larix laricina* seed broken at approximately 55% of its original length as measured from the micropylar end.

A critical comparison must be made between the larger piece (more than one-half the original size, so "pure seed") shown in Fig. 2 with the smaller piece (less than one-half the original size, so "inert matter") that was broken off when the piece of seed shown in Fig. 3 was formed. These two pieces are shown side by side in Fig. 4. Likewise, the larger piece (more than one-half the original, so "pure seed") shown in Fig. 3 must be compared with the smaller piece (less than one half, so "inert matter") that was broken off when the piece of seed shown in Fig. 2 was formed; these two pieces are shown in Fig. 5.

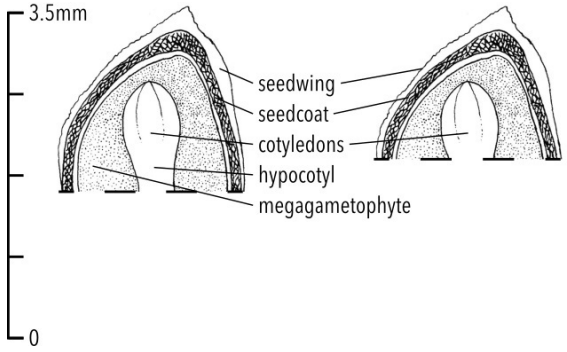

Figure 4. Line drawing showing the piece of a *Larix laricina* seed broken at 55% of its length from its chalazal end (as in Fig, 2) and the smaller than one-half piece that was formed when the seed was broken at 55% of its length from its radicle (Fig. 3).

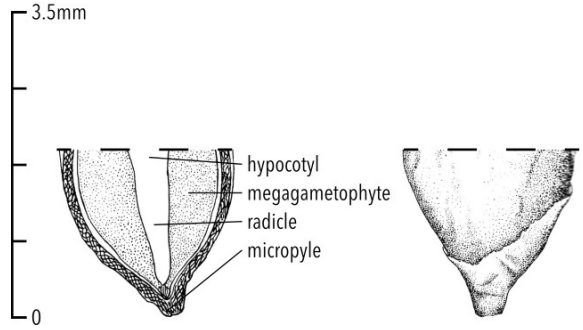

Figure 5. Line drawing showing a *Larix laricina* seed broken at 55% of its length from its micropylar end (as in Fig. 3) and the smaller than one-half piece that was formed when the seed was broken at 55% of its length from the chalazal end (Fig. 2).

What is the difference between these pairs of pieces of seeds? **The only difference is an arbitrary, small variation in size.** In each case, one piece is 55% of the original, so "pure seed", while the other is 45% of the original, so "inert matter". Yet **neither have any potential for producing a new plant.** From this it should be obvious that no scientific principle is at work. **The distinction is pure unadulterated rubbish.**

Rule 3.2.1.1.2 assumes that the analyst knows the original size of the seed, a contradiction in itself since the seed has been broken and a piece is missing. Crop seeds, around which the Rules were originally formed, being highly bred may be quite uniform in all aspects, including size, making it easy for the purity analyst to judge the relative size of a broken seed: likely all seeds in that working sample look alike. However, again see Ashton (2000).

In contrast, for the vast majority of tree seeds, even those from seed orchards, seed size is far from uniform. As all tree seed producers/processors are aware, this variation in seed size must be considered when the seedlot is cleaned, especially if an aspirator cleaning system is used. To avoid small filled seeds from being removed with large empty seeds, the seedlot first must be sized. A series of vibrating, inclined screens is used for this task. When all size components have been satisfactorily cleaned, all the filled seeds from each size class must then be thoroughly remixed, a vital step in retaining the genetic integrity of the seedlot. However, because such sizing is an integral part of tree seed processing, application of Rule 3.2.1.1.2 to tree seeds makes no sense whatsoever. Other cleaning methods may be used, but it must be recognized that seed size varies within any and all seedlots. This **degree of variation differs** among species, from seedlot to seedlot within a species, but the purity analyst must apply Rule 3.2.1.1.2 **uniformly.** A review of seed mass in European larch (*Larix decidua*) showed that across its natural range seed size in this species may vary by up to 250% (Gorian et al. 2006). Suppose the purity analyst is presented with a working sample from a range-wide collection of *L. decidua* (modern forest science would forbid such a collection) how would he/she know if a piece of seed is a small piece (smaller than one-half the original size) from a large seed and therefore "inert matter", or a large piece (larger than one-half the original) from a small seed (2.5 times smaller than other seeds in the sample), and therefor "pure seed"? The analyst is not supposed to stop and consider such matters. And if one analyst does so, the next analyst may disagree (see Ashton 2000).

For a working sample from a seedlot with even a modest degree of variation in size it is difficult *if not impossible* for the analyst to correctly judge whether a "piece of seed" is larger/smaller than one half of the original size because the "original" seed is not available to make a correct decision. My original review (website version) goes on to consider seeds broken at 75%, and also 90% of their original size, but this is not so important here.

The genus *Eucalyptus* requires special attention where Rule **3.2.1.1.2** is concerned, for several reasons. First, there are more than 523 known species of eucalyptus, and 138 varieties, and new species and varieties are still being described (Krugman and Whitesell 2008). Among these species and varieties the length of fertile seeds varies from as small as 0.75 mm to 4.25 mm. For any given seed collection within a species, for example in *E. camaldulensis*, one of the smallest eucalyptus seeds, seed length may vary by a factor of more than 230%, from 0.75 mm to 1.75 mm. PSD 60, as in all other definitions, requires that the pure seed fraction shall include pieces of seeds more than one-half the original size (with or without testa). This means that the purity analyst is required to recognize broken seeds of *E. camaldulensis* possibly as small as 0.38–0.41 mm; even at 75% of the original, a piece will be no longer than 0.56–1.3 mm in length. Then there are "ovulodes" which are known to be difficult to distinguish from the seeds. Even if a piece of *E. camaldulensis* seed is 90% of the original size as measured from the chalazal end it will be useless for propagating a new plant because the minute hypocotyl and radicle will be missing. This makes it clear that the biological knowledge of eucalyptus seeds has been completely ignored and that there is no legitimate scientific reason for the inclusion of **Rule 3.2.1.1.2.**

Most agricultural seed crop plants produce seed annually, but tree seed crops are periodic, and often unpredictable. Most stands of trees produce sizeable seed crops erratically. "Bumper crop", or "heavy mast" years, based on pre-collection inspections, make it worth the expense and effort of bringing the crop to the processing plant. To meet requirements for annual forest regeneration objectives over several years, the bulk of the seeds - those not used the first year - are placed in dry, cold storage until they are sown in a nursery. The principle objective of storage is to reduce seed metabolism as much as possible without damaging viability, and to prevent attack by microorganisms. The principles and practices of forest tree seed storage have been recently reviewed by Bonner (2008), where the most up-to-date information for all gymnospermous and angiospermous genera included on the Rules is available. Another earlier, excellent source is Wang (1974).

Thirty or so years ago forest tree seeds were classified as either "orthodox" or "recalcitrant" for storage needs, but current terminology is moving away from "recalcitrant" to "non-orthodox". Coniferous seeds are regarded as "orthodox" meaning that they can withstand being dried to low moisture contents (5–10% of fresh weight) and held for several years at -17ºC without losing viability. Their longevity for survival depends on

their *seed coats remaining intact*. This is **crucial.** Many angiospermous seeds, in contrast, are non-orthodox: they do not take kindly either to drying or freezing.

For coniferous seeds, structurally the seed coat is an inactive (non-living) covering that imbibes moisture rapidly when the seeds begin to germinate, but - more importantly - protects the internal tissues, *viz*. the embryo from which a new plant may be (not always) derived, and the female megagametophyte from which the embryo derives its source of energy for germination. The seed coat prevents germination in the wild until climatological conditions are favourable. In large part the seed coat is the cause of seed dormancy. However, if it is damaged in any way, even cracked, it loses its protective abilities (microorganisms may enter) and viability is impacted if/when returned to storage; respiration increases (Leadem 1993) until moisture levels have decreased to prevent further gas exchange. If this happens when seeds are merely cracked, what chance is there for seeds that have been broken into pieces, no matter what proportion the piece is relative to the original size of the seed?

With this **scientific knowledge**, as claimed in the Introduction to the Rules, why must an analyst classify damaged pieces of tree seeds as "pure seeds"? Another question: Who wrote **Rule 3.2.1.1.2** and on what **scientific knowledge** is it based?

Looking for the origin of Rule **3.2.1.1.2,** a crucial 1965 report by Dr. Harald Esbo (Sweden) (1965), who became ISTA President (1965–68), states that until 1950 a so-called "Stronger method" (S.M.) for seed purity analysis was prevalent, but at the 1950 ISTA Congress in Washington the so-called "Quicker method" (Q.M.) was agreed upon. According to S.M., only seeds that could possibly give rise to normal seedlings were considered pure seeds. In contrast, Q.M. was to include all questionable, damaged or badly developed seeds in the pure seed fraction leaving the evaluation of live or dead seeds to the germination test. This "new" method saved time, hence its designation as the Q.M. In this, Dr. Esbo declared that anything in the working sample that resembles a seed, even a clearly diseased or shrivelled seed, except for a piece of seed less than one-half its original size, was to be regarded as a pure seed. He went on to state that there was no doubt that "the Q.M. not only diminished the influence of personal judgement and led to more uniform results, but was really time saving."

However, Dr. O.L. Justice (USDA) (1965), in the same publication, reported that both the S.M. and Q.M. were included in the original Rules adopted in 1931, and retained until 1953. At the 1950 ISTA Congress Dr. W.J. Franck (Netherlands) made a strong plea for adoption of a single method. This and similar representations by Dr. H.A. Lafferty (Ireland) paved the way for the general acceptance of a single purity method. Dr. Justice also noted that it was known that the "Piece of seed" issue, and that both S.M. and Q.M. had been in the Rules since 1938 following adoption by the General Assembly in Zurich in 1937. This is documented in Proc. ISTA Volume 10 (undated), Fourth Part (International Rules for Seed Testing), section II Purity (beginning on page 412) which provides a "Definition of pure seed according to the a) Stronger Method (S.M.) and b) Quicker Method (Q.M.)". Dr. Justice commented that when the Q.M. is used, it is left to the germination test to determine the "planting value" of the seeds. So, is the Q.M., which is still the method used today (hence this review), really doing its job of determining the purity value of the seeds?

More details are given in my website version, but it is important to note that for both methods the Rules stated that: "If the sample contains a great many severely injured, poorly developed or discoloured seeds, this fact should be reported on the international analysis certificate, and in such cases it is advisable to make a supplementary germination test in soil." This begs the question: Does not "**severely injured**" apply to **broken pieces of seed**, large or small?

But why was *speed* so important? The answer lies in an equipment bottleneck. In the early days of seed testing, some 80+ years ago, purity analysts (and anyone else needing to weigh objects accurately) were limited to using an analytical beam balance. A very sensitive instrument yielding precise weights, it had to be used in a draught-free environment: it was very slow and laborious to use, even for an experienced analyst. A single submitted purity work sample may take upwards of 15 minutes – or even longer. Anything that could be done to speed up the process was very welcome. This is where the Q.M. came into its own. By weighing only three components instead of five, the time spent per working sample was reduced by 40%. This is what Dr. Esbo meant when he claimed that the Quicker Method was "really time-saving".

Since the early 1960s, however, electronic balances have come to the fore. Although these need to be protected from air currents also, the time required for weighing the components of a purity sample has been reduced to a fraction of that using a beam balance. Instead of minutes per component, each can be weighed in seconds.

Many models now print out the weight at the push of a button. With electronic balances being readily available there is no scientific or operational reason for not weighing broken seeds of any size, and reporting them.

For this reason, **Rule 3.2.1.1.2** has become completely redundant for forest tree seeds, perhaps for all seeds. Having gained the superior weighing speed provided by electronic balances, why does ISTA persist in applying this scientifically bankrupt rule to forest tree seeds (or all types of seeds)?

Is it not time for the International Seed Testing Association to move the **Purity Test into the 21st. Century**?

All forest tree seed analysts have the botanical expertise and experience to collectively make the case for revision of the ISTA Rules as they are applied to forest tree seeds. Failure to do so in effect means that ISTA will be allowed to remain satisfied with the early 20th Century *status quo*, that is, the **Dark Ages for purity testing.** All tree seed analysts should pursue the required changes, vigorously and promptly, to ensure that ISTA reverts to the original so-called "Stronger Method" of performing the Purity Test of forest tree seeds.

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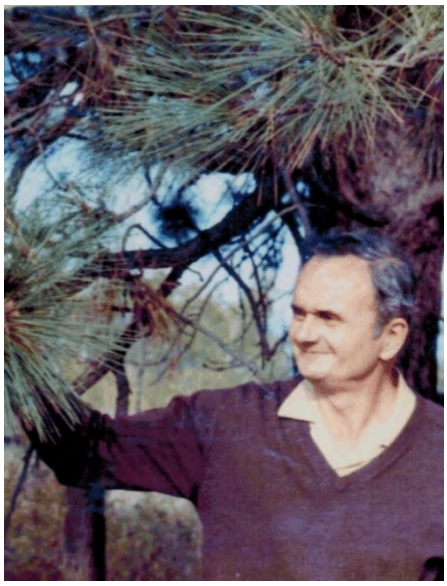
IN MEMORIUM, FRANK DOUGLAS BARNARD



Frank Barnard, (October 19, 1922 – July 14, 2015), was born, raised, and lived most of his life at Blind Bay on Shuswap Lake near Salmon Arm, British Columbia (BC). His parents settled in the area in 1905, cleared the land, farmed, and established an apple orchard. After completing high-school Frank worked for his parents on the family farm, harvesting and packing apples, and all that goes with farming. Two years later he enlisted in the Canadian Army and served overseas with the Royal Canadian Corp of Signals. After the war, he returned to Blind Bay to help on the family farm, do odd jobs, and work in the bush. In 1950 he married Muriel Dobson, the sister of one of his friends. Frank and Muriel were married for 52 years until her passing. Frank realized that he needed a more stable income, and saw an ad in the Salmon Arm Observer accepting applications to write the Assistant Rangers exam. He wrote and passed the exam. Frank worked for the BC Forest Service for several years before being approached by Oscar Sziklai from the Faculty of Forestry at the University of British Columbia about the possibility of making seed collections for the International Union of Forest Research Organizations in Europe. He recognized that the market for tree seed in Europe presented a good business opportunity and he started Western Tree Seeds Ltd. in 1961. Frank visited other seed processing facilities in BC, the USA, and Europe to learn how to process tree seed, and make connections with potential buyers. By the 1980's Frank's reputation for integrity and seed quality extended to Scandanavia where there was tremendous interest in high quality lodgepole pine seed from Northern BC and the Yukon. As a result, Western Tree Seeds' business flourished. The majority of the seed processed came from cone collections made by residents in small communities in BC and the Yukon. Frank liked nothing better than to travel throughout BC, sit in a coffee shop, and negotiate with the locals to collect cones for him. Frank's honesty and integrity made loyal partners out of his collection supervisors, cone pickers, and clients.

Frank was instrumental in having the Federal government become a member of and manage the OECD Forest Tree Seed Certification Scheme that still exists today. The Scheme ensures the quality and origin of seed sold to clients in other countries. Frank had the ability to recognize talent and work ethics in other people. The employees Frank hired to work in the seed plant worked hard as a team and he rewarded them for their efforts including a group vacation to Hawaii. The first employee Frank hired was Tom Hillman, a young lad just out of school who had an outstanding mechanical aptitude. Between Tom and Frank they developed revolutionary seed processing equipment and techniques.

In 1989, at the urging of Forestry Canada, Western Tree Seeds, Reid Collins, Silva Enterprises, Forest, and Yellow Point Propagation formed the BC Tree Seed Dealers Association. Albeit competitors, they soon formed a long lasting bond to address issues around seed collection, seed certification and testing, and research. Frank was elected the first president. In 1996, under Frank's guidance, we collaborated on a "A Field Guide to Collecting Cone of British Columbia Conifers". Collectively, we organized and attended several national and international meetings. Frank's affable nature, and wry sense of humor lent itself to the many enjoyable social events related to the seed business that we had. He will be sorely missed.

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INFLUENCE OF TEMPERATURE ON WATER ACTIVITY

Interest in water activity (A_w) or equilibrium relative humidity (eRH) applied to forest tree seeds is increasing. The International Seed Testing Association intends to produce rules with regard to A_w and discussions continue on this topic (sample volume, how many reps for each seedlot, temperature for the measuremet, etc.).

Several months ago, Dave Kolotelo initiated a small discussion group of *water activists*, as Dave called us, to discuss different aspects of A_w. Among others, the issue around standardization of the temperature at which the measurements are made has been raised.

A recommendation was made to have the results expressed for a common temperature, even if data were obtained at different temperatures. A converter was recommended: http://www.cactus2000.de/uk/unit/masshum.shtml. However, this tool applies solely to the humidity of the air. For example, if temperature is reduced, the relative humidity of the air is going to increase. This can result in condensation if the dew point[1] is reached. If this tool is to be useful for humidity of the air, it cannot be used with eRH obtained on seed samples. In fact in a system of air, seeds, and water the effect of temperature is the opposite from what it is when the system is just water and air. This is because as the air warms its water potential increases and water is pulled from the seed causing an increase in eRH. With air and water alone, without the seeds as a source of water, the relative humidity decreases because the air is now holding less water than its maximum potential. See Colas 2015 for further explanation.

To demonstrate this, we measured A_w of 6 different white spruce (*Picea glauca*) and black spruce (*Picea mariana*) seedlots at different temperatures (5, 10, 15, 20, 25, and 30°C) to evaluate the impact of temperature on A_w results. We used a Rotronic Hygrolab C1 hygrometer with 4 A_w DIO probes which were installed in a growth chamber. Temperature varied but samples were kept in the test chambers with the probes for the duration of the test so that no moisture entered or exited the test chambers. The effect was totally one of changing temperature. Results are presented in Fig. 1.

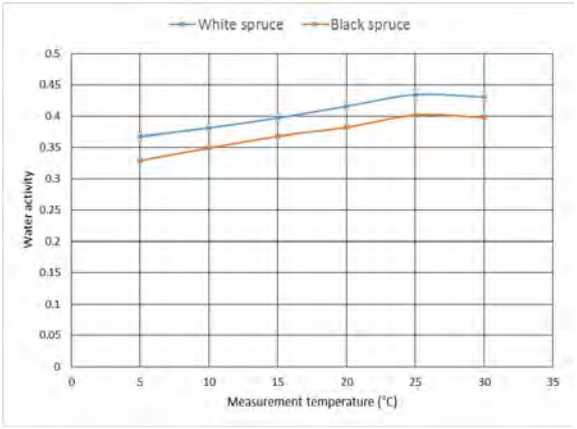

Figure 1. Mean water activity variation of 6 seedlots of white spruce and black spruce with measurement temperature.

For the two species, there is a slight variation in A_w with changing temperature, about 3 to 5% between each temperature. For each species, the 6 seedlots exhibit similar behavior.

If we had used the Cactus converter with the white spruce seedlots, our values would be higher: at 25°C 0.58 instead of 0.417, at 20°C 0.78 instead of 0.4, and at 15°C 1.0 instead of 0.385.

In a subsequent article we will present detailed results, but for now we thought it was important to show that this converter should not be used for seed data.

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[1] Temperature at which vapour in the cooling air begins to condense.

THE WELL-INFORMED COLLECTOR: NOW BETTER INFORMED

I would like to take a moment to clarify details in my last article (News Bulletin No. 62, December 2015); I have humbly had many ideas I once thought were practical ways to use seed science adjusted in light of new research, and underpinnings of water activity theory in relation to seeds instilled with more data and hands-on experience. I offer credit where credit is due; the effort put into the Tree Seed Working Group News Bulletin, CON**FOR**GEN Forum 2015, researchers willing to share open discussion, and sometimes inaccessible or long-ago papers is an education hard to find. I extend great thanks to Dale Simpson and the Canadian Forest Service for letting me volunteer my time at the National Tree Seed Centre (NTSC) this past winter. Five weeks of putting skills to the test and time for self-directed learning was invaluable. Though I assisted in general operations like seed cleaning, germination testing, 1000-seed weights, and gravimetric moisture contents, Dale offered his time, guidance, and resources for many burning questions that I have had while seed collecting, and since having taken the Seed Conservation Techniques course at KEW.

Do We Have to Adjust for Temperature in Water Activity Readings?

I thought this was true for precise results and practiced with an online calculator (http://www.cactus2000.de/uk/unit/masshum.shtml) but in fact it does not translate into how seeds behave when properly handled and stored. In testing the limits of my ExTech humidity probe against Dale's HygroPalm 23-AW unit, I cleaned and conditioned some garden onion (*Allium cepa*) seed and sealed it in a Mason jar before returning home. After a visit with Fabienne Colas in Quebec City where she demonstrated changing temperature on sealed seedlots, the basic principles became abundantly clear. Please see the article in this issue from Colas, Karrfalt and Baldet but I offer my home experiment in support.

A 125 mL Mason jar, 2/3 full of seed equilibrated at 22% eRH and 20°C at NTSC, was fitted with a rubber seal lid with Extech Big Digit Dew-Point Hygrometer probe tip inserted and moved to various temperature regimes without opening the container. Table 1 shows the results.

Table 1. Impact of temperature on eRH calculated by the Cactus calculator.

Time	Temperature (°C)	eRH (%)	Cactus calculated eRH% at 20°C
08:00	17.8	22	19
13:00	14.4	22	15
16:00	4.3*	24	8.5
17:00	33.1**	23	49.7

* after 1 hr in the fridge
** taken from fridge, 1 hr on heat vent

Having a hygrometer is important to improve one's understanding of these dynamics at the beginning of the seed quality process, and it is of great interest through its life in storage. Hopefully one day I can get a HygroPalm or similar Rotronic device for more accurate and faster readings!

Why are Targets and Standards for Moisture Content % or Water Activity Readings so Different Between Seed Banks?

I thought everyone followed the international FAO gene bank recommendations of equilibrating seed to 15% eRH and 15°C. I appreciate now that it takes time to move confidently away from the gravimetric oven method for moisture content. Learning a whole new system for which a detailed protocol from the International Seed Testing Association is still being developed is an operational challenge when you are busy and are not familiar with water activity equipment. You are all working with dramatically different ambient conditions and windows for drying seed, different equipment, and for some, new species for which detailed physiology and drying behaviour is not fully known. Getting seed extremely dry is both added cost in seed facility design and staff time. And perhaps, as has been suggested, there is no single "right" target for different objectives: operational short or medium storage vs long-term gene conservation. I think we also overlook the human element of uncertainty to gamble on unknown risks for a product that takes so much effort to procure. The discussion is lively and it's a very interesting time and place to be as scientists and practitioners catalyze questions to each other to solve and properly implement. Keep it up, it's called progress!

Can You Dry Seed Too Aggressively?

Another avenue where the patience of seeds is usually greater than ours. It is important to ensure seeds do not deteriorate in quality from poor handling (usually lack of air circulation or protection from deleterious elements to blame), but Dale made me question my practice of using silica gel as a chemical aid immediately after collection versus a means to monitor air leakage in long-term storage. My intention was not to present my mini-dry room pail as the sole means of conditioning all seeds in any situation; it is merely another option. Proper conditioning involves significant understanding of the species, seed physiology, degree of maturation, and climatic conditions during and after dispersal. Armed with a good hygrometer, silica gel can protect fully mature collections (seeds below 85% eRH) from absorbing moisture in the evenings or to bring fully mature collections through the 60–90% RH "danger" zone at a more controlled rate than ambient fluctuations (Smith et al. 2003, Gold 2008) until they can be sent to the processing facility. I find the amount of silica gel in a sealed system can be altered to a lower gel:seed ratio than the recommended 1:1 or allowed to turn completely green before mixing in new silica gel to avoid creating too large a difference between the seed eRH% and the air in the pail.

When handling anything but fully mature seed, chemical drying is admittedly risky. Aggressive drying of seeds, especially large seeds with thick seed coats, can effectively dry only the outside of the seed and not equilibrate with internal tissues. This would result in poor storage potential if sealed and frozen. Immature collections must be ripened more fully while mimicking natural (usually 65–75% RH) conditions for several weeks or months so seeds may acquire dessication tolerance to lower eRH% (Probert et al. 2007, Gold 2008).

Dale also warned me about conditioning seed in his lab too low, more so for angiosperm species that do not have long germination test series as compared to conifers to support ultra-low conditioning; so far 5–7% MC has worked. The most interesting seedlots I germinated and conditioned there were those of Salicaeae spp., naturally short-lived in nature due to their physiology. With immediate drying after collection, *Populus grandidentata* germinated at 93.5% after 19 years in storage at 6.27% MC. The oldest angiosperm in Dale's germination tests, *Betula allengheniensis*, remained unchanged at 83%, 38 years later at 5.27% MC. Despite wanting to push the boundaries for the sake of science, only continued care and maintenance of conservation collections like those at NTSC will tell the story.

Thank you again for the outlet and opportunities this unique group has offered.

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A HISTORY OF SILVA ENTERPRISES: A SMALL FAMILY OWNED CANADIAN FOREST TREE SEED COMPANY

Pre-Silva, Childhood Memories

There is a picture in my head, from the mid 1950s at my home in Aleza Lake, of large metal cans (the ubiquitous use of poly had not yet taken over) set before a window on the landing at the top of the stairs outside my bedroom. In the cans are Aspen whips sprouting pollen buds. There must have been some family drama for me to remember this, as my mother was severely allergic to pollen. The pollen was collected and shipped to my father's Finnish homeland as part of an international research exchange by the BC Forest Service Research Station at Aleza Lake. Being fluent in Swedish and Finnish, Rolf Hellenius had occasion to translate technical forestry related

papers from those languages to English as part of his job. This put Rolf in direct contact with forest researchers of the period from these countries.

Research sharing of conifer seed from northern British Columbia (BC) also became a common interest of Scandinavian foresters. So, already having experience of an earlier enterprise operating a sawmill in Yellowknife, and looking forward to compulsory retirement, Rolf launched Silva Enterprises Limited in 1965. After all, who would think retirement was for relaxing!

Early Years

In the summer of 1965 my brother, Lawrence, planned and built a modest cinderblock seed extraction shop just across Vienna Creek from Red Rock Nursery near Prince George, BC. This building housed a small kiln of ~ 10 hl capacity, a M2B Fan Mill, a tumbler, and a cement mixer de-winger. Over the next few years a gravity table and an air separator were added to the equipment repertoire. Until my father retired from the BC Forest Service in 1972, Lawrence organized much of the seed collection which consisted mainly of *Pinus contorta*, *Abies lasiocarpa*, and *Picea glauca* from as far north as Chetwynd and Dawson Creek, Yukon. This was during the time of the construction of the WAC Bennett dam on the Peace River near Hudson Hope.

With the sad passing of Lawrence in 1974, Rolf, a retired Forester and my mother, Kathleen, a retired Teacher, took on the company operation by themselves, hiring help as required, as I had followed a separate career path and had a young family at the time. During the following decade Rolf and Kathleen made many trips north collecting *Pinus contorta* and *Abies lasiocarpa* as far afield as Whitehorse, Carmacks, and Ethel Lake, Yukon for the Swedish market. The Yukon is a special land 'under the **midnight sun**', men and women living in isolation for months at a time are sometimes afflicted with a condition commonly called ‘cabin fever’. Rolf and his assistant encountered such a person when they were held up on the Faro Mine Road at gunpoint and tied to a tree in the woods for the better part of a day because their assailant thought he needed Rolf's truck to get away....to anywhere. There was also a time when my mother got lost in the woods near Ethel Lake overnight and Dad and I thought we had lost her forever. A tiny, elderly lady, she survived the freezing night calmly and walked out on her own, finding hunters on a trail and approaching them with a quiet “excuse me”. These are but two of the many strange and occasionally wonderful experiences we have had. You might think Stan Rogers’ song “Canol Road” is just another tune but it enters the realm of possibility to many in the Yukon.

During this time John Revel and Jingi Konishi were constant and loyal supporters adding a valued knowledge base to Rolf's enterprise. Friends Bob and Barbara Studds in Teslin and later Whitehorse were invaluable for their Yukon contacts with First Nations families who benefited greatly from the added income that cone collection brought. Notable among these people were the Sam family, of which Russell Sam was head. His wife Emma created the first Tlingit dictionary for translation to English, including oral tapes, thereby immortalizing their dying language. Frank Portlock, our Canadian Forest Service OECD inspector was always valued for his Yukon insight.

Passing the Torch

There came a time, as with us all, that Rolf could no longer maintain the steady toil of Silva's demands. In 1987 my wife Linda and I, with our three children, decided to move from our home in Gibsons back to Prince George to learn the business of Silva Enterprises. With the gracious help of Linda's father, Bob Flewelling, Linda and he designed and built a fine home on the company property near Red Rock. Rolf and Kit bought the house and property next door, where we built an excellent proper cone storage building. Then I went to work on the slow process of upgrading the extraction facility. Slow because, with the boss living next door, it was also an exercise in utmost diplomacy which has never been a personal strength for me.

In 1988 we all travelled to Europe and Scandinavia to visit family and customers. Rolf was proud to receive a special award from the Finnish Forest Research Institute for services to them. We were happy to notice the strong contribution of Canadian forest species present at the Mustila Arboretum in Finland. While visiting Ola Rosvall at the Swedish Institute of Forestry in Savar, Sweden I was impressed by their demonstration of the use of IDS technology to improve germination percentages by the removal of dead or damaged filled seeds. We have since designed and installed a close replica of this equipment in our lab. This equipment is also very useful for washing batch lots of some seed species. During this period George Edwards and Frank Portlock were very supportive with seed workshops and advice which helped us fine tune our understanding of seed handling. As a consequence of this knowledge I gradually introduced a walk-in seed cooler, proper scales, a dedicated apparatus for performing moisture

content tests on seed, better internal ventilation in the kiln, and upgraded thermostats.

Taking Up The Torch

In the fall of 1991 we were asked by Pacific Regeneration Technology to host two Chinese gentlemen from Langxiang, PRC and tutor them in the "Canadian" perspective of tree and shrub seed collection and processing. Wang Qi Juin, Zsung Min, and I took a maiden trip to collect *Pinus ponderosa*, *Juniperus scopulorum*, and *Pinus aulbicalis* on Lime Mt. near Clinton. We returned to Prince George with adequate raw material for some limited laboratory instruction, seed physiology observation, and testing. We then proceeded to the Yukon evaluating cone crops along the way with a longer stop at the Liard Hot Springs to evaluate and compare the influence of the hot springs on the growth rate of *Larix larcina*. Their visit was an altogether rewarding and enjoyable experience for our entire family. These young fellows sure could cook some fine northern Chinese food.

Beginning in 1989 Silva began a custom extraction program for local forest companies. With encouragement from Norm Crist (Northwood), Bob Baker (Canfor), and others it quickly became apparent that our seed extraction plant would not be able to match demand for both domestic and export service. In the summer of 1993 we removed the roof of the extraction plant and added a second floor and also added conveyor systems to handle post separation cone waste material. But the largest, potentially disastrous, leap of faith was building my own variation of a rotary kiln I had seen earlier in Oregon. My variation sported fifteen screens built into a six by six by twelve foot cube which had three doors on two opposing sides for loading and unloading cones. This compartmentalized cube revolved within the kiln at a snails pace of one revolution per two minutes and was automatically timed to revolve gently one half revolution every half hour or so depending on the species being processed. Hot air within the kiln was stirred by two large squirrel cage fans. The screens were sized so that, first debris (needles, dirt, etc.) and later seed would fall onto a conveyor which fed a chute into a tumbler on the floor below. Thankfully, with the help of my faithful neighbour, Roy Goheen, we got it all functioning in time for the huge and last natural *Picea glauca* crop we processed in BC (1993).

During the 90's decade we relied heavily on helicopters for seed crop monitoring, sampling, and harvesting of *Picea* species, *Abies lasiocarpa*, and *Pseudotsuga menziesii*. There is nothing I enjoyed more than hanging out of a helicopter at tree top level to snip cone samples. I was lucky to have some great pilots to keep me alive. Our harvesting equipment was smoothly and professionally leased from Helmut Fandrich, who never failed to offer new designs for special applications.

From 1994 to publish date in 1996, Silva was proud to participate with other BC Tree Seed Dealers' Association members, Don Pigott, Paulus Vrijmoed, and Frank Barnard, as well as Provincial and Federal Forestry staff, in publishing "A Field Guide to Collection of Cones of BC Conifers".

As the 1990's progressed spruce seed orchards quickly took over the supply of spruce seed to industry. *Pinus contorta* orchards were far less productive, so as the Mountain Pine Beetle (*Dendroctonus ponderosae*) began ravaging pine forests in the 2000's, timber companies scrambled to collect seed to match the increased harvest of dead and dying pine. Consequently for us, there was over a decade of constant activity, so much that we required an additional two thousand square foot building for cone storage. This was followed by a dramatic slow down both in domestic and export markets for pine seed. While still processing *Pseudotsuga menziesii* and *Abies lasiocarpa*, these collections from northerly provenances were in less demand and more periodic in nature than the serotinous pine. In 2015 I decided to retire and relax; the extraction equipment was dismantled or removed and the property sold.

Thank you to the many people from all walks of life who supported our endeavour, from the Forest Industry, BC Ministry of Forests Tree Seed Center, Canadian Forest Service, BC Tree Seed Dealers' Association, as well as our customers and friends in the Scandinavian countries, and our employees and cone collectors from Northern BC and Yukon.

Without Canada's participation in the OECD Forest Seed Certification Scheme the export of forest seed would likely have been impossible. We appreciate and would like to thank our OECD Inspectors, Frank Portlock, John Denis, and Gary Roke for their polite, professional, always friendly service.

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STATUS QUO? YES AND NO FOR SOUTHERN ONTARIO FOREST GENETIC RESOURCE MANAGEMENT

It has been almost three years since our last major update (News Bulletin No. 58, December 2013) on the status and progress of the Forest Gene Conservation Association (FGCA). We are both operating as we always have, in line with our forest genetic resource managment (FGRM) mandates and well-established programs, and operating as we never have. The years 2014–2015 saw the synergy of merging Trees Ontario with the Ontario Forestry Association to become Forests Ontario. It also saw the beginning of the end of some of FGCA's long-term partnerships. Forest Genetics Ontario was disbanded, of which we were a member, and there was significant transformation within Ontario's Ministry of Natural Resources and Forestry (MNRF). Specifically, MNRF no longer supports private land forest management beyond the Managed Forest Tax Incentive Program (MFTIP) and funding of the 50 Million Tree Program, which led to the loss of southern Ontario forester positions, support for local Stewardship Coordinators and Councils, and the FGCA coordinator position.

Thankfully, due to the FGCA's Board of Directors' long-term commitments to "do the right thing" and sound fiscal management, we have time to be strategic in developing a new approach, including succession planning. In this vein we have been lucky to engage Melissa Spearing and Heather Zurbrigg as 'intern coordinators' of, respectively, our seed management and species conservation programs. And though our traditional provincial support has waned, local partner interest and support for gene conservation challenges has not.

Species Conservation: Butternut (*Juglans cinerea*) Recovery

Strong local partnerships are supporting our Canker Tolerance Archiving Program and has resulted to date in over 75 putatively tolerant trees being cloned via grafting and established in 3 protected, managed areas in Southwestern, Central, and Eastern Ontario. The goal includes seed production and eventually, canker tolerance screening. The first seed was produced on the oldest grafts in 2015 – an early sign of, what we hope, is much more to come (Fig. 1).

Figure 1. Seed developing on a clone at the Eastern Ontario Butternut Archive at the Ferguson Forestry Centre site. Photo taken June 16, 2016.

The Butternut Recovery program and new ex-situ seed banks of representative population genetics is a significant milestone in gene conservation practices for Species at Risk (SAR) in Ontario. Many non-SAR species are facing rising threats, notably American Beech (*Fagus grandifolia*) from beech bark disease and all ash species (*Fraxinus* spp.) as the wave of emerald ash borer (*Agrilus planipennis*) continues to move into Central Ontario. While ash seed can be banked, and has been through our assistance in seed crop forecasting and collections sent to the National Tree Seed Centre, we may need a different approach for beech. We have initiated work with Central Ontario's Crown Forest Sustainable Forest License holders (SFL) in order to develop a *Beech & Beech Bark Disease Management Proposal for Crown Forests.*

Seed Collection Area Network (SCAN)

Since 2010, FGCA has assisted with an effort to collect detailed information on high quality seed collection sites of important afforestation species in all seed zones, with help from Forests Ontario and the 50 Million Tree Program, SFLs, and MNRF GIS data analysts. We now have a database of over 1,000 sites from Ontario Seed Zones 28–38. Through Forestry Futures Trust funding, Dr. Dan McKenney, John Pedlar, Glenn Lawrence, and Kevin Lawrence of Natural Resources Canada (NRCAN), Sault St. Marie trained Melissa Spearing on detailed use and understanding of SeedWhere, a climate-matching web tool for seed deployment and procurement. In addition, Melissa reviewed the tool and offered suggestions for enhanced user-interface design.

The universal response functions (URFs) for white pine (*Pinus strobus*) and black spruce (*Picea mariana*) (Yang et al. 2015) is new science to us. Incorporating it as a SeedWhere mapping function for projected growth under climate change scenarios, represents the species-specific data we all need to make "best bets, no regrets" decisions for future forests. It supports the notion that white pine may be a "climate change winner" with enhanced growth in Central Ontario as mean annual temperatures warm. NRCAN also assisted in beta incorporation of our SCAN database to determine exactly where, under various climate change scenarios, a SFL could procure seed from, instead of using bulked collections by seed zone. The combination of these two tools was powerful in convincing SFLs to think differently about seed source. This work will continue in 2016 as we work with SFLs on promoting strategic seed banking, developiing a larger network of seed contacts in the United States based on SeedWhere analysis, and enhancing Ontario's seed source tracking in an operational effort to track performance in a changing climate.

Assisted Migration Trials

Since 2010, the FGCA has informed and implemented five assisted migration trials for hardwood species with partners across Ontario, and has fielded much interest for new sites. Our existing trials focus primarily on red oak (*Quercus rubra)*, white oak (*Quercus alba*), and bur oak (*Quercus macrocarpa)*, with a range of seed sources selected using SeedWhere analysis for long-term monitoring of genetic responses to climate change at the planting site. Establishment of any hardwood planting is the initial challenge, and with early survival and growth uncertain, trials are designed for a future spacing of ~5m x 5m or ~100 trees per source, at 40 years; a large enough genetic base for potential seed production. These sites will be maintained in the SCAN database for future work.

Southern Ontario White Pine Seed Orchards and Realized Gain Trials

After initial MNRF investments in the 1980s to establish white pine orchards for tree improvement, fiscal constraints resulted in a period of abandonment. In the the mid- 2000s, the FGCA began a process of remedial management for a renewed objective of gene conservation and seed management. The orchards' production of high quality seed crops supports the Crown Forests and the 50 Million Tree Program. Orchard management is done with the help of local partners who tend and monitor potential crops. The results have proved the time reinvested: in 2014, a light to medium crop with 16–20 seeds/half cone cut test was observed at the Scugog Seed Orchard (clones from Ecoregion 6E west) and collected during thinning and topping operations. Forty-six hL of cones were collected by contractors. Staff at the Ontario Tree Seed Plant noted this crop broke records for highest number of viable seed per hL. The same year, Cayuga Seed Orchard (clones representing EcoRegion 7E) produced 34.4 hL of cones for the 50 Million Tree Program. While not staggering in comparison to other conifer orchards in Canada, it is a small victory for genetic material that could have been lost. There was substantial flowering of white pine this spring in both natural stands and our orchards, so we will be monitoring and hoping for collections in 2017.

We have also been tending and doing early assessments on 2 of 3 white pine realized gain trials that were established in 2009. Initial analysis by Dr. Pengxin Lu suggests Cayuga Seed Orchard stock has performed very well (Table 1), even though it had the largest 2.55°N latitude shift from Cayuga (edge of Lake Erie) to Gratton (near the Ottawa Valley). We will see as time progresses how the various sources grow in pace with a changing climate, and if the universal response function supports white pine's preference for a central climatic optimum around 11°C mean annual temperature.

Ensuring Biologically Appropriate Reforestation

In 2014, we accomplished a major revision of *Seeds of Ontario Trees & Shrubs* in partnership with the Ontario Tree Seed Plant and Forests Ontario. This manual is being widely distributed and will form the foundation of our continued Seed Forecasting and Certified Seed Collector workshops. This work directly supports Forests Ontario's Seed and Stock Management Plan, which addresses the chain of custody from seed source to planting site. To be able to support operational needs of the 50 Million Tree Program, and any efforts to enhance assisted migration strategies, we must ensure there is an adequate supply of high quality seed from within the operational seed zones (or a SeedWhere supported climate-matched site) to fulfill growers' and planting agents' needs for years to come. We also participate in a reforestation sector placement program through Fleming College called PLANT (Program for Local Afforestation Network Training) that provides graduating Forest Technician students with a minimum six-month co-op placement for hands-on training in proper stock procurement, planting, tending, and forest

Table 1. Early assessments of white pine seed orchard stock for height, DBH, and survival at two realized gain test locations in Ontario. Cayuga highlighted for realized gain in height and DBH (cm) relative to the control (local source).

Test	Source	Mean Ht (cm)	RG (%)	Mean DBH (cm)	RG (%)	Survival (%)	RG (%)
Ferguson	Cayuga	328.19	23.10	4.46	42.12	94.44	4.29
Ferguson	Conger	242.10	-9.19	2.97	-5.32	85.56	-5.52
Ferguson	Control	266.60	0.00	3.14	0.00	90.56	0.00
Ferguson	Gratton	217.07	-18.58	2.38	-24.31	77.78	-14.11
Ferguson	Glencairn	284.94	6.88	3.71	18.35	90.56	0.00
Ferguson	OFRI	276.23	3.61	3.47	10.52	81.67	-9.82
Ferguson	Taylor1	292.47	9.70	3.82	21.87	93.33	3.07
Ferguson	Taylor2	302.66	13.52	3.80	21.24	93.92	3.72
Ferguson	Taylor3	275.75	3.43	3.45	9.96	87.78	-3.07
Gratton	Cayuga	256.81	14.92	2.98	26.73	88.33	-0.63
Gratton	Conger	214.96	-3.81	2.30	-2.25	81.67	-8.12
Gratton	Control	223.47	0.00	2.35	0.00	88.89	0.00
Gratton	Gratton	250.99	12.31	2.88	22.52	87.22	-1.88
Gratton	Glencairn	219.24	-1.89	2.32	-1.47	88.33	-0.63
Gratton	OFRI	218.05	-2.43	2.33	-0.93	93.33	5.00
Gratton	Taylor	233.68	4.57	2.50	6.06	88.33	-0.63

management planning. It is a highly valuable training opportunity and graduates are sought after for their breadth of experience.

We have plans to enhance general outreach efforts e.g., our website www.fgca.net. FGRM principles need to be translated into practices that are more easily understood and adopted by private landowners in Ontario. Interested landowners are the key to stemming the erosion of Southern Ontario's forests while we search for solutions to maintain them in a challenging future.

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Yang, J.; Pedlar, J.H.; McKenney, D.W.; Weersink, A. 2015. The development of universal response functions to facilitate climate-smart regeneration of black spruce and white pine in Ontario, Canada. Forest Ecology and Management 339:34–43. DOI:10.1016/j.foreco.2014.12.001.

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MONITORING CONE MOISTURE CONTENT CHANGES AFTER COLLECTION

During the summer of 2015 we initiated a small exploratory investigation to determine the variability of cone moisture content at harvest and the rate of moisture loss during cone storage. The exploration looked at three species: interior lodgepole pine (*Pinus contorta* var. *latifolia*), interior spruce (*Picea glauca* x *engelmannii*), and western larch (*Larix occidentalis*) from multiple seed orchards at the Kalamalka Seed Orchard (KSO) site in Vernon, British Columbia. We wanted to quantify initial cone moisture content and rate of cone drying during cone storage. With limited resources and the wide variability in individual cone moisture contents we decided to follow individual cones from the time of harvest until processing.

Staff at KSO selected an individual random cone, placed it into an inert (non-hygroscopic) bag (Fig. 1), that allowed for free air-flow, and then placed this small bag into an operational burlap cone sack stored under operational conditions. The initial weight of the cone was obtained and the same cone was periodically weighed at roughly four day intervals. Once cones arrived at the Tree Seed Centre (TSC) the labelled cones were again re-weighed and then the oven-dry weight was determined prior to processing. This oven-dry weight allowed us to calculate the moisture

content (fresh weight basis) of the cone at each sampling point during cone storage.

Figure 1. An illustration of a cone inside the non-absorbent, aerated bag that was placed within an operational cone sack used to maintain the identity of individual cones for repeated cone weighing.

The sample sizes were relatively small with 61 cones being followed across all three species. We are hoping to improve the process this year with a better sampling strategy and more standardized procedures, but we thought it was worthwhile to introduce the topic and encourage others to consider it, or offer feedback, in the monitoring of this year's cone crops.

The process provided some documentation on the initial cone moisture content at harvest and variability between and within species (Table 1). There were obvious differences between the species in terms of average cone moisture content at time of collection. The variability in cone moisture content is large and it was surprising how high the moisture content was for some of the individual cones. The higher variability found in western larch cones agrees with orchard staff observations and is the greatest current challenge for determining the best time to collect cones on a given tree.

The primary motivator for this work was to look at the drying rate of cones. Figure 2 illustrates the average pattern of cone drying after cones were removed from the tree. The first striking aspect is the rapid drying of the cones and equilibration with the environment at roughly 12% cone moisture content within the first two weeks of cone storage. The rapid rate has not previously been quantified, but should not be surprising given the hot, dry nature of the Okanagan Valley in August with temperatures approaching 40°C on some days. The second striking feature is the initial 'spikey' nature of the curves. This can be explained by the small sample sizes and the fact that although all cones had an initial weight at harvest, which occurred on different calendar dates, subsequent measurements were performed on regular calendar dates resulting in some 'days since collection' being based on only a few data points. For example, the interior spruce spike on days 5 and 9 was only based on two cones and the lodgepole pine spike on day 1 only based on one cone. The method is also quite sensitive to changes in fresh weight due to the low weight of cones. For the upcoming year we will ensure each data point of ' days since collection' is represented by a much larger proportion of the cones sampled and to reduce the sensitivity of the technique we plan to place multiple cones into each aerated bag.

Table 1. Initial cone moisture content (fresh weight basis) at time of collection for cones followed through cone storage for three species.

Species	# Cones	Mean ± standard deviation	Range	95% Confidence interval
Interior spruce	24	59.3% ± 6.5%	47.6% to 72.6%	56.5% to 62.1%
Western larch	19	46.6% ± 7.6%	29.8% to 61.6%	42.9% to 50.3%
Interior lodgepole pine	18	38.7% ± 4.1%	29.4% to 43.7%	36.6% to 40.8%

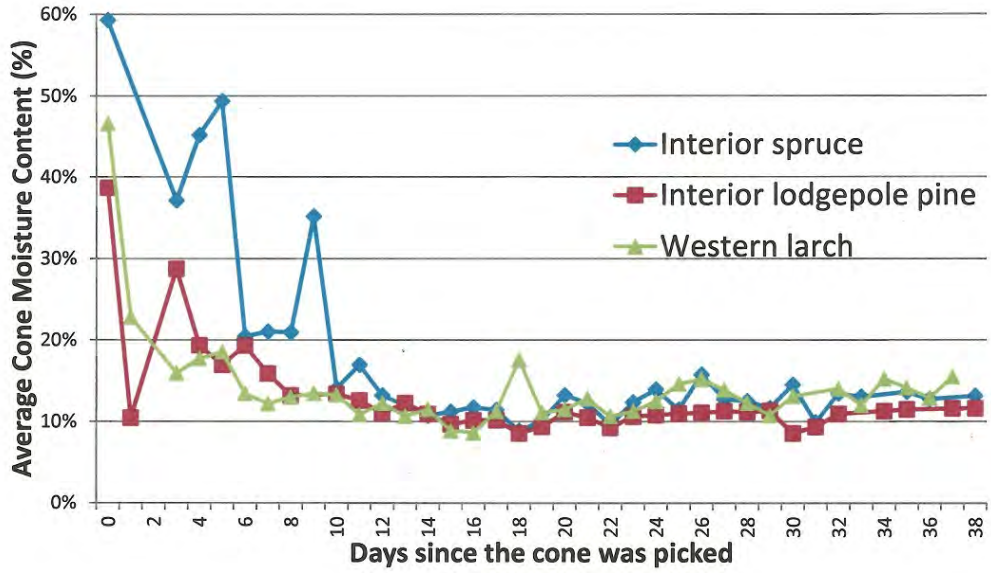

Figure 2. The pattern of cone drying after collection for three species at Kalamalka Seed Orchards.

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NEW PESTICIDE REGISTRATIONS FOR THE CANADIAN SEED ORCHARD INDUSTRY

Pest management in Canadian seed orchards has reached a bit of a tight spot with the useage curtailment of important pesticides like dimethoate, and increasing pest incidence as a result of orchard age and perhaps climate change. This situation has prompted the search for other pesticides effective against key pests, with the intent of gaining registration for seed orchard use. These registrations would proceed through the URMULE program.

URMULE: **U**ser **R**equested **M**inor **U**se **L**abel **E**xpansion.

This is a federal program of the Pest Management Regulatory Agency (PMRA), designed to allow proponents of minor crops to get registrations of chemicals that are important to their crop systems, but not of interest to the chemical manufacturers that originally registered the product in Canada. It is User Requested... not requested by the manufacturer or the PMRA. It is for a minor crop in Canada, whereas typically a chemical company would be interested in registering a product only for major crops like wheat, canola, soy, etc. Aa well it is a label expansion, not a new label. New labels in Canada require a huge amount of data costing several millions of dollars, including mammalian toxicity, non-target hazards, environmental fate, persistence and residual effects, toxicity of degradation products, groundwater contamination, and more. URMULEs are a label expansion, so all this background work was previously completed. All that is needed are data on efficacy against the target organism(s), information on appropriate application rates and timing, and the manufacturer's cooperation.

My lab, in cooperation with many other groups, has screened several products not currently registered in seed orchards. Below is a quick description of these projects. In all, we started with small-plot (individual tree) trials, first by screening a variety of pesticides, then by testing rates and timing of the most promising candidates.

Then we moved on to area-wide trials applied, as an orchardist would, with an airblast sprayer to a large portion of an orchard.

MATADOR Against *Leptoglossus*

There are no registered insecticides against the Western conifer seedbug (*Leptoglossus occidentalis*), and sprays of Sevin (carbaryl) applied against other pests have had limited success in controlling *Leptoglossus*. Matador is a pyrethroid called lambda-cyhalothrin, which is a synthetic analogue of the natural Chrysenthemum extractive pyrethrin. It is not systemic. It has moderate mammalian toxicity and is used in such small amounts that the sprayed mixture is safe relative to other chemicals.

Small-plot trials against *Leptoglossus occidentalis* indicated it would be successful; subsequent area-wide trials with an airblast sprayer showed increases in seedset of up to about 50% (2014, Fig. 1) and 25% (2015, Fig 2) over unsprayed control areas. Laboratory tests with field-aged foliar samples showed that it has an active residual of about 4 weeks even with rain and hot sun, leading to long-lasting control in the field.

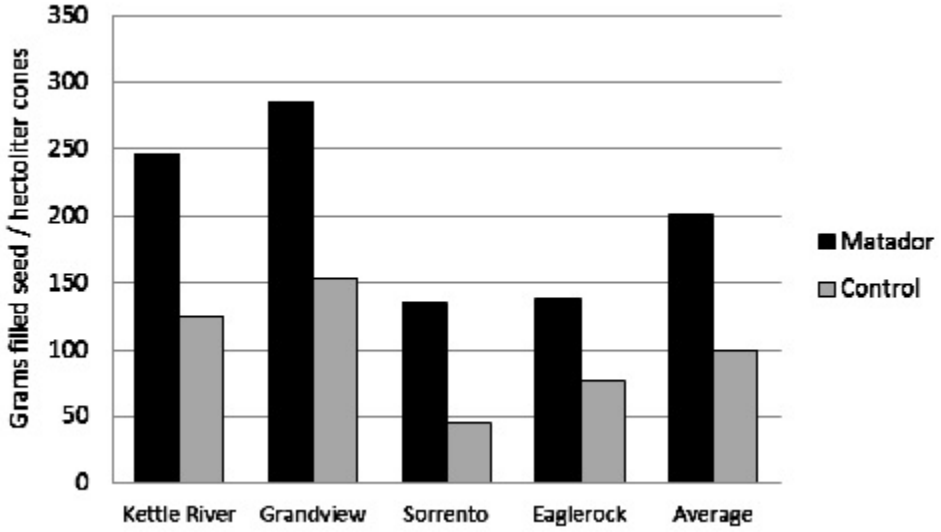

Figure 1. Seed yields of sprayed vs unsprayed areas in 2014 in the area-wide Matador trials against *Leptoglossus*

Based on the prior small-plot trials, an URMULE application was submitted in early 2015. The application was approved. The manufacturer, Syngenta, created an amended label and returned it to PMRA for final approval in September 2015. As of early July 2016 we are still awaiting final approval, partly because PMRA has recently started a re-evaluation procedure.

DELEGATE against *Dioryctria*

Fir coneworm (*Dioryctria abietivorella*) has been controlled until now with dimethoate, which recently underwent a re-evaluation procedure by the PMRA. As a result, there is a 45 day re-entry interval, which limits its usefulness. Plus, dimethoate is expensive and highly toxic. Delegate is a spinosyn, which is a synthetic analog of a bacterial fermentation product called Spinosad. It has very low mammalian toxicity, which combined with its low rates of use make it extremely safe for workers. It is not systemic.

Small-plot trials against *Dioryctria abietivorella* suggested excellent efficacy, with up to a 95% reduction in cone damage (Figs. 3 and 4). This success is likely due to killing larvae shortly after they hatch, while they are still crawling around the cone surface and taking their first bites to gain entry to the cone interior. Large-scale trials have not yet been initiated. Based on this work, an URMULE application was submitted in early 2015. PMRA approved the use in early 2016. The manufacturer, Dow, has created an amended label and submitted it to PMRA in May 2016. As of July 2016 we are still awaiting final approval by PMRA.

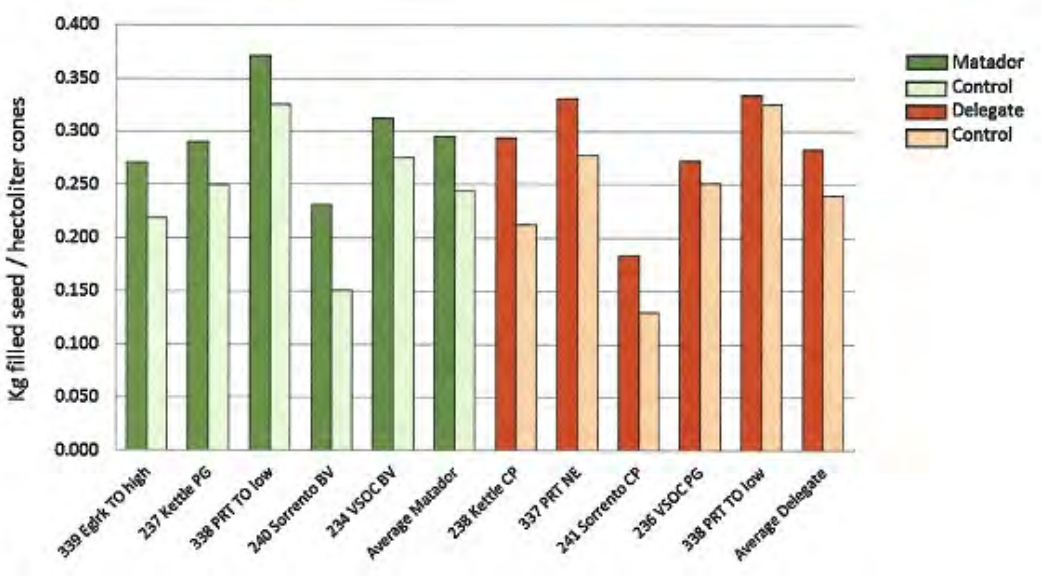

Figure 2. Seed yields of sprayed vs. unsprayed areas in 2015 in the area-wide Matador trials against *Leptoglossus*.

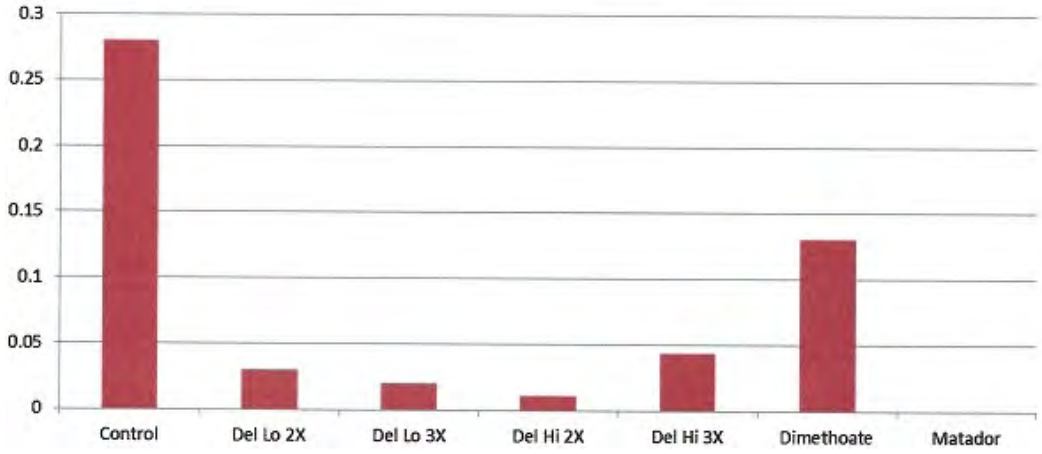

Figure 3. Results from small-plot trials in 2012 of Delegate against *Dioryctria*.

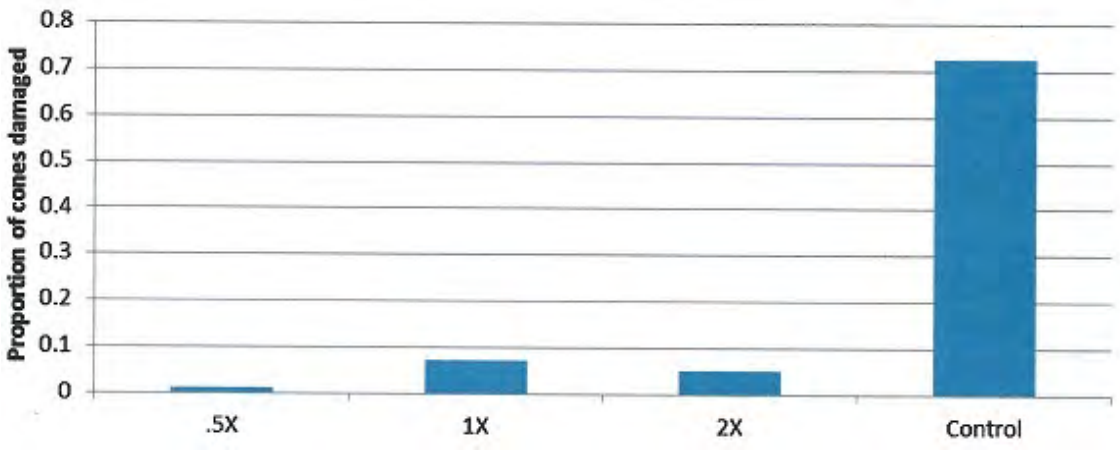

Figure 4. Results from small-plot trials in 2014 of Delegate against *Dioryctria*.

MOVENTO Against Cone Midges

Cone midges include such pests as the Douglas-fir cone gall midge (*Contarinia oregonensis*), the redcedar cone midge (*Matetiola thujae*), and the spruce cone axis midge (*Kaltenbachiola rachiphaga*). These pests have been controlled up to now with dimethoate, with varying success, and dimethoate has the issues identified above. Movento is a systemic insecticide that can translocate into cones once sprayed, and is specific to sucking insects and gall midges. It is quite safe to humans, with a low mammalian toxicity and moderate rate of application.

Small-plot trials were conducted against *Contarinia*. Up to 97% reduction in midge numbers were found (Fig. 5). Movento appears to move into the cone and has a sufficiently long residual there to wipe out the midges hatching inside. An URMULE application was submitted in May 2015, the application approved, and an amended label submitted by Bayer in September 2015, and registration was completed in early 2016. The Movento registration includes *Mayetiola* and *Kaltenbachiola* even though we have no efficacy data because of the similarity of their life histories to *Contarinia*. Trials against *Mayetiola* and *Kaltenbachiola* will be the focus of future work.

Other Pesticide/Pest Combinations Under Investigation

Delegate against *Leptoglossus*. In our small-plot trials with Delegate, there was some indication that it was effective against *Leptoglossus*, so in the area-wide trials of 2015, Delegate was included as one treatment. It can be seen from Fig 2 above that Delegate was as effective in increasing seedset as Matador was, likely because it was killing *Leptoglossus*. It would be good to have two pesticides registered against *Leptoglossus* to prevent pesticide resistance buildup and secondary pest outbreaks. This will continue to be investigated.

Matador against *Dioryctria*. In our small-plot trials against *Dioryctria*, we included Matador in some of the experiments. As shown in Fig. 3 above, Matador was as effective in reducing *Dioryctria* as Delegate was. Again, a second pesticide to rotate with would be an advantage, so we will be investigating this option further.

Matador against European Pine Shoot Moth. *Rhyacionia buoliana* is becoming an increasingly serious problem as killing winter low temperatures are less common. Dealing with them has proved frustrating; the two registered chemicals, dimethoate and diazinon, have not proved to be effective. I conducted a quick 20-tree trial in 2015, applying Matador during the oviposition period, thinking that it might kill newly hatched larvae as they crawl around and take their first few bites getting into needle sheaths and buds. This is similar to how it works against *Dioryctria* and we know Matador has a 4-week residual. The results were very promising (Fig. 6). This will be investigated further.

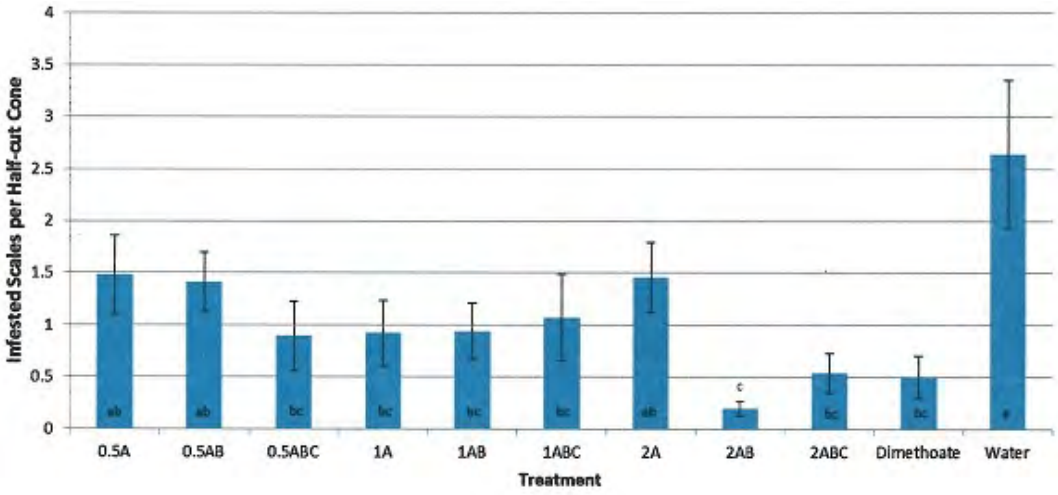

Figure 5. Movento trial results against *Contarinia*, 2013.

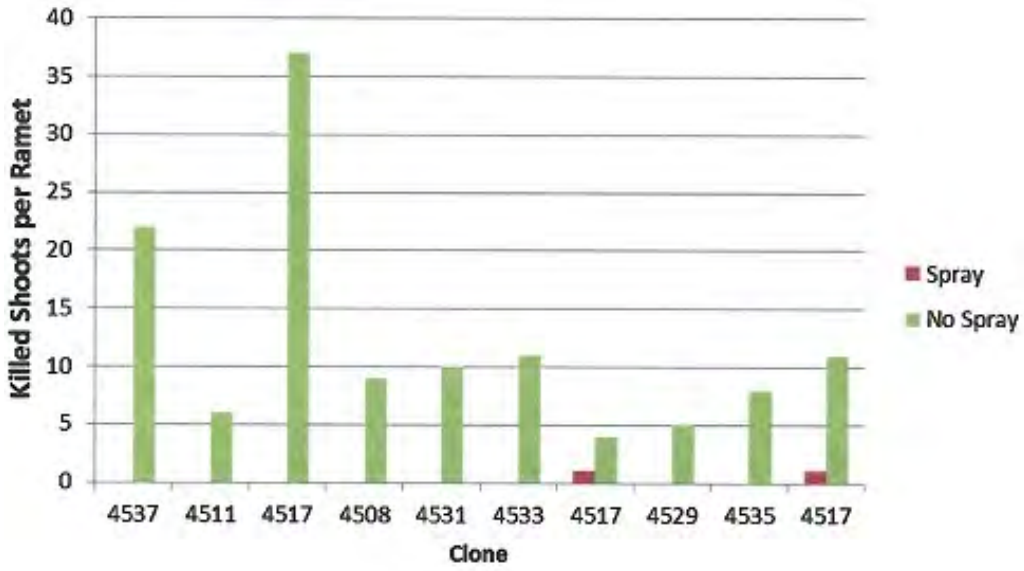

Figure 6. Shoots attacked by *Rhyacionia* on trees sprayed or not sprayed with Matador.

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THE PROPORTION OF FULL SEEDS VARIES DRAMATICALLY BETWEEN TREES AND CLONES OF NORWAY SPRUCE

Flowering and thus cone production of Norway spruce (*Picea abies*) varies between individual trees in a forest and between clones in a seed orchard in a given year (Eriksson et al. 1973, Nikkanen and Ruotsalainen 2000). This is the first step causing uneven representation of offspring of mother trees in a seedlot and eventually in a seedling lot. Due to asynchrony in female and male flowering as well as other processes, not all eggs are fertilized in female strobili. Since all Norway spruce seed will develop into full size seed regardless of being fertilized or not, a good cone crop does not directly indicate an abundance of full seeds. In addition, insects and diseases take their share of the seed crop (Annila 1981). Due to the nature of the reproductive system of Norway spruce one can ask: Are the offspring of individual trees or clones equally represented in seedlots? Are seedlots and seedling lots in fact narrower in their genetic diversity than one might expect, even based on the amount of flowering or collectable cones?

Determining Variation in Seed Quality and Weight

We collected mature cones from 7 trees in a forest stand and from 5 clones in a clonal seed orchard in central Finland. Each seed from each cone was extracted, weighed, and x-rayed to assess their quality.

Radiography revealed that the proportion of full seed varied from 25 to 86% between the trees in the forest stand. In the seed orchard the proportion of full seeds varied from 33 to 79% between the clones. The proportion of empty seed was high in the trees and clones with a small proportion of full seeds indicating variation in fertilization success between the mother trees or clones.

In addition to this, the proportion of insect damaged seeds also varied between trees and clones. This means that the susceptibility of trees or clones to cone and seed insects differed and insect damage may affect the genetic composition of a seedlot. The most prominent damage was done by spruce seed moth (*Cydia strobilella*) and spruce seed chalcid (*Megastigmus strobilobius*). Damage by both of these insects cannot be detected on the surface of the cone. Assessing the effect of insect damage to a seed crop thus requires radiography of the seeds or at least dissection of the cones and performing a cutting test on the seeds (Fig. 1).

Seed weight data were analyzed with variance component analysis. In this analysis, variation in seed weight was divided between different sources: inter-tree or inter-clone, inter-cone, and intra-cone. The analysis showed, surprisingly, that the largest variation in seed weight resided within each cone (intra-cone variation). Intra-cone variation explained 85% and 80% of the total variation in seed weight in the forest stand and seed orchard material, respectively.

Although the mean seed weights were different between different trees and clones, individual or clonal differences were not the main source of variation in seed weight. This result gives reason to re-evaluate the common belief that weight based seed sorting results in genetic sorting in conifer seedlots (Hellum 1976, Lindgren 1982).

All That Glitters is Not Gold

These results emphasize the need to be aware of processes in seed production that may cause an unintentional and uncontrollable decrease in the genetic diversity of seedlots and eventually seedling lots. For example, in a seed orchard even the ideal situation of collecting equal quantities of cones from the clones does not transfer directly into equal proportions of full, germinable seeds from each clone.

It is also important to realize that the small and varying proportion of full seeds in Norway spruce cones is important when planning or studying natural regeneration: flowering or abundance of cones in seed trees is a poor indicator of the true regenerative potential.

However, it must be noted that trees or clones absent or under represented in a seedlot contribute to the genetic composition via pollen.

This article is based on the following publication: Himanen, K.; Helenius, P.; Ylioja, T.; Nygren, M. 2016. Intracone variation explains most of the variance in *Picea abies* seed weight: Implications for seed sorting. Canadian Journal of Forest Research 46: 470–477.

Figure 1. (Top) Empty (bottom right corner) and spruce seed chalcid (*Megastigmus strobilobius*) infested (bottom left corner) seeds appear similar to full and viable Norway spruce seeds (top row) when viewed externally (Bottom). Radiography or a cutting test is necessary to determine the proportion of full seeds in seedlot after kilning and seed extraction. (Photos: Katri Himanen).

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UPCOMING MEETINGS

Seed Ecology V - Seeds in the Web of Life
August 21–25, 2016 Caeté, Brazil
www.seedecologyv.com

35th Annual General Meeting Forest Nursery Association of British Columbia joint with Quebec Association of Seedling Producers
October 4–6, 2016 Sidney, BC
https://www.eply.com/FNABC2016

National Native Seed Conference
February 13–16, 2017 Washington, D.C., USA
http://nativeseed.info/

ISTA Annual Meeting
June 19–22, 2017 Denver, Colorado, USA
http://www.seedtest.org/en/home.html

Canadian Forest Genetics Association
June 25–29, 2017 Edmonton, AB
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