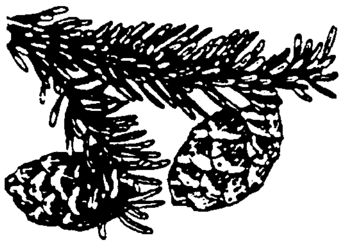
CANADIAN FOREST GENETICS ASSOCIATION
ASSOCIATION CANADIENNE DE GÉNÉTIQUE FORESTIÈRE



Tree Seed Working Group

NEWS BULLETIN

No. 61 June 2015

THIS ISSUE AT A GLANCE

CHAIR'S 'ARMCHAIR' REPORT

Hello, and welcome to the sixties for the Tree Seed Working Group News Bulletin. Last edition I indicated that I would pass on our latest TicTalk link which includes a few tree seed related articles: http://www.fgcouncil.bc.ca/TICtalk2015_Vol12_Feb18_2015.pdf . There are also a wide variety of tree improvement materials on the BC Forest Genetics Council site and worth a wander. I was saddened to hear about the pull-out of the government from Forest Genetics Ontario. Randy elaborates further on the current situation, but it certainly leaves a large gap in a system that really flourishes as a co-operative between government and industry. I certainly feel fortunate to be working where I am, although we have our struggles like everyone.

One of our current struggles is the very warm and very dry weather that we have been experiencing in BC to date. Interior BC seed orchards are one to three weeks ahead of schedule for growing degree day (GDD) accumulation. This is equating to mid July collections in some cases and causing stress for some orchard managers. Traditionally the mantra has been that one should collect as late as possible or close to natural seed dispersal to maximize seed quality. In BC for lodgepole pine (*Pinus contorta*) we have been seeing a consistent decline in filled seed per clone after late July/ early August and the mantra needed to change. This was the primary topic discussed in several of the abstracts in the 57th News Bulletin. The philosophy or question is now ' how early can we collect?' This has re-sparked an interest in early collections and cone handling which caused the resurrection of an uncompleted article on the topic. In this vein I'm also curious about how others are calculating GDD or if they are using these at all? Is everyone using a 5°C minimum threshold? Is everyone using a maximum threshold and what is the justification for the value chosen? I would appreciate feedback if you are using anything different than 5°C as a minimum and any information on what you are using as a maximum would be appreciated.

On hot topics, the restoration of whitebark pine (*Pinus albicaulis*) continues to be a significant issue in BC and Alberta. It is one of the few tree species identified as endangered in Canada (butternut (*Juglans cinerea*), cherry birch (*Betula lenta*), and the entire Garry oak (*Quercus garryana*) ecosystem being some of the other species) and is stuck between being a non-commercial timber species [the rock] and suffering greatly from an introduced disease – the white pine blister rust (*Cronartium ribicola*) [the hard place], although other challenges are also taking their toll. There are two upcoming meetings on the topic and in my opinion the critical question is how can we accelerate the resistance testing program to identify resistant individuals and start getting this material out on the landscape. I actually see somatic embryogenesis as being useful in the large scale propagation of resistant individuals, but this usually goes down like a lead balloon in whitebark pine circles.

Thank you to those that responded to my “Cone and Seed Processing Questionnaire”. I’ve included a few highlights in my enclosed article. I’m especially interested in further discussions on the kiln function as we further evaluate optimum regimes, especially for serotinous species, and build a case for the modernization of our kiln. This is a large capital effort and there certainly seems to be many fewer experts and companies involved in their construction than 30 or more years ago when many of the cone kilns were constructed.

Water activity continues to be an area of interest to us, especially with our genetic conservation collections. It simply is the most appropriate technology to use to maximize longevity of tree seeds. It is good news to hear that Rotronic is establishing an office in Canada and although we don’t specifically endorse any particular manufacturer, for water activity it does seem to be the standard for many seed storage facilities throughout the world. I think that a better understanding of psychometrics and your unique environments for storing cones, drying cones and seed or moistening seeds or cones is critical to maximizing the efficiency of your operations. Thank you Fabienne for continuing to educate people on the benefits when dealing with our hygroscopic materials. I’m looking forward to our upcoming workshop in Fredericton and hoping for a good turn out to further discuss the use of water activity.

Last, but not least I was fortunate to attend the Alberta Seed Conservation course put on by Lindsay Robb in Smoky Lake, Alberta. I thoroughly enjoyed the workshop and highly recommend it to others looking to deepen their understanding of seed science. I had many people ask “Don’t you already know that stuff?” and although there was some review material there was a lot that I learned to bring back to our program in BC. I wish everyone the best for a fun and safe summer and hope to see some of you in Fredericton in August.

Dave Kolotelo

EDITOR’S NOTES

Welcome to summer! At least on the east coast of Canada summer seems to have gotten started on July 1. Let’s hope it lasts for a couple of months. There is a seed crop on many species in the Maritimes this year. It is not a heavy crop but certainly collectable.

This issue contains a good variety of articles. Dave Kolotelo has outdone himself by writing two - one about cone collection timing and post harvesting plus another summarizing a cone and seed processing survey that he conducted. Fabienne Colas talks about the relationship between water activity and relative humidity and how to use a psychrometric chart. Speaking of water activity, Julie Wardell notifies us that ROTRONIC, the manufacturer of water activity instrumentation, is opening an office in Canada. Jack Woods informs us of results from trials in lodgepole pine orchards using Matador® to reduce seed losses due to Leptoglossus. Mike Crawford tells us about an innovative means of monitoring cone crops in seed orchards using drones! Tannis Beardmore informs us of an international *ex situ* conservation initiative to bank seed from tree species that are threatened. Al Foley updates us on facilities and activities at the Onterio Tree Seed Plant. Randy Ford reports on the latest developments on how tree improvement activities will be delivered and managed in Ontario.

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

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COLLECTION TIMING AND POST-COLLECTION HANDLING

The timing of collection, relative to natural seed dispersal, and the effort exerted in post-collection handling are intimately connected to final seed quality. A large historic research effort has informed both activities, but it has been my observation that collection timing receives a great deal of operational attention while post collection handling practices have not received nearly the same degree of operational optimization. This is an attempt to review the literature on the topic with respect to conifer species.

The definition of seed maturity should be reviewed and several authors have differentiated between anatomical and physiological maturity. Anatomical maturity is identified by the presence of a fully developed embryo and megagametophyte tissue and usually corresponds to the point of maximal dry weight. In conifers, anatomical maturity is a key stage in development and is generally accepted as an indicator when cones can be picked and successfully ripened artificially (Edwards 1980; Winston and Haddon 1981). Physiological maturity has not been as clearly defined, but is generally identified by a reduction in moisture content, slowing of enzymatic activity, rearrangement of substances and membranes to withstand drying, and as the point in time when maximum germination can be attained (Skre 1988). Another way of looking at this is that anatomical *immaturity* is identified by partially developed embryos and physiological *immaturity* identified by seeds composed of a set of incomplete storage materials (Zasada 1988). A certain stage of anatomical and physiological maturity must be reached before cones can be separated from the tree and for artificial ripening to be successful. Krugman (1966) showed that there was a progression from dependence on the tree to dependence on the cone to total independence of the seed. For slash pine (*Pinus elliottii*) in Australia it was found that the time between anatomical and physiological maturity varied by cone storage treatment (Bevege 1965). This time may correspond to the formation of abscission layers isolating the structures from their former source of moisture and nutrition and possibly also the attainment of desiccation tolerance in the seeds. Desiccation tolerance in Scots pine (*Pinus sylvestris*) though seemed to correspond to anatomical maturity and the attainment of maximum dry weight (Sahlén and Abbing 1995).

Collection timing was initially determined based on trial and error and observations on the changes in cone, seed, and seed wing characteristics like colour, firmness or flexibility. These have worked well for some species, but not forothers and can be problematic due to the inherent variability between individual trees for these characteristics (see Edwards 1980 for a thorough review). I think these characteristics can be good indices that seeds are still immature, but not necessarily good indicators of complete seed maturity. The success of these subjective indicators seemed to be tied to practitioner experience and there was a desire to produce some more objective or quantitative means of determining proper collection timing.

The use of cone specific gravity was used as early as 1940 to assess the maturity of conifer cones (Maki 1940; Rudolf 1940). Cone and seed maturation is associated with a decrease in moisture content. Due to the time required to obtain moisture content tests (=overnight), specific gravity was used as a good approximation for immediate collection decisions. For many species a target specific gravity was established to correspond to cone and seed maturation and many references are available on the topic (see Edwards 1980 for a review). A liquid of that 'maturation' specific gravity was then used in sink-float tests of cones until a proportion (i.e., 19/20) cones floated. Some of the common chemicals used were kerosene and motor oil. Disposal of the liquids and 'contaminated' cones in the field became a problem causing a reduction in the technique's use although it was simple and required very little equipment or training. My queries to a chemist have not identified a liquid in the 0.8 to 0.9 density range (target specific gravity for many species) that would not pose disposal issues. General instructions are available to determine cone weight and specific gravity through floatation, but this requires more effort and time than the simple float/sink test used in the field (Karrfalt 2008). For coastal loblolly pine (*Pinus taeda*) it was found that specific gravity was not a good indicator of maturity due to variability between clones, especially in terms of the rate of drying (Cobb et al. 1984). As a practical field test, the cone 'axis test` was developed for non-serotinous species. A cone is cut longitudinally and the condition of the axis is examined – if it is brown and dry it is assumed that the connection with the tree has been severed and this is used as a guide for initiating cone collections (Giampa 2013). At our facility we also look at the ease of separation of the seed wing from the cone scale as one of our indices of seed maturity.

Finnis (1950) tried using different salt solutions for measuring cone specific gravity, a sodium beselenite biochemical test and germination tests, to assess maturity in Douglas-fir (*Pseudotsuga menziesii*). He found that the salt solutions did not work well (salts increase density above 1.0), but the excision of embryos during the biochemical test and the germination results lead him to the observation that embryo length may be a good criterion to use for assessing seed maturity. It seems like common sense now, but truly ground breaking at the time – actually looking inside the seeds to assess maturity! Early recommendations were that embryos should be 75% of the corrosion cavity, but work by Zasada (1988) and Winston and Haddon (1981) showed that completion of embryo growth is a good index to use for commencement of cone collections provided subsequent cone handling includes artificial ripening. The current recommendation in British Columbia (BC) is that the embryo should be at least 90% of the corrosion cavity before cone collections should be initiated. This agreed with the recommendation of Ching and Ching (1962) based on a detailed study of the physical and physiological changes in maturing Douglas-fir cones and seed. In addition to the embryo, it is also critical to consider the development and condition of the megagametophyte which should be full sized, firm, and white, not 'jelly-like'. Some advocate placing cut seeds at room temperature overnight and observing whether the megagametophyte shows any appreciable shrinkage – the lack of shrinkage is considered an indication of maturity (Dobbs et al. 1976). For a more detailed analysis of seed characteristics it has been our experience that imbibing the seeds overnight prior to performing a cutting test can be more informative regarding the presence of any developmental or quality issues.

In terms of collection timing, early work by Zasada (1973) indicated that degree days were a good measure of seed maturity and that heat requirements varied by provenance. A previous review of some of the literature on degree day summations was provided by (Kolotelo 2009). Of interest to this topic is the continued use of degree day summations during after-ripening to guide minimum cone storage durations (Mosseler 1992). Two options were identified by Zasada (1973) for collecting coniferous cones: 1) collect cones at full seed maturity or 2) collect cones early and store under cool, <u>moist</u> conditions to allow seed development to complete, although he also cautioned about potential fungal problems under these cool, moist conditions. That is basically how collections are dealt with today with the exception that most of the subsequent literature and experience has emphasized 'dry' and not 'moist' storage of cones after collection. The notable exception was the early published work of Silen (1958) who collected cones up to five weeks before natural seed fall and was able to successfully artificially ripen the cones by storing them in wet peat moss. This was not without problems as the earliest collections became heavily molded during storage and experienced difficulties with seed extraction. He also tried dry and wet storage, but seed germination from the wet stored cones (cones stored in well-aerated water) was poor, although it was also noted that this treatment caused the widest spread of the cone scales and easiest extraction of seed. The dry-stored cones opened uniformly, but not far enough to allow for easy seed extraction. Additional trials with Douglas-fir indicated cone collection date and cone storage treatment did not significantly affect germination capacity, but for germination rate about 68% of the variation was attributed to cone storage treatment (Edwards and El-Kassaby 1988).

I'd like to also present some interesting information that was produced as an internal BC Forest Service document comparing cone collection timing and three after-ripening treatments (Drew et al 1983). Figure 1 presents the germination results across a range of collection dates and with 1) immediate extraction of seeds, 2) storage under ambient conditions for four weeks, and 3) storage at 5°C and between 75 to 100% RH for 4 weeks in a refrigerated reefer.

Very poor germination results were experienced when seeds were extracted from cones immediately after collection, especially for the earliest collection dates. The reefer storage seemed beneficial, although this benefit decreased with advancing seed maturity. In a complimentary trial the benefit of reefer storage (vs. sack or tray storage) was also verified by germination tests at time of seed processing. The results of retests performed after one year of storage unfortunately illustrated larger germination reductions for reefer stored material and the authors were hesitant about recommending it, except as a last resort and with the addition of forced air exchange which was not utilized in either trial (Wallinger and Cousens 1987).

For red pine (*Pinus resinosa*) and white spruce (*Picea glauca*) it was found that cones could be collected early and artificially ripened. In addition to air storage, they also tried storage in moist peat, but for both cold and ambient treatments the results over several storage durations were generally disappointing (Winston and Haddon 1981). They also tested white spruce germination after two years storage and concluded that seed viability is retained provided seeds have obtained a critical level of development before extraction (Haddon and Winston 1982). It was also shown for Douglas-fir that after storage for eight years there was no viability loss in both early picked and mature seeds (Rediske 1969).

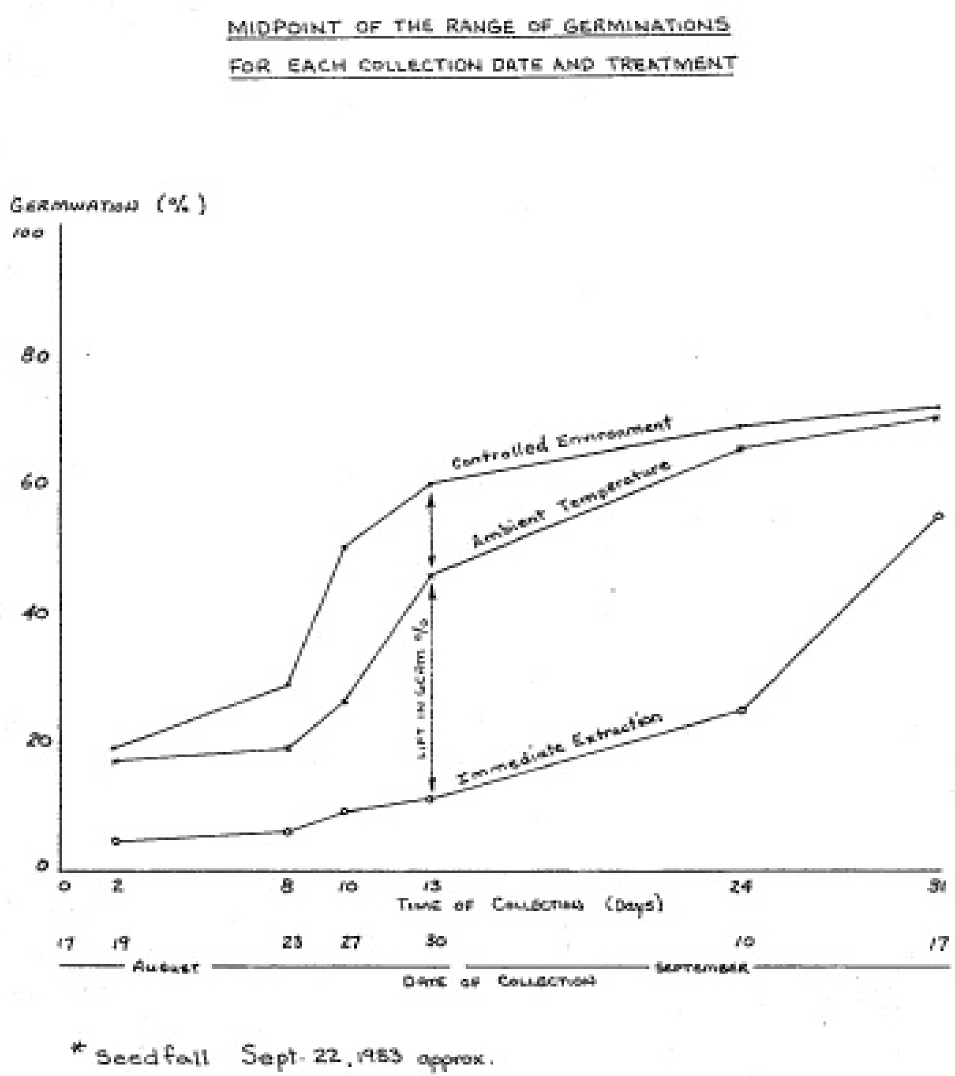

Figure 1. Germination results of interior spruce cones collected over time and treated in three different ways. (From Drew et al 1983).

In white spruce the duration of post-collection cone storage in 1984 had a significant impact on germination with two weeks of storage in a ventilated building resulting in 62% germination and six weeks storage resulting in 95% germination. The increased cone storage also increased germination rate and decreased the variation among the 18 open-pollinated families sampled for the study (Caron et al. 1990). The study was repeated in 1988 (13 of the 18 trees were the same as in 1984) with a wider range (2 to 14 weeks) of cone storage durations. The germination percent and rate were not significantly different between collection dates. This result was attributed to the seed being more mature in 1988 (146 more growing degree days) and emphasizes the greater importance of longer post-collection handling durations when collecting relatively immature cones (Caron et al. 1993).

For Scots pine, it is commonly found that cone and seed maturation does not occur in the northern and high elevation portions of its range. Several artificial ripening variables, at two different locations in 1988 and 1989, were tested including treatment duration, temperature, light levels, and whether cones were maintained attached to branches. These treatments were performed in controlled environments of saturated air. For very early collections they found that a warmer temperature (15°C vs. 6°C) was beneficial and that drying of the cones should be minimized. Later collections should maintain the higher temperature for the first 2–3 weeks and then reduce to 5–6°C with cones allowed to slowly dry. Unique to this study the researchers also recommended that artificial ripening be performed with continuous light (Sahlén and Bergsten 1993). In a follow-up study three temperatures (5, 10 and 15°C) and two cone moisture levels (50% and 38%) were used as after-ripening treatments on seven collection dates. Complete physiological maturity was possible, but best results were obtained after anatomical maturity was reached with earlier collections benefiting from the prevention of drying (Sahlén and Abbing 1995).

For southern pine species, post-collection handling recommendations vary by species. Early collections (2–3 weeks before natural dispersal) followed by after-ripening is considered an acceptable practice in loblolly and slash pine, but maximum yield and germination were obtained when cones were fully mature. For longleaf pine (*Pinus palustris*) it was recommended that only mature cones be collected (Barnett 1976; McLemore 1975). As a simple and inexpensive post-harvest treatment for loblolly pine it was recommended that muslin cone sacks be placed on the ground at the base of orchard trees for four weeks (Cobb et al. 1984). This type of treatment would be of concern to me in areas where precipitation could delay or reverse cone drying as well as the potential transfer of soil-borne pathogens like *Caloscypha fulgens*. Our first basic recommendation for post-collection handling is to protect the cones from precipitation and direct sunlight. In the serotinous Ocala sand pine (*Pinus clausa*) it was found that an optimum collection timing exists and that it may be more efficient to base collection timing on clonal ripening dates (Barnett and Brandt 1990). This appears to be the most similar situation to our lodgepole pine (*Pinus contorta*) seed production issues (serotinous species showing declines in filled seed per cone over time), but the decline is much more gradual than what we are experiencing in BC.

Although not the emphasis of this review, there has been research into various biochemical indices being used to assess seed maturity. For conifers the work of Rediske (1961) was pioneering as he compared the pattern of seven biochemical seed constituents in Douglas-fir over the seed maturation time and in comparison with germination tests. He found the most promising pattern was with the reduction in amount of reducing sugars with seed maturity, and when the level had fallen to 13 mg/g that the seed was mature. More recently leachate conductivity was used with Scots pine and indicated a consistent decrease during ripening until the point of anatomical maturity (Sahlén and Gjelsvik 1993). These offer potential tools for assessing maturity, but to my knowledge they have not been optimized as a field test method. The potential may exist as field based electrical conductivity (EC) meters are relatively inexpensive ($40 to $300). There would certainly still need to be a dissection of seeds from cones and determination of species-specific target maturation EC levels. Equipment calibration should be an important consideration and I think that this technology has potential in helping with collection timing and as a general seed quality assessment tool.

An extreme example of what is possible is illustrated by the practices with radiata pine (*Pinus radiata*) in New Zealand. For decades cones have been **collected up to three months early** and then artificially ripened in ‘dry’ storage for nine weeks (Ribawanto et al. 1988). The limiting factor was not anatomical maturity, but having the serotinous cones dry enough to be successfully kilned to open and release the seed. During artificial ripening cone specific gravity (and moisture content) decreased primarily during the first three weeks of dry storage. The cone and seed coat colour changed during artificial ripening, but there were no apparent changes in seed dry weight or in anatomical development based on x-rays. Operationally, this after-ripening occurs in an enclosed curing facility with an emphasis on reducing humidity through removal of moist air. This process has no effect on seed viability with seedlots routinely exceeding 90% germination in 14 days (pers. comm. Shaf van Ballekom, 19 June 2014). Is this methodology possible with all conifers or is it a 'perfect storm' with the exotic radiata pine under New Zealand environmental conditions?

Various jurisdictions around the world have had to determine the appropriate time to collect conifer cones and how to subsequently store and handle the cones prior to seed extraction. It is generally a trade-off between attaining the required degree of seed maturity and trying to extend the harvest period before seed begins dispersing. An adequate sized work force to collect cones in a condensed time frame is often a significant bottleneck. The literature provides some common elements, but also a range of findings and recommendations that may appear contradictory on the surface. The contradictory results have a variety of reasons including no standard method used by all to define 'early' or 'late' collections. Comparisons with natural seed dispersal timing are a good way to integrate many factors for non-serotinous species, but may also be problematic in areas with high humidity during dispersal causing cone scales to open and close in response to precipitation events (Harris 1969) making it difficult to accurately define time of dispersal. There is also a wide range of conditions that cones are exposed to within the context of `dry` cone storage. The poor results in some studies may be due to the lack of aeration and creation of high humidity conditions by storing cones in polyethylene bags (Rediske and Shea 1965). Transferability of the results should be considered in terms of whether the study was performed under operational conditions or in a lab or office in which the actual environment may not be simple to reproduce in operations.

In an attempt to generalize, it appears that if cones are collected prior to anatomical maturity that maintenance of an environment that eliminates or minimizes cone drying (i.e., moist storage) is beneficial. This seems more common in the high latitudes of Europe or for very early collections (thankfully rarer these days), but could also be applicable to conifers that appear to produce immature embryos such as *Pinus albicaulis*. The more common situation today appears to be that anatomical maturity has been attained at collection time, but physiological maturity has not and cone storage conditions should allow for the drying of cones and seed prior to kilning and seed extraction. This situation still poses hazards if moist cones are exposed to high temperatures, especially if the environment does not allow for the dissipation of the moist air and heat generated through the drying cones. Most of the studies focused on the impacts on germination, but several authors have also stated that 'early' collections may pose operational problems in maximizing seed yield (i.e., seed extraction problems) and must be considered in order to provide a practical assessment of different collection timings and cone storage conditions and durations (Cram and Worden 1957; Silen 1958; McLemore 1975). Collection timing and post-collection handling is an important area for further exchange of information as most of the published work in this area is decades old and the assumption seems to be that we have all the knowledge we need. It is also a good reminder of something a wise man recently said regarding our poor performance in reporting on failure in the literature. It may not be very refereed, journal friendly information, but we welcome such contributions to the News Bulletin – crop failures can be one of our greatest learning tools in helping to identify problems and ensuring the same mistakes are not repeated. I appreciate any feedback on the article, but think this basic theoretical diagram (Fig. 2) from the Woody Plant Seed Manual (page 59) captures the essence of the article's message that good cone and seed handling is critical to final seed quality (Karrfalt 1980). The challenge is still in defining good and poor cone and seed handling practices that vary by collection timing and environments available for after-ripening your crops. I think it is safe to say that the earlier you collect crops, relative to seed dispersal, the more effort needs to go into post-collection handling and monitoring. Some facilities may have the advantage of an ideal post-collection environment, but many seed orchards are located in relatively harsh environments that allow for relatively easy cone induction. These sites can also be challenging for early collections by providing conditions that may accelerate drying of cones prior to the attainment of dessication tolerance or the accumulation of a full complement of storage products.

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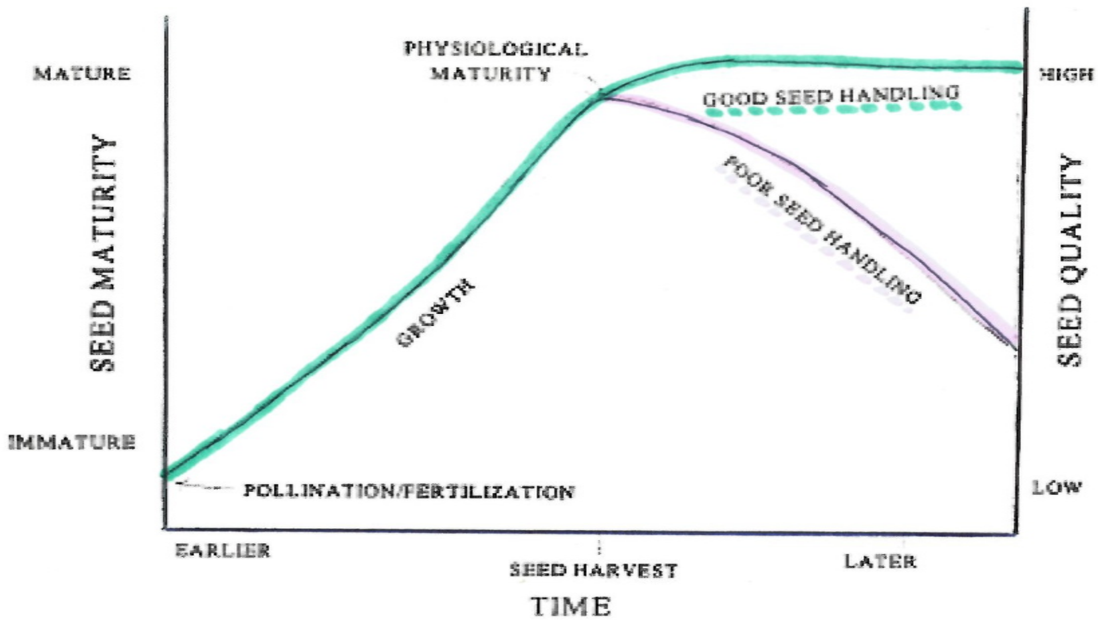

Figure 2. Seed quality changes over time. (From Karrfalt 1980)

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SOME ONTARIO PERSPECTIVE

In the world of negatives that are often offset by positives as many of you already know during the 1990's the Ontario Tree Seed Plant lost all capacity to engage in science, however the positive was that we now operate under an innovative business plan which has helped us not only survive within government but thrive. The difficult side to that is we have had very little pure science to contribute to this newsletter for the last 15 years and that I truly regret.

Innovation

During this period of relative business success we have really only seen minor changes to the processes and equipment we have been using since 1923. As our 1945 vintage fanning mills began to fail we did embark on a mission to find a replacement. With the modern equivalent in place seed cleaning staff remain emotionally attached to the last of the surviving vintage machines.

We have also made significant changes to refrigeration equipment over the last 15 years, abandoning old water cooled units and replacing them with much more efficient air cooled equipment with higher "tonnage" of cooling capacity to ensure our ability to maintain storage temperatures in a hotter climate changed world. Reducing our electrical requirements and dependence on the grid were part of these upgrades as we also introduced generator capacity on site so we can survive for days in the event of a hydro grid failure. Of most critical importance in addition to maintaining cold storage temperatures is the microwave and coffee pot continue to function!

The electrical innovation I am most proud of is our conversion to LED lighting. As I have previously written first was the "high bay" lighting in our warehouse, followed closely by the lighting in all our cold storage units. It is wonderful to flip on the lights at any temperature and not have flickering bulb and ballast issues and know we are using about one-tenth the electricity. Most recently the Ontario Government has undertaken a project to convert all exterior lighting to LED, a big success at this site as we were well lit for the darkest cold winter night.

Orchards

Although we stay at arms-length from the day to day management of Ontario's seed orchards we are the recipient of some of the cones for processing. At the present time we are still waiting for final totals and germination data of seed collected in 2014 but there have been two significant orchard happenings. The first is white pine collected from the Scugog orchard in the summer of 2014. We are seeing yields almost 50% higher than the norm, hard data to follow. The second is the Island Lake orchard near Chapleau where there was a bumper crop of black spruce unlike any we have seen before; again hopefully hard data to follow.

The Future

Many may have heard about the "Transformation" the Ontario Ministry of Natural Resources and Forestry (MNRF) has gone through over the last three years. While that has significantly changed areas of our Ministry it is business as usual at the Ontario Tree Seed Plant.

In addition to our regular business providing native tree seed for the nursery and forest industry, we are a part of Ontario's 50 Million Tree Program, and we also have a role in MNRF initiatives around biodiversity, species at risk, and climate change.

Having watched a tornado pass within 500 metres of our gate last summer, we are exploring options for fortification of our facility. Much work is currently underway to replace our aging boilers with a view to improving efficiency and converting to biomass as a fuel.

And finally even with a Business Plan in place, leading edge energy efficient facilities, and an amazing team of highly skilled experienced technicians, we will always be at the mercy of whatever cone crops the forest environment provides us and we do not control.

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HUMIDITY 101

As the use of water activity to monitor seedlot quality increases in seed banks, I thought it could be useful to clarify some basic concepts about air humidity and its variation. Many websites provide information on this topic. I have included a list of selected links at the end of this article.

Water activity (a_w) is the ratio of the vapour pressure of a given sample (p_s) to that of pure water (p). It ranges from 0 (totally dry) to 1 (pure water). We use a_w to describe water in solids such as cookies or seeds and relative humidity (RH, also called hygrometry) to measure water vapour in the air. Measuring a_w has 3 advantages: 1) it is rapid, 2) reproducible and, most of all, 3) non-destructive, which allows repetitive measurement of the same sample.

Until now, we thought that keeping seed samples in freezers was our best insurance for long-term conservation. However, close monitoring has revealed that a_w and moisture content of seedlots can increase during conservation and lead to reduced germination capacity. How then can we establish the ideal conditions for long-term preservation?

HUMID AIR DIAGRAM

The amount of water in the air depends on both RH and temperature. The hotter the air, the more water it holds before condensation occurs. Our "best friend" to help us to understand the physical phenomena governing the interaction of RH and temperature is the humid air diagram (also called a Mollier Diagram) or psychrometric chart, which presents RH and enthalpy (= energy of a kg of air, in kJ/kg). The horizontal axis indicates temperature and the vertical axis indicates the humidity ratio, which is the quantity (in kg) of water in a kg of dry air. RH is represented by the various curves (Fig. 1). Some Mollier diagrams have many other axes, but the simpler one is sufficient for our needs.

Dew Point

The dew point is the temperature at which vapour in the cooling air begins to condense. As air temperature decreases, the quantity of water vapour it contains remains stable, but RH increases. On the Mollier diagram, the dew point temperature is obtained by following the horizontal line from a given humidity ratio and then reading the temperature directly below its intersection point with the saturation curve (Fig. 2). Each humidity ratio has a unique dew point temperature that does not depend on air temperature.

Evolution of a_w and RH With Temperature

Prior to conservation, seedlots are stabilized at lab temperature (20°C) to a target a_w defined by some seed banks at 0.15 to 0.25, which is equivalent to 15 to 25% RH at 20°C. These values correspond to humidity ratios of 2.1 and 3.7 g/kg air, respectively.

What happens to a_w when the seedlots are transferred to colder temperatures in the freezer? As temperature decreases in the container, air RH increases (Fig. 3). At the dew point (-1°C for a humidity ratio of 3.7 g/kg, associated to an initial a_w of 0.25 or 25% RH), water will condense and transfer from the air to the seeds. When this happens, a_w can increase to levels that can be harmful for seeds. If the initial air RH is 15% (initial a_w of 0.15), water will transfer to the seeds at a lower temperature, because the dew point is lower than -5°C (Fig. 3).

Other factors can cause a_w to increase over time: air leakage around the container lid, porosity of the container material, etc. Another article will address this topic later.

CONCLUSION

Stabilizing seeds to the correct a_w before storage is important, but not enough to guarantee proper long-term conservation. Humidity transfer between the air and seeds should be minimized. Such transfers can happen as the air cools in the container. A greater volume of air in the container also increases humidity transfer to the seeds. To ensure better seed preservation, the volume of air in the container should be minimized.

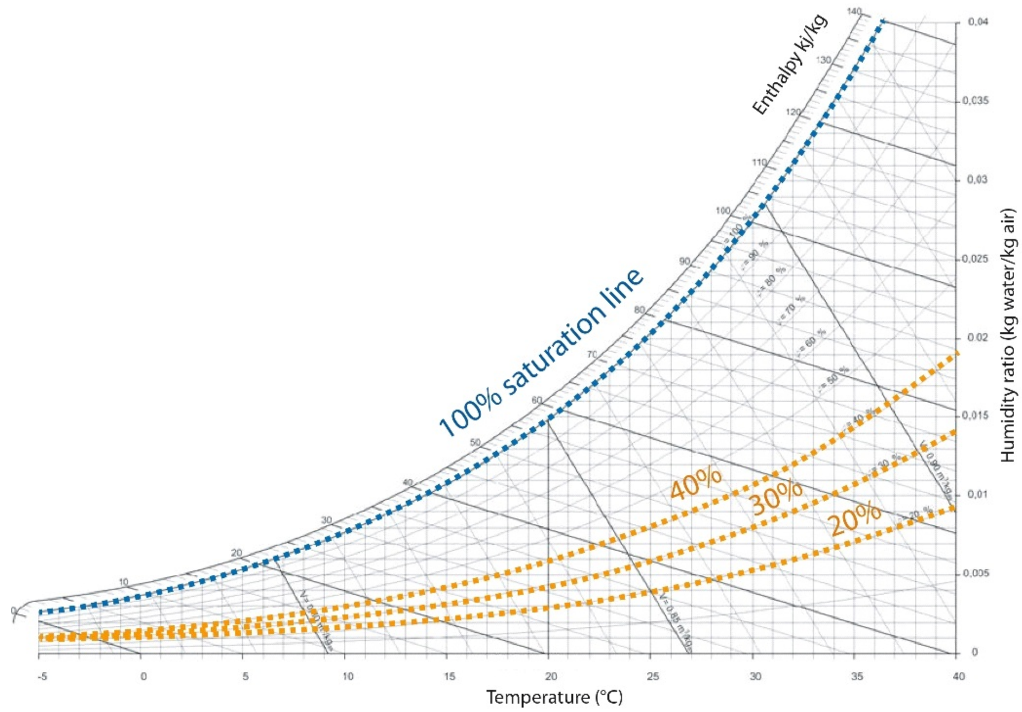

Figure 1. The orange dotted lines on this Mollier diagram correspond to RH values of 20, 30 and 40%. The blue saturation line (=100% RH) shows the maximum amount of water vapour the air can hold before condensation occurs.

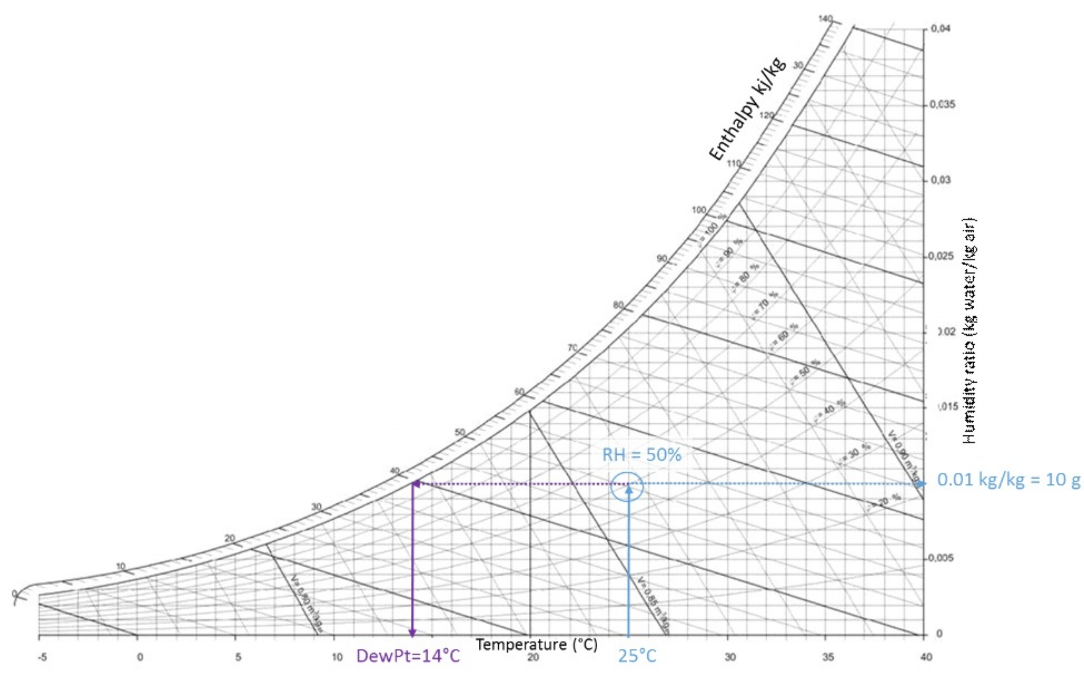

Figure 2. Air at 25°C and 50% RH contains 10 g of water/kg of air. If this air is cooled, RH will increase until it reaches 100% RH. The temperature at this saturation point is the dew point (in this example: 14°C). At lower temperatures, water will condense.

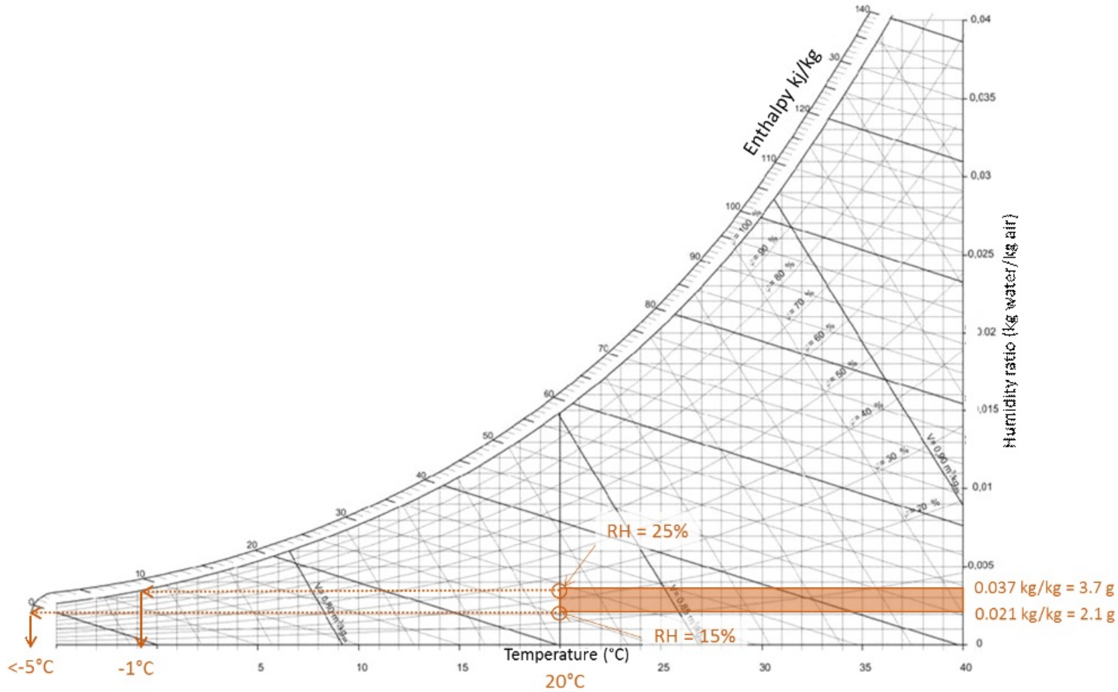

Figure 3. Orange lines show the evolution of RH with a decrease of temperature. Air with an initial RH of 25% at 20°C becomes saturated at -1°C, and air with an initial RH of 15% at 20°C becomes saturated below -5°C.

Selected Links

Rotronic USA website with different technical notes. http://www.rotronic-usa.com/humidity-academy/technical-notes/

Decagon website dedicated to water activity. http://www.wateractivity.org/

Psychometric chart tutorial (scroll down on the page to find the tutorial). http://www.energy-design-tools.aud.ucla.edu/

Online calculator provided by Holsoft Physics Resources. http://physics.holsoft.nl/physics/ocmain.htm

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GLOBAL TREE SEED BANK INITIATIVE

There are an estimated 80,000 species of tree in the world. Approximately 450 species are used today in commercial forestry and are stored in forestry seed banks leaving the remaining 79,550 species with uncertain representation in *ex situ* conservation (Oldfield et al. 1998). Over 8,000 tree species are currently assessed as threatened with extinction and over 1,100 species are listed on IUCN red lists as Critically Endangered and they are likely to become extinct unless urgent action is taken now (Newton et al. 2003). There is such uncertainty with regard to the full impact of a species going extinct. Species diversity ensures ecosystem resilience, giving ecological communities the scope they need to withstand stressors. The U.S. Fish and Wildlife Service has estimated that losing one plant species from an ecosystem can create a cascade of up to 30 other localised plant and animal extinctions (USDA 1993).

Seed banking is having more impact than ever as species populations are disappearing at greatly accelerated rates as a result to a variety of stressors. Given the magnitude and scope of the challenges we face in conserving plant diversity, seed are often the propagule of choice to collect and store. Seed banks can offer the most cost-effective means for storing large numbers of species over long periods of time. Many seed banks were created in the 1970's and 1980's and were developed to address a global surge in agricultural crop yields. It was recognized that a vast amount of agricultural biodiversity was being lost, as farmers abandoned old seeds, often locally developed over centuries, for the new hybrids. Excellent initiatives have been developed primarily to address the *ex situ* conservation of agricultural seed. Recently, there is focus on the *ex situ* conservation of tree species.

In 2014, the Global Tree Seed Bank Initiative was developed and became possible through funding by the Garfield Weston Foundation (£5 million of funding) (Global Trees Campaign 2015). This initiative is a 4-year project which involves the Global Trees Campaign (GTC) and the Millennium Seed Bank Partnership (MSBP) who will work with partners around the world to provide training on seed collection and establish *ex situ* seed collections for threatened tree species. The GTC was launched as a joint initiative in 1999, between Fauna & Flora International and Botanic Gardens Conservation International to conserve the world's threatened tree species, while the MSBP is an international conservation project coordinated by the Royal Botanic Gardens, Kew, United Kingdom. The goal of the Global Tree Seed Bank Initiative is to establish *ex situ* collections in each species' country of origin, while back-up collections will also be stored at the Millennium Seed Bank.

This initiative has the goal to secure *ex situ* collections of seed from 500 priority tree species from around the world with a focus on threatened trees. The partnership also aims to increase capacity for seed collection of threatened trees and raise awareness of the value of establishing seed collections for the world's threatened trees. Currently, the MSBP has already collected seed from 3,900 species during the last 14 years, and as a result of this new project aims to increase its tree collections by 50% over the four years (by March 2019).

This initiative will work with existing and new MSB partners across the world to target seed collection of the rarest, most threatened, and useful tree species. Along-side seed collecting, a research program will be undertaken to improve our knowledge of tree species leading to improved conservation. Propagation protocols will be established for key species and used for forest restoration projects. A DNA fingerprint library of important timber species will be assembled to provide the ability to pinpoint the geographical origin of timber exports. Storage protocols for recalcitrant tree species like oak (*Quercus*), buckeye (*Aesculus*), and chestnut (*Castanea*) will be developed. Genetic studies on rare trees will be carried out to help design species recovery programs in island habitats. Methodologies will be established to study tree species traits and their resilience to environmental threats, leading to better prioritisation of species for seed banking.

Canada, among other countries, will be participating in the Global Tree Seed Bank Initiative. As part of this initiative the MSBP has the goal to collect and seed bank 200 priority tree species from North America between April 2015 and March 2019. The project in Canada is intended to complement existing national and provincial efforts to conserve and manage genetic resources by securing seed from at least one population of each target species.

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DRONES IN THE ORCHARD

In early June of each year, Bureau of Land Management (BLM) orchard staff in Oregon visit Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) trees to estimate the number of bushels of cones to be collected in August. Timing of this early survey is tied to the need to provide anticipated yields for developing collection contracts. These tree-by-tree estimates are then used to pre-print bar coded bag tags to correctly identify each collection.

Accurately estimating crops when the cones are not yet fully developed and their color tends to blend in with the new, lush vegetative growth of the branches has proven to be a time-consuming and difficult task, often requiring many years of sampling experience by an individual before consistent results are acquired.

Discussion over the years on how to improve the accuracy of this process kept gravitating back to the use of infrared (IR) photography. IR has been extensively used in agriculture for monitoring irrigation needs, analyzing fertilization success, and determining crop yield. Our desire was to utilize this technology to help to better determine cone crop size.

The Department of the Interior recently acquired a number of military surplus Unmanned Aircraft Systems (UAS), commonly referred to as drones, for use in developing telemetry for biological studies. An orchard research proposal was selected to test various types of miniaturized cameras on a variety of UAS platforms to determine their ability to distinguish the signature of a confer cone to help estimate potential crops.

Two UAS devices were tested at Horning Seed Orchard in summer 2014: a Raven and a T-Hawk (Fig. 1). The Raven is a fixed-wing aircraft weighing about 4.2 lbs. that flies at a speed of up to 60 mph and up to an altitude of 20,000 ft. The T-Hawk, is a gasoline powered micro-air vehicle that can fly at speeds up to 45 mph, but has the ability to hover, offering greater data collection capabilities in a seed orchard situation. Both types of UAS can be fitted with a GPS and a variety of cameras and video recording devices.

Figure 1. Unmanned aircraft systems tested in a Douglas-fir seed orchard; Raven (left), T-Hawk (right).

Color Infrared (CIR) cameras were used for the base flights conducted in 2014. CIR film uses the light spectrum just beyond the sensitivity of the human eye, resulting in images that are shades of red. Although CIR has been used with subsequent statistical computer analysis to correlate the density of a number of agricultural crops with their eventual yield, this method proved ineffective in estimating a Douglas-fir cone crop.

The next set of tests will be conducted in summer 2015 using thermal infrared cameras, which can differentiate temperature variation. The BLM is working with manufacturers of these specialized cameras to find a device that will meet the weight limitations of cargo for the T-Hawk.

The use of thermal infrared imagery for detection of western white pine (*Pinus monticola*) cones was showcased in (Takács et al. 2009), where researchers (including Robb Bennett and Ward Strong from British Columbia) found that radiation from cones attracts seed feeding insects. The article states that cones were up to 15°C warmer than needles, absorbing more solar radiation than the surrounding vegetation. The cones, which appear as bright yellow in the images, are easily discernable (Fig. 2). We are hopeful that Douglas-fir will present a thermal signature with this degree of variation in temperature.

Figure 2. Thermal infrared imagery of western white pine (*Pinus monticola*) conelets. (From Takács et al. 2009)

Using this technology, the photos will be computer analyzed to correlate the digital signature of the cones on an individual tree with the actual yield in hopes of determining a model for future estimates. Although the experimentation process for this project is just beginning, it may be possible at some time in the future to collect UAS data on individual trees with higher accuracy and in a fraction of the time required to do a ground survey.

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IMPACT OF MATADOR® ON LODGEPOLE PINE FILLED SEED PRODUCTION IN SOUTHERN INTERIOR BC SEED ORCHARDS

Introduction

This article summarizes a report posted on the Forest Genetics Council of BC (FGC) website (www.fgcouncil.ca).

Filled seed production in lodgepole pine (*Pinus contorta*) seed orchards in the north Okanagan of British Columbia is frequently low, resulting in financial losses for orchard businesses and creating a barrier to meeting FGC objectives for orchard seed production and use. Many possible causes have been investigated (Webber 2014). This report summarizes the methods and results from four lodgepole pine seed orchards that applied the pesticide Matador® to control *Leptoglossus occidentalis* (Leptoglossus) populations during the 2014 cone production season.

Work by Strong (2015) on the timing of Leptoglossus emergence and feeding suggests two key periods for control; late May through June when overwintering Leptoglossus begin to feed on developing ovules in maturing cones and mid July through to late August or early September when newly hatched nymphs begin to feed on developing seeds and mature to adults. It is believed that the early feeding kills ovules and limits seed development resulting in a reduction in the total formed seeds (filled and empty) in a cone. The latter feeding is thought to reduce the number of filled and viable seeds. Both feeding periods will reduce filled-seed production by first reducing the total number of developing seeds and second by reducing the number of filled seeds among those still developing after the first feeding period.

The trial reported here includes three components:

1. Operational seed production in multi-hectare Matador® spray blocks compared to large non-sprayed control blocks.
2. Per-cone seed production in and outside insect exclusion bags in both spray and control blocks.
3. Per-cone seed production in collections from a random sample of cones prior to operational harvest (mid July).

Methods

This trial was implemented on four orchard sites located in south-central British Columbia. Each orchard produces seed for a different seed zone. Matador® (Sygenta Canada Ltd.) was applied to spray blocks in each orchard at the rate of between 71 and 104 ml of product per hectare two or three times between mid May and mid July. Control blocks from the same orchards were left un-sprayed. Spray blocks ranged in size from 3.4 to 5.0 ha and control blocks ranged in size from 1.8 to 4.8 ha. Application timing varied among sites and was driven by surveys of Leptoglossus populations. Cones were collected operationally from spray and control blocks in August, 2014. All cones had seed extracted at the Ministry of Forests Lands and Natural Resource Operations Provincial Tree Seed Center (TSC). TSC staff conducted standard tests for moisture content and germination on lots from spray and control blocks.

Screen-mesh insect-exclusion bags were applied in late April to cones on a single ramet from each of 20 parental clones in each orchard in both spray and control blocks (1 ramet x 20 clones x 2 treatments x 4 orchards = 160 ramets). About seven cones were bagged on each ramet. Another seven or more cones were identified on the same 160 ramets and left un-bagged for comparison (bag/no-bag trial). Cones contained within insect-exclusion bags and cones flagged as controls were collected from all treatments and orchards August 4 – 7. These cones were dried and seeds were hand extracted and counted. Total formed seeds per cone (TSPC), filled seeds per cone (FSPC), and the percent filled seed (%FS = FSPC/TSPC) were estimated from these data.

In addition to the operational collections and the bag/no-bag information, random cone samples were collected from spray and control blocks in mid July and seeds were hand extracted and counted using the same protocol as for the bag/no-bag trial. The intent of this collection was to estimate the number of filled and empty seeds in cones prior to the seed set decline that is known to begin in mid to late July.

Results and Discussion

Operational harvest

Filled seed yield in grams per hectoliter of cones from Matador® treated blocks ranged from 182% to 300% more than from non-treated control blocks, across the four orchards (Fig. 1). Yield differences between treated and control blocks were highly significant ($p = 0.004$). Seed weight and seed germination were not significantly different between the treated and control blocks ($p > 0.1$).

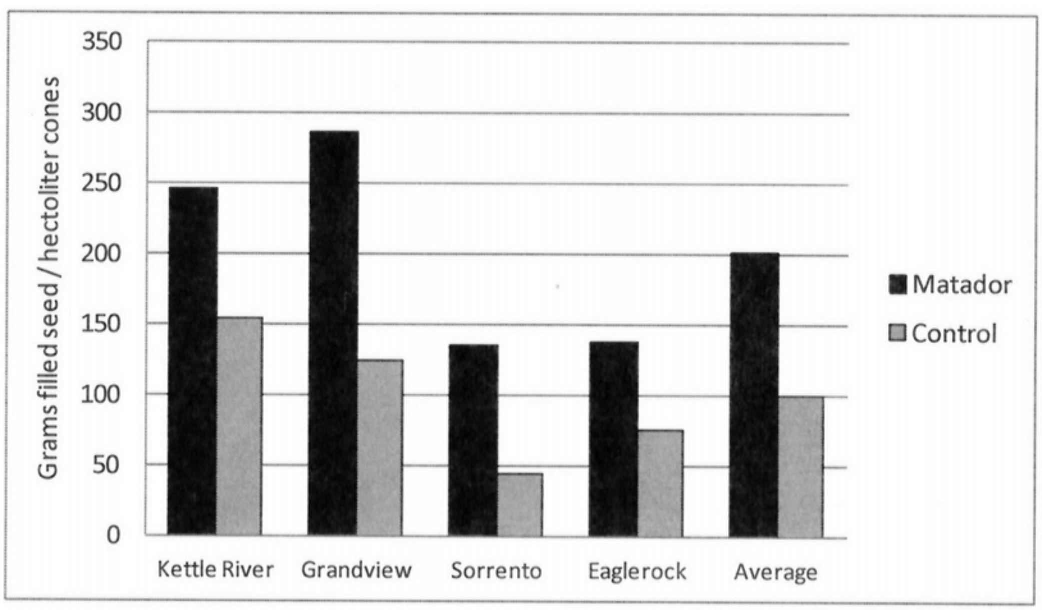

Figure 1. Operational yield of seed by orchard for Matador ®treated and control blocks.

Insect-exclusion bags

Bagged cones in the non-sprayed blocks averaged 47% more TSPC (P=0.0186) and 175% more FSPC (P=0.006) than non-bagged cones. For non-bagged cones, Matador® spraying increased both TSPC and FSPC by an average of 41% (P=0.059) and 147% (P=0.0179) respectively, relative to non-sprayed cones without exclusion bags (Fig. 2), suggesting that the spray treatment was nearly as effective as the bag treatment at increasing the number of both filled and formed seeds.

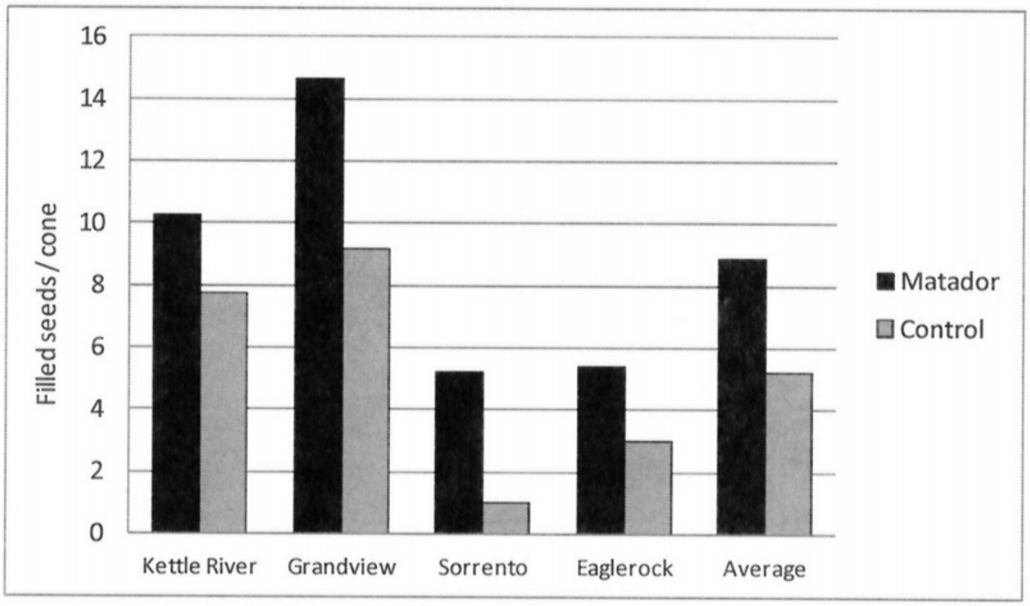

Figure 2. Average FSPC for Matador® treated blocks and control blocks across four orchards.

Percent Filled Seed

The development of a formed seed is dependent upon successful fertilization in late June to early July of the same year that cones would normally be harvested (Owens 2006). Therefore, TSPC is a measure of successfully fertilized ovules and any reductions in TSPC are an indicator of the loss of ovules or an interruption of fertilization before about mid July. Reductions in TSPC in the control treatments relative to both the spray or bagging treatments is likely the result of early-season ovule predation by Leptoglossus that have overwintered.

Percent filled seed (%FS) is a useful indicator of the proportion of fertilized ovules (TSPC) that become filled seeds (FSPC) at the time of harvest. Spraying of non-bagged cones increased the average %FS by 61% across all orchards relative to the control, with a range from 21% to 153% (P= 0.0126). Insect-exclusion bags increased the %FS by an average of 75% relative to the non-sprayed control, with a range from 25% to 169% (P=0.0243), suggesting that the spray treatments applied in these trials were somewhat less effective than insect exclusion bags at increasing filled seed production.

Gains in FSPC with Matador® treatment result from both a gain in TSPC and a gain in the percentage of seeds that develop and remain filled following fertilization. Assuming that every fertilized and formed seed has equal potential to become a filled seed following fertilization, then the %FS times the increase in TSPC due to treatment is a measure of the early-season gain of potentially filled seeds. Late season gain in filled seeds is the gain not accounted for by early-season gain. When expressed as a percentage relative to FSPC for the control treatment, these gains in FSPC are assumed to measure the gain from controlling early and late seed predation. Averaged across the four orchards, the Matador® spray treatment resulted in an early season FSPC gain of 40% and a late season gain of 29% relative to the control (Fig. 3).

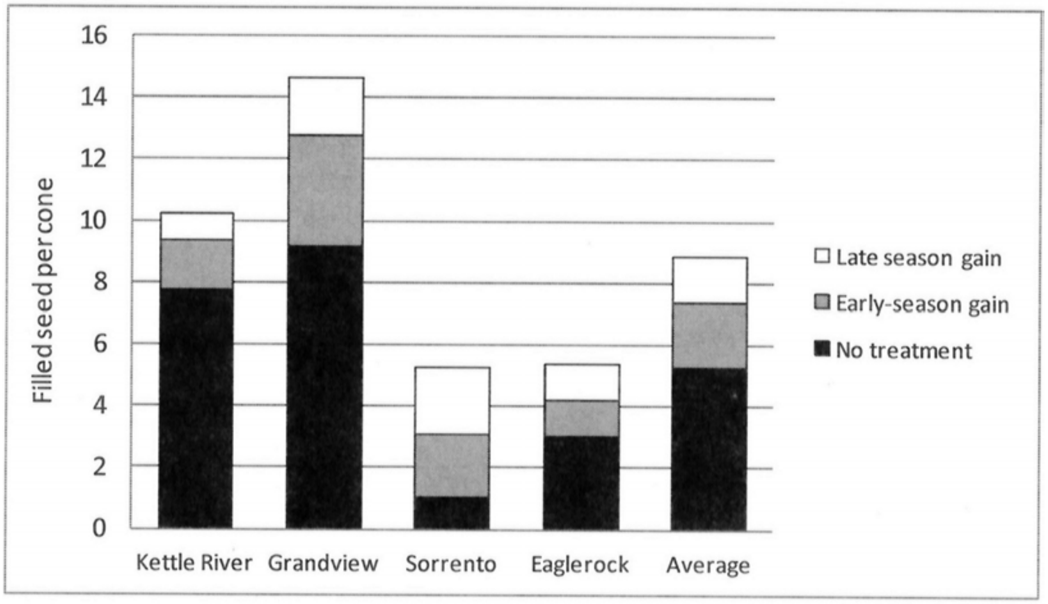

Figure 3. Estimated early season (before mid July) and late-season (after mid July) gains in FSPC with no treatment, by orchard.

Early random cone collections

Mid-July cone collections were made to compare TSPC and FSPC prior to the mid-summer Leptoglossus feeding period with seed obtained in early August through other components of the trials. TSPC and FSPC in the sprayed blocks showed little decline from mid July to mid August. Control blocks, however, showed both a decline in TSPC and FSPC in July, and a further decline in both TSPC and FSPC by early August. The mid-July decline in FSPC in control blocks relative to spray blocks is largely explained by TSPC decline, suggesting that late summer Leptoglossus feeding had not yet substantially reduced filled seeds by mid July.

Conclusion

Data from the trials reported here support the hypothesis that seed predation by Leptoglossus is a primary cause of poor seed set in lodgepole pine orchards in the southern interior. The use of Madador® to control Leptoglossus was successful and increased filled-seed production close to levels obtained with insect exclusion bags. As this trial was only conducted in a single year, results should be used with some caution. Components of this trial are being repeated in 2015.

Acknowledgements

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CONE AND SEED PROCESSING SURVEY

I'd like to thank the eight facilities who sent in responses to the questionnaire I had sent regarding cone and seed processing in Canada. The intent was to provide a general overview of the situation in Canada and get a better idea of the range of kilning options people are using operationally as this is an area we in BC are looking to modernize.

The responses indicate that in an average year, Canadian facilities are receiving approximately 25,000 hL of reproductive materials for processing. The vast majority of these are conifer cones, but some jurisdictions also have needs for deciduous species, with some of these species having quite large fruits. Annual processing volumes ranged from about 540 to about 7,200 hL and several facilities emphasized the wide range of volumes they may experience from one year to the next. For storage, most facilities are using burlap sacks, with jute or woven plastic sacks also being utilized by some. The grey IPL plastic trays were identified by a few facilities as part of cone storage or as a part of their processing for specific species. Monitoring activities during storage varied by facility from none (cones received ready for processing) to visual monitoring and problem identification to a more formalized monitoring of cone and seed condition and moisture content, and in one case monitoring the water activity of cones.

Several species stood out as needing specialized care and the most common indicated 'inconvenience' was with white pine (*Pinus strobus*) and its associated pitch loads. Most facilities generally delay processing of this species until the resin crystallizes usually in association with sub-freezing temperatures in the cone storage environments. Black spruce (*Picea mariana*) is another species that can be problematic due to its "semi-serotinous" nature, general need for extended or multiple kilns, and the associated dust and less than pleasant aroma. Several of the questions asked how serotinous cones are dealt with and this leads into the variability of kilns found at Canadian facilities.

Out of the eight facilities, six predominantly use rotary kilns (two of these facilities also have smaller batch-style kilns) and the remaining two use only a batch style kiln. Most of the facilities simply use the kiln heat to break cone serotiny. Two facilities currently use a hot water dip and a third used to use an infrared heater, but it's use has been abandoned. One facility scorches its serotinous cones for a short duration prior to kilning. This area is of particular interest to me as we ask how long do we need to maintain the resin-bond-breaking temperatures in terms of cone opening and energy efficiency and/or do we need to integrate a dedicated resin bond breaking activity prior to kilning?

Kiln capacities ranged from 15 to 80 hL of cones that can be treated at one time and durations ranged from a facility average of seven hours up to twenty-four hours with most facilities kilning overnight. The kilns were run on a variety of energy sources including natural gas fired boilers, direct natural gas fired, an oil burning forced air furnace or steam boiler, diesel fuel, and at one site they used ground-up empty cones as a fuel source, but could also use oil or wood chips. An additional facility had previously also used empty cones in their boiler, but were no longer using this technology. In terms of environmental controls, all facilities were dealing with the removal of humid air through passive or motorized venting systems. Not all facilities had the ability to increase humidity, but some were utilizing spray valves to produce atomized air and some were simply wetting the cones. Poor cone opening was considered by most to be rare and was usually dealt with by extending the kiln duration.

For final cleaning, most facilities were using an aspirator or pneumatic separator (with seed sizing being performed previously at some facilities) and a couple of facilities were using gravity tables. Most of our seed processing technologies are derived from agricultural equipment, but the gravity table is unique as it originates in the mining industry and is used to sort various ores and debris based on their specific gravity.

There are really only a few references available on cone and seed processing as a great deal of optimization is species and processing environment specific. I'm including a few references that I think are valuable reference sources on the topic.

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NEW DIRECTION FOR FOREST GENETICS IN ONTARIO

The delivery model for forest genetics has changed in Ontario. A decision was made by the Forest Genetics Ontario (FGO) Board of Directors to dissolve the corporation effective March 31, 2015. The three independent member associations will continue to deliver their regional forest genetics programs. These organizations are the Forest Gene Conservation Association (FGCA) operating in the southern part of the province; Northeast Seed Management Association (NeSMA) in the northeast and Superior-Woods Tree Improvement Association (SWTIA) in the northwest. The Ministry of Natural Resources and Forestry has approved financial support for forest genetics activities which benefit Crown forests for the 2015-16 and 2016-17 fiscal years.

The Ontario Tree Improvement Board was incorporated in 1993 and officially changed its name to FGO in 2001. The organization was initially formed as an industry/government cooperative for the purpose of ensuring the sound management of the genetic resources of woody plants. Collectively and individually the corporation and its member associations have accomplished a great deal including: 1) the establishment of about 300 forest genetics sites with more than 70 being seed orchards, 2) orchard seed for the planting of more than 142 million black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), and white spruce (*Picea glauca*) trees between 2009 and 2013, 3) the conservation and recovery of butternut (*Juglans cinerea*), and 4) increasing the awareness about the collection and deployment of adapted seed and stock.

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ROTRONIC OPENS ITS NEW CANADIAN SUBSIDIARY: ROTRONIC CANADA INC.

In support of its commitment to the Canadian market, ROTRONIC Canada Inc. was formed on January 1, 2015 and will take over servicing the Canadian market from Rotronic USA as of July 1, 2015. The new office is located in Hamilton, Ontario and is led by Country Manager, Phil Alfieri.

About ROTRONIC Measurement Solutions

Created from a need for a precision instrument to measure relative humidity, ROTRONIC was established in Zurich, Switzerland in 1965. In its 50 year history, ROTRONIC has grown to provide its measurement solutions in more than 60 countries worldwide and has subsidiaries in eight global markets.

ROTRONIC offers a comprehensive line of reliable humidity probes; humidity indicators and meters; humidity data loggers; and fixed install humidity transmitters to precisely measure relative humidity, dew point, temperature, CO_2, differential pressure, water activity, and other psychrometric parameters. ROTRONIC's water activity instruments give accurate results within a few minutes and are characterized by their high efficiency, exchangeability, and ease of calibration.

ROTRONIC Measurement Solutions for the Tree Seed Industry

Storage Conditions

One of the most important factors in seed lifespan is the storage environment. Controlling the temperature and humidity of seed storage is essential for maintaining the germination capacity of seeds. As a rule of thumb, for every 1% decrease in the moisture content, seed storage life will double. The same applies for every 5°C decrease of the storage temperature. Another rule of thumb is; the sum of the temperature (°F) and the relative humidity (%) should be less than 100 for optimum seed storage conditions.
Proper storage conditions maintain relative humidity levels between 20% and 40% providing corresponding seed moisture content between 5% – 8%, depending on the species of seed. This range is safe for most seeds. When seed moisture content drops too low (< 5%), storage life and seed vigor may decline. When seed moisture content rises above 8%, aging or seed deterioration can increase. Deterioration involves cell membrane integrity, along with other biochemical processes, all resulting in loss of vigor and viability. Seed moisture contents above 12% will promote growth of fungi and insects.

Water Activity

The free water in a product influences its microbiological, chemical, and enzymatic stability. This is of great importance especially for perishable products such as seeds. The Water activity (a_w) value (range: 0.00...1.00 a_w) is an important indicator for the shelf life of seeds, and it strongly influences the occurrence and growth of microorganisms. Table 1 shows typical growth thresholds below which the specified organism cannot reproduce and therefore spoil the product. Therefore water activity has a significant impact on the shelf life of a product.

Table 1. Water activity (a_w) levels below which the corresponding organism cannot reproduce

Water activity	Contaminant
0.91 – 0.95	Many bacteria
0.88	Many yeasts
0.80	Many mildews
0.75	Halophile bacteria
0.70	Osmiophile yeasts
0.65	Xerophile mildew

ROTRONIC's water activity measurement devices include the HygroLab C1, a high-end laboratory device for water activity measurements with up to four probes, the HygroPalm HP23 for on-site water activity measurements, and Aw Insertion probes for direct measurement of water activity in bulk samples (Fig. 1). ROTRONIC products are freely combinable and can be adapted to fit any application.

Figure 1. ROTRONIC instrumentation for measuring water activity.

Regular a_w measurement takes about an hour to determine the exact a_w value. The ROTRONIC a_w Quick function allows Aw measurement results in 5 minutes or less and is nearly as precise as the regular measurement method. It requires an environment with stable temperature variations which is mostly given in laboratory and indoor applications. ROTRONIC's bench-top unit HygroLab C1, handheld HygroPalm HP23, and HW4-P-QUICK-Vx software all include the Aw Quick capability.

To learn more, visit ROTRONIC Canada Inc. online at http://www.rotronic.ca . Country Manager, Phil Alfieri can be reached by phone at 905-754-5164 or email: phil.alfieri@rotronic.ca.

Julie Wardell
ROTRONIC Canada Inc.

UPCOMING MEETINGS

Canadian Forest Genetics Association
August 17–20, 2015 Fredericton, NB
http://forestgenetics2015.ca

Whitebark Pine Workshop
July 29–31, 2015 Dunster, BC
www.whitebarkpine.ca/mcbride-2015.html

Seed Ecology V - Seeds in the Web of Life
August 21–25, 2016 Brazil
http://seedecology.wix.com/seedecologyv

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