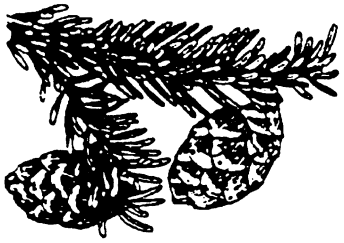
CANADIAN FOREST GENETICS ASSOCIATION
ASSOCIATION CANADIENNE DE GÉNÉTIQUE FORESTIÈRE

Tree Seed Working Group



NEWS BULLETIN

No. 56 January 2013

THIS ISSUE AT A GLANCE

CHAIR'S 'ARMCHAIR' REPORT

Hello, welcome to 2013 – I hope everyone had a wonderful holiday season. It's the first time in about seven years we've been here for the holidays, generally finding ourselves somewhere tropical. Back to Plan A next year ☺.

Planning is continuing for the Forest Genetics 2013 meeting to be held in Whistler, BC from July 22 to 25. The webpage is being continuously updated (http://www.forestgenetics2013.ca/), so check in to see the latest news of this joint meeting. We encourage early registration and staying at our conference venue, the Whistler Hilton Resort and Spa. The organizing committee has arranged for an excellent price of $147 per room that is available until June 22nd. Additional details can be found on the webpage. An optional post-conference field trip is also being organized to view a variety of forest genetic installations on Vancouver Island.

The plan is to have a Tree Seed Working Group workshop and tour on July 22nd at the provincial Tree Seed Centre in South Surrey. We would have a technical session in the morning, lunch, and a tour of our facility in the afternoon. Transportation to Whistler would then be made available. Considerations regarding travel to the Tree Seed Centre in South Surrey will be based on feedback and need, so if you aren't planning on having a vehicle in BC let me know. The tentative theme for the workshop is "Reproductive Biology" and although this will tie in with some of our lodgepole pine seed production issues it is open to all topics dealing with an extension of knowledge on the topic. If you aren't sure if your topic fits, just call or e-mail Dale or myself.

This is somewhat different from past workshops as it will not be at the main conference site. This entails additional logistics including separate catering and transportation. These considerations result in us having to charge a registration fee and to have an early indication on numbers attending. If you are interested in presenting at or attending the workshop I would appreciate knowing before the end of February. **Please**, provide feedback on this strategy – we know that many of you may not have travel approval, but we also can't organize a venue, meal, and transportation for a few people and expect them to foot the entire bill.

What have I been up to? I feel like I'm mining for gold as I go through our standard five-year estimate of our species' germination deterioration rates and review retest frequencies. Our information systems have progressed to allow for a much deeper review and filtering of past data based on the question being posed. It certainly was less work than manually calculating all those deterioration rates as I have done in the past, but still quite a bit of data checking to ensure the proper dataset is constructed. The enclosed article on 'Quantifiable Germination Influences' is the initial product of this mining, but there are many other questions that I'm interested in pursuing with these data. Feedback always greatly appreciated – it also reassures me that someone reads this.

The Tree Seed Centre had a co-op student, Chase Benning, on site last term. He wasn't our first co-op student, but the first Engineering one. The project focus was on kiln monitoring and a set of improvement recommendations to our existing 26-year-old batch-style kiln. It is a big project for us and I would greatly appreciate talking to others regarding kiln upgrades they have undergone or strategies regarding serotinous cone bond breakage. In particular, what are the reasons you had for integrating or separating the resin bond breaking and cone drying steps? I'll keep you updated on how our kiln review project progresses. Wishing you the best for 2013. Hopefully I'll get to see many of you this summer.

Dave Kolotelo
TSWG Chairperson

EDITOR'S NOTES

You may have noticed that this issue is a little late. Well Dave and I are to blame due to the need for more time to complete our respective articles. We hope that the delay was worth it.

Dave mentioned that he is planning a seed workshop prior to the Canadian Forest Genetics Association meeting. Having a workshop is a tradition which takes time to plan and organize. Please help Dave by indicating to him your intention to hopefully attend.

Dave's article on germination influences will hopefully generate some discussion and feedback for him. Michele and Fabienne have provided an update on their ISO certification program. Dale and Bernie show the storage potential of spruce and pine seed. I hope that you enjoy all the articles.

Dale Simpson
Editor

TREE SEED WORKING GROUP

Chairperson
Dave Kolotelo
BC Ministry of Forests, Lands and Natural Resource Operations
Tree Seed Centre
18793 - 32nd Avenue
Surrey, BC V3S 0L5
Tel.: (604) 541-1683 x 2228
Fax.: (604) 541-1685
E-mail: Dave.Kolotelo@gov.bc.ca

Editor
Dale Simpson
Natural Resources Canada
Canadian Forest Service
National Tree Seed Centre
PO Box 4000
Fredericton, NB E3B 5P7
Tel.: (506) 452-3530
Fax.: (506) 452-3525
E-mail: Dale.Simpson@nrcan.gc.ca

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

All issues of the News Bulletin are available at:
www.for.gov.bc.ca/hti/treeseedcentre/tsc/tswg.htm

QUANTIFIABLE GERMINATION INFLUENCES

I have been thinking about our BC tree species, seedlot deterioration rates, retest frequencies, and our seed bank in relation to germination. I thought of 14 factors that I believe can be quantified and could influence seedlot germination or be useful in seed related decisions. These are illustrated in Fig. 1. Factors in green are already being quantified in BC while those in yellow currently are not. Quantified influences are still subject to having their methodology or specific measured attribute changed to improve the information provided. The intent is to raise awareness of these quantifiable influences, open the discussion on how they may be useful and further develop the concept and its presentation. It is a preliminary part of a report I am writing to review our seed testing program and I view this as a good opportunity for feedback. There certainly may be additional influences and I encourage your feedback on the influences and their utility. I wasn't totally convinced 'influences" was the correct word for the title – factors, ingredients, elements, components – none fit as well as I would have liked. Some influences are similar, some share components and some readers may question the influence appearing at all (or the relation of the text to the subtitle), but I wanted to say a little about each one presented. This article is a bit of a story containing plenty of opinions, hints, allegations, and regurgitations – Enjoy.

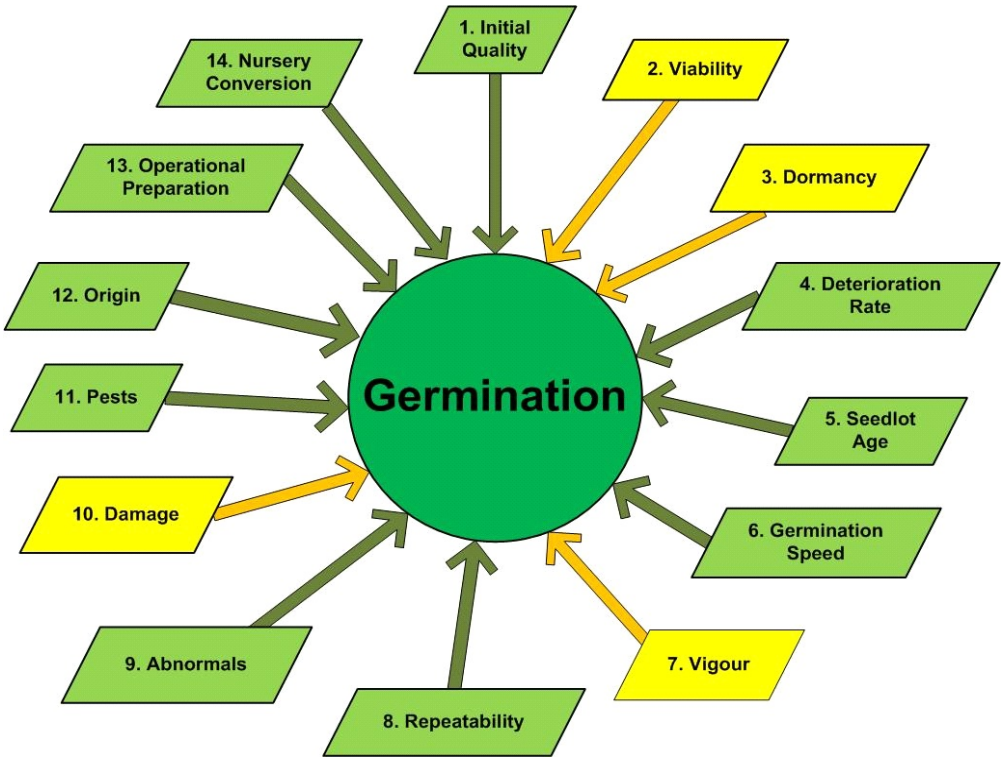


Figure 1. Quantifiable germination influences.

To provide context for the discussion I have provided some background information on usage of our top 16 tree species (Table 1). These data are based on our last five sowing seasons (2008–2012) which is the timespan we often use for summarizing and planning in BC. The cumulative species sowing is intended to provide a cumulative level of sowing by species (i.e., top 5 species account for 94% of sowing). Orchard seed use (%) by species for 2012 is also illustrated to give a sense of current orchard seed sowing levels.

Table 1. Mean five-year (2008–2012) seed use patterns for the 16 top BC reforestation species.

Species	BC code	Seedlings sown (M)	Cumulative species sowing (%)	Orchard seed used (%)	2012 orchard seed use (%)
Pinus contorta var. *latifolia*	**PLI**	105.18	49.4	25.0	27.5
Picea glauca, engelmannii and hybrids	**SX**	63.52	79.3	89.3	95.2
Pseudotsuga menziesii var. *glauca*	**FDI**	12.19	85.0	25.6	31.1
Pseudotsuga menziesii var. *menziesii*	**FDC**	10.20	89.8	94.2	97.4
Thuja plicata	**CW**	8.81	94.0	64.1	66.6
Larix occidentalis	**LW**	5.24	96.4	80.4	86.1
Tsuga heterophylla	**HW**	1.60	97.2	70.5	71.5
Abies lasiocarpa	**BL**	1.05	97.7	0.0	0.0
Callitropsis nootkatensis	**YC**	1.02	98.1	0.0[1]	0.0
Abies amabilis	**BA**	0.83	98.5	0.5	0.0
Picea sitchensis	**SS**	0.79	98.9	64.2	74.5
Pinus ponderosa	**PY**	0.72	99.3	0.0	0.0
Pinus monticola	**PW**	0.67	99.6	99.5	100.0
Picea x *lutzii*	**SxS**	0.32	99.7	0.0	0.0
Alnus rubra	**DR**	0.27	99.8	0.0	0.0
Tsuga mertensiana	**HM**	0.10	99.9	0.0	0.0
TOTAL		212.75	100.0		

[1] Yellow cypress improved reforestation materials have been produced from rooted cuttings: 15.9% of propagules for the species over the five year span (2008–2012) and 28.0% in 2012.

To provide some context for the influences, a depiction of many of these is provided in Fig. 2 for reference throughout the document. I didn't get all 14 on the plot, but hopefully there are enough to enable several to be considered together in this new format. Species are ranked in order of decreasing germination capacity. I will also be producing a matrix of species by quantifiable influence, but I am still working on the format and level of detail to include. The data that were used for Fig. 2 were obtained on December 14, 2012 from both Active and Expired seedlots. Seedlots created from returned seed were removed as their parent seedlots were already represented and one may think of these as second-hand seedlots and possibly not representative of the initial collection.

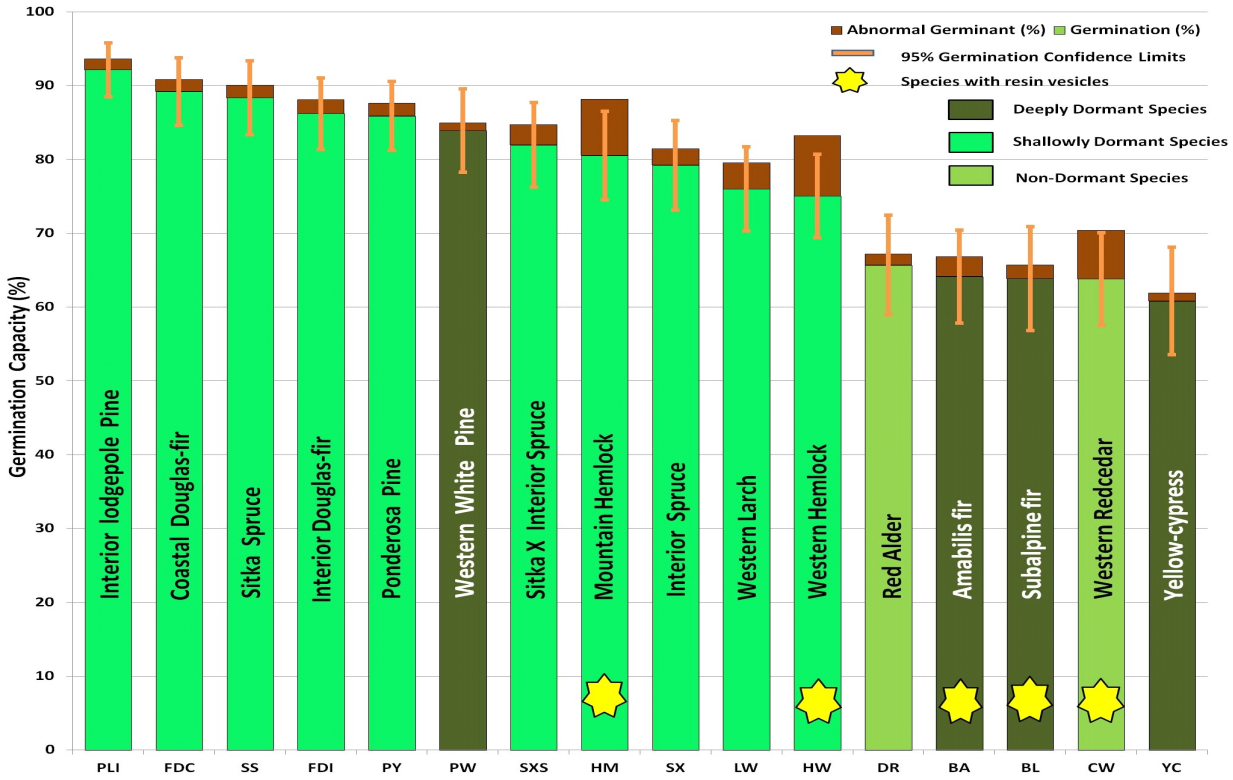


Figure 2. Germination characteristics of the top 16 species used for reforestation in BC. Green bars indicate germination capacity.

For estimation of the Deterioration Rate and all variables in Table 2, seedlots with less than 500 days long-term storage, with only one germination test, or seedlots which had been upgraded for viability were removed in addition to the returned seed seedlots (also based on a December 14, 2012 query). I deliberately chose to initially take the broad view by including all seedlots, but sensitivity of the parameters will also be estimated using Active seedlots only, seedlots used in the last 10 years, and other criteria to evaluate the robustness of these estimates to dataset assumptions. No outliers were removed, but this will also be evaluated further. For brevity, our BC species codes are used throughout the text with scientific names provided in Table 1 and common names provided on the bars in Fig. 2.

Initial Quality

Initial quality is the first influence as it represents the highest quality that one will achieve under a specific test regime. It is a variable that is indicative of the reproductive success in terms of complete seed development, proper collection timing, and proper handling of cones during harvest and post-harvest conditioning (in the field or orchard and at the processing facility). Initial quality could also be influenced by site-specific challenges like the Mountain pine beetle infestation. There is an obvious close association between initial quality and viability, but the focus here is on the influences that affect the quality of fertilized seed. Aspects of the influence of 'Viability' related to pollination and fertilization success and subsequent cone and seed processing decisions involved to produce a seedlot are discussed in the next section.

The timing of cone collection and therefore seed maturity is an attribute considered to have a significant impact on initial and subsequent quality. Current maturity criteria include observations such as cone lignification, ease of release of seed wing from the ovuliferous scale, firmness of megagametophyte tissue, degree of embryo elongation, and the variability found in these tissues. There is often a general focus on embryo length as it is generally easier to quantify, but all of these criteria are worthwhile considering. There is a certain latitude to degree

of maturation that will result in good germination, but factors such as longevity in storage, vigour (ability to germinate under sub-optimal conditions), and germination speed may be impacted by non-optimal collection timing which can impact seed use efficiency.

Collection timing is also something that needs to be weighed against potential crop losses later in development and this is something seed orchard managers consider in collection timing. Seed orchards also usually represent greater variability in maturation than wild stands and clones (or related seedlings), which display similar maturation characteristics, are often collected individually or in groups. An additional factor to consider with seed orchard seed is the relatively rapid turnover rate of seed onto the landscape compared to our historical large wild stand collections. Avoidance of a pest's impact may increase the amount of seed sent to the extractory, but if losses are due to intrinsic factors, the drop-off in filled seed per cone may occur whether cones are attached to the tree or not. Collection timing is a topical consideration in BC as we try and improve the efficiency of our lodgepole pine seed orchards.

The title of this article is "quantifiable influences" and I haven't really talked about any yet! This preamble is meant to emphasize the importance of factors, prior to cone processing, that may impact initial quality for the seedlot's entire life. Factors in post-collection handling that can be quantified are the moisture level of the cones and the temperatures they are exposed to. The combination of high values in both factors (especially without adequate air movement or sack rotation) can result in or accelerate seed deterioration, promote fungal proliferation, or make seed extraction difficult or impossible due to case-hardening. Temperature is a relatively simple measurement either in terms of point measurements or with the various portable temperature and humidity sensor recording devices available (i.e., i-buttons) that can track these factors over time. The biggest disappointment in interim storage is the statement that "once cones are in the sacks we don't look at them again" and it is highly recommended that cone collectors monitor cone condition during interim storage, even if it is only to observe drying progression and the lack of problems.

The initial germination test results are a guide to quality and initial results can vary greatly by species with PLI averaging 95% and CW averaging only 83% (Table 2). Although CW provides one of the lowest average germinations it is the one seed orchard species which does not show an increase in germination with seed orchard production. Other later described quantifiable influences like fungal assay results, germination speed, abnormal germinant %, resin vesicle damage, and others can all help to quantify initial quality.

Viability

Viability is a term used to describe the proportion of living or potentially germinable seed and therefore is the maximum potential germination. It is differentiated from germination by dormancy, so there is a close relationship between these factors (Viability% = Germination% + Dormancy%). Viability is also a function of pollination and fertilization success as well as the decisions made during the extraction, purification, and empty-seed removal processes. Some people may think that the removal of non-viable seed (final cleaning usually as a form of density separation) is a simple filled vs. empty seed separation process, but there are often many seeds falling below optimum quality and decisions are required as to whether they are retained or discarded from the seedlot. For most species, the objective is 100% viable seed, but other factors such as species and potential for mechanical or resin vesicle damage must also be considered. Decisions are made to terminate final cleaning without achieving 100% viable seed if there is a suspicion of processing damage (or the potential), developmental problems, or questionable quality seed that can't be removed with available methods. In some species, non-viable but substance-filled seeds (commonly referred to as 'woody', 'resin-filled', or 'tar-filled') are not easily separated from viable seeds due to similarities in specific gravity (i.e., *Abies* spp.) making 100% viable seed generally an impractical objective without moving to a more refined physiologically based process (i.e., IDS – Incubate-Dry-Separate).

Table 2. The estimated average deterioration rate, original germination capacity (GC), and seeds per gram of BC tree species. Species with seed orchard programs are presented as Combined (Wild + Seed Orchard) and separately.

Species	Genetic class	Sample size (# seedlots)	Deterioration rate (GC% per year)	Average original GC (%)	Seeds per gram
BA	Wild	192	0.172	65.1	28
BL	Wild	146	0.248	65.3	88
CW	Seed Orchard	87	-0.084	82.2	777
CW	Wild	333	-1.564	82.8	836
CW	Combined	420	-1.258	82.6	823
DR	Wild	27	0.377	65.4	1795
FDC	Seed Orchard	186	-0.085	92.6	86
FDC	Wild	147	-0.159	88.1	100
FDC	Combined	333	-0.118	90.6	92
FDI	Seed Orchard	8	0.321	95.0	89
FDI	Wild	650	-0.215	89.9	103
FDI	Combined	658	-0.209	89.9	103
HW	Seed Orchard	109	-0.299	91.5	436
HW	Wild	271	-0.966	86.5	496
HW	Combined	380	-0.774	87.9	479
LW	Seed Orchard	21	-0.153	90.2	238
LW	Wild	173	-0.427	79.7	279
LW	Combined	194	-0.397	80.9	275
PLI	Seed Orchard	105	0.043	94.9	255
PLI	Wild	1879	-0.049	93.2	339
PLI	Combined	1984	-0.044	93.3	335
PW	Seed Orchard	70	0.276	89.5	47
PW	Wild	77	-0.119	78.8	60
PW	Combined	147	0.069	83.9	54
PY	Wild	219	-0.130	89.0	19
SS	Seed Orchard	26	-0.080	95.7	395
SS	Wild	170	-0.052	87.7	445
SS	Combined	196	-0.056	88.7	439
SX	Seed Orchard	167	-0.281	90.4	401
SX	Wild	1064	-0.260	82.3	493
SX	Combined	1231	-0.263	83.4	480
SxS	Wild	47	-0.201	83.9	470
YC	Wild	28	-0.118	42.4	207

Viability is not something currently quantified, although options exist through the use of cutting tests, x-rays, or Tetrazolium chloride tests. None of these are perfect and all involve a large degree of subjectivity. If a standard viability determination is important the sample sizes of these assessments would need to be increased compared to current practices. Tetrazolium has shown to provide variable results and best used for determination of whether a certain practice (or accident!) has "killed" seed in general vs. trying to predict a specific Viability %. I am aware of other chemical viability tests, but do not have experience with them, although I would definitely like to hear from those using them operationally. I consider Viability quantification to be a relatively low priority as a standard activity.

Dormancy

Dormancy can be defined as the inability of a viable, imbibed seed to germinate under optimal conditions. For most of our species, dormancy, associated with the embryo, is alleviated by a period of moist chilling after which germination is prompt and maximal. Several species have unique needs like YC and its requirement for a warm and cold stratification period at high moisture levels, the long soak and stratification period for PW, and the split stratification moisture regime used for BA and BL. Variation exists within species, but generally these species (BA, BL, PW, and YC) are considered the most deeply dormant commercial species used for reforestation in BC.

Two species are considered non-dormant (CW and DR) and in BC these dry seeds are typically pellet-coated for nursery sowing due to their lightweight, static-rich, and irregular shaped seed. It isn't equivalent to dormancy, but the pelleting process acts like a delay mechanism as water must penetrate the pellet before seed imbibition can occur and the radicle must also exit the pellet prior to entering into the growing media. Dormancy is considered by some to be an impediment to germination, but I view it as a mechanism intended to maintain seed viability over an extended period of time and therefore beneficial. Dormancy is not a variable we currently quantify, but can be based on the difference between a stratified and un-stratified germination test. Dormancy quantification is easy, but basically doubles the number of germination tests performed on a seedlot. Current stratification regimes are intended to release even the most dormant seedlots within a species, so dormancy quantification, although biologically interesting, is not considered a quantification priority. In cases where germination is poor and no other influence appears responsible for this then dormancy quantification may be worthwhile and alternative pretreatments investigated depending on seedlot value.

Deterioration Rate

The deterioration rate is simply the change in germination capacity divided by the time elapsed between initial and current germination tests. It is critical that both test results represent the same germination test type and that seedlots have not been upgraded to improve viability between the tests. It is a simple linear estimate of a more complex phenomenon. Its utility benefits from the relatively large sample size of seedlots of different ages and quality. It is dependent on storage conditions and in our case represents seedlots below 10% moisture content stored at -18°C. The average species deterioration rate has been a key factor in establishing appropriate germination retesting frequencies. It can also provide a sense of how individual seedlots are deteriorating compared to the species average. The intent was to move to individual seedlot retesting frequencies based on deterioration rates, but a large proportion of seedlots requiring retests have only one germination test result. With larger proportions of seed orchard seed being used, the question of how often we retest germination of wild stand seedlots is a consideration that we will consult clients on. I have a few ideas, such as above a certain proportion of orchard seed use (i.e., 80%) wild stand seedlots will only be tested every second or third scheduled retest date unless advised by the client. There are certainly many other possibilities and obtaining client feedback will be a critical aspect to making our retesting program even more efficient.

The estimated deterioration rates are presented in Table 2 with CW again being our fastest deteriorating species. For the first time I have looked at the deterioration rate separately for wild and seed orchard seed, as well as the traditional Combined analysis that was done with previous Deterioration Rate estimates. This analysis is also different in that both Active (i.e., still having seed) and Expired seedlots have been included together while other analyses only used active seedlots. In Table 2, Deterioration Rate differences can be found between seed orchard and wild stand seed in all species except SX and SS. Age is a confounding factor as wild stand seedlots are, on average, significantly older than seed orchard seedlots – see Seedlot Age influence for further discussion.

You will notice that there are some positive Deterioration Rates in Table 2 and this represents seedlots that have had an increase in the estimated germination from the initial to current test. I think this is simply caused by the variability around each estimate as illustrated by the 95% confidence limits in Fig. 2. By chance an initial test may be at the bottom of the confidence interval and the current test at the top creating the illusion of germination gain. For BA and BL, in particular, there is a different explanation. For these species we switched on April 9, 2008 from a 48-hour standing water soak to a running water soak for testing. For most seedlots, this resulted in a germination increase probably due to a reduction in surface-borne pathogens. Maximizing operational germination is the priority even if these adjustments result in less helpful Deterioration Rate estimates. Insufficient data are available since 2008 to estimate a more representative Deterioration Rate for these species.

Seedlot Age

Seedlot age is connected with the deterioration rate and their product is the total reduction in germination. There is no magic number after which seedlots become useless and even 50-year-old seedlots are still being used for reforestation in BC. At the other end of the spectrum some have suggested CW germination drops after ten years storage, but seedlots over 20 years old can still have over a 90% germination capacity. It is true that once CW seedlot deterioration begins it progresses rapidly and this is probably related to the relatively small size of the megagametophyte. As current test types may not be original test types I've quantified Age as the difference between December 14, 2012 and the Collection end date (for Active seedlots) as that seemed more reliable with older seedlots than registration date. Age is an influence worthy of consideration in assessing seedlot value and prioritizing seedlots for sowing. In general, in BC, the seed orchard seedlots are on average younger and have lower deterioration rates. Does seed orchard seed deteriorate slower or are they just earlier along the same deterioration pathway as wild seedlots? I will be looking at various ways to try and separate these two confounding factors.

Germination Speed

Germination speed is currently quantified as the Peak Value or the point at which the germination curve exhibits the steepest slope. We currently present this as "Peak Germination / Peak Days" to identify both aspects of the rate at its peak, but it may also be presented as an integer. Germination speed shows a large amount of variability between species with PLI clearly the fastest germinating species (Fig. 3). The average initial Peak Value was used to avoid differences in average species seedlot age biasing the values. Germination speed seems to be associated with the species' general moisture regime: arid species germinating fastest and species from moist environments showing much slower germination rates.

The Peak Value factor is independent of the germination capacity or viability and therefore I consider it a valuable biological variable for quantifying inherent seed quality. I also think it has operational utility in helping to determine the order of sowing. To ensure an even crop when moving from the germination test regime to a growing one, it makes sense to sow the slowest seedlots first and the fastest germinating seedlots last. Sounds good, but other factors may be more important like keeping a stock type together or having all of the seedlots for one client together. I am not convinced this variable has been utilized to its potential, but I am optimistic, if considered, it can provide practical economic benefits. Perhaps the "Peak Germination / Peak Days" format is awkward to use operationally compared to a simple integer to allow the ranking of seedlots?

Vigour

Vigour is one aspect that is widely debated as to its meaning and how one might quantify it. I think of it as the ability to germinate under suboptimal conditions after dormancy is broken. Others may associate vigour with vigour classes used by some in categorizing germinants in germination tests, but that is not my intent. A vigorous seedlot will germinate optimally over a wider range of temperatures (or moisture regimes, nutrition levels, etc.) than a non-vigorous seedlot which will be more exacting in its requirements. I suspect (hope) that germination speed can be used as a proxy for vigour and it has been referred to in this way by some. I also believe vigour is intimately tied to initial quality; a seedlot with low initial quality will probably also have low vigour. It is a variable I see as being important when there is a potential for sub-optimal conditions such as crops that are sown early in northern greenhouses or poor weather conditions at germination with open compound crops. Quantification can be as simple as the difference is germination between the optimal and a

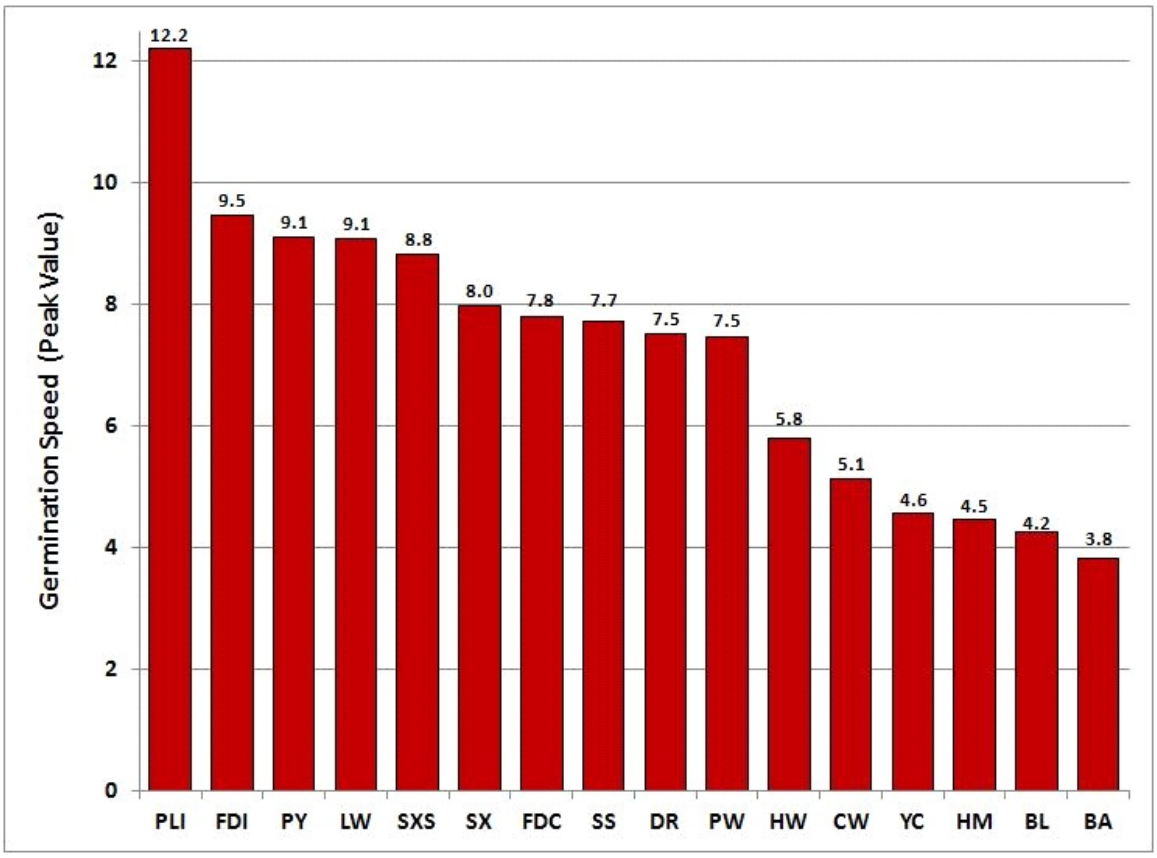


Figure 3. The average initial germination speed of BC tree species presented as the Peak Value.

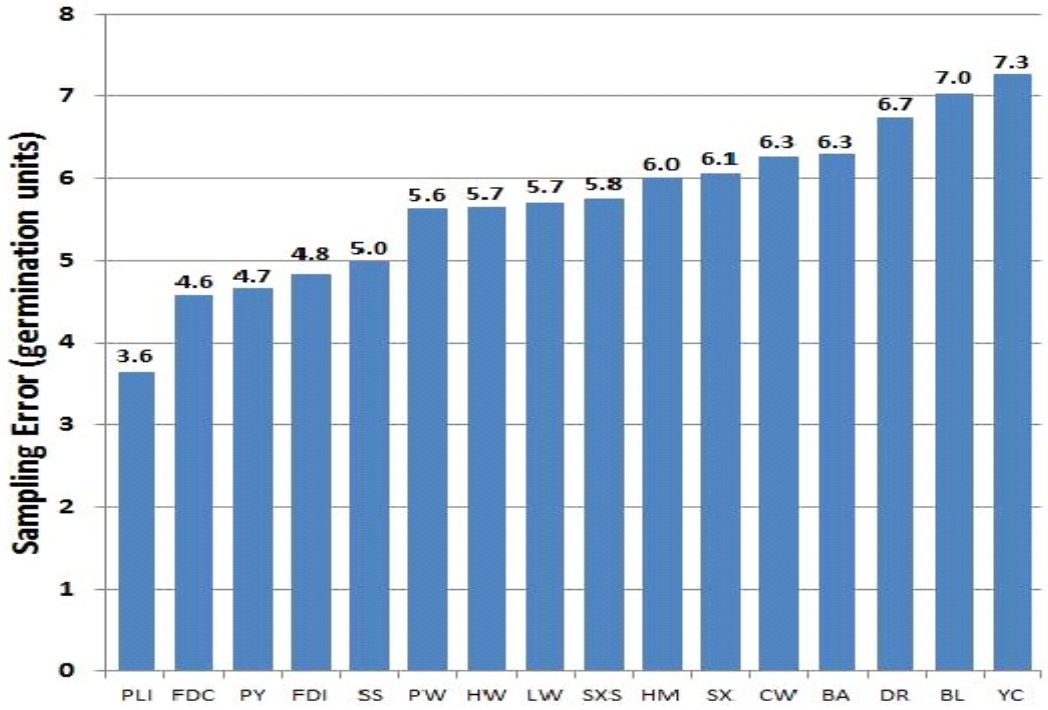


Figure 4. The sampling error or half-width of the 95% confidence interval for germination capacity (GC) estimates of BC tree species.

standardized poor germination regime, but like dormancy this results in the doubling of testing efforts for each seedlot.

Repeatability

The term repeatability is being used here to represent the average amount of variability within a germination test. It can be represented in a variety of ways: standard error, sampling error (appropriate t-value * standard error), or in terms of a confidence interval. The statistic provides information regarding variability and therefore degree of confidence around the reported germination capacity. This may be used to fine-tune seed sowing decisions. Growers can see this in crops and in BC nobody growing both species would put the same degree of confidence in the germination of a PLI and a BL seedlot. This repeatability influence is an opportunity to put it on an individual seedlot basis. Fig. 4 shows the average sampling error for BC tree species and should be interpreted as the range of GC values (plus or minus) that could be obtained. For example, if a PLI GC is 94% the 95% confidence interval would be from 90.4 to 97.6%. This variable has not been made available and part of the reason for that is the uncertainty around which format would be most useful to clients for seedlot decisions.

The replicate variability is also subject to the International Seed Testing Association (ISTA) tolerances for the maximum acceptable range between replicates. If the range between two replicates exceeds a tabulated threshold, provided by ISTA, the test is repeated to ensure that the seedlot has been properly sampled and tested. If a seedlot continues to result in out-of-tolerance test results then seedlot reblending is an option, but for resin vesicle species extra care must be employed to avoid damaging these structures during reblending

Abnormals

Abnormal germinants are not included in the estimate of the germination capacity (GC), but are tallied separately. They are generally a small proportion of total seeds and vary greatly by species with stunted radicles being by far the most common. The other abnormal categories in decreasing observation order are: Rotten, Reversed, Weak, Megagametophyte Collar, Pregermination, Other, Twisted, Stunted Hypocotyl, and Thickened Hypocotyl. Most of these categories represent viable seed that germinated abnormally, but the Rotten category is different and does not provide an indication of viability. The Abnormal Germinant % (without Rotten%) can provide a closer estimate of Viability by summing the GC and Abnormal %.

It is interesting to compare the relative Abnormal% with the 95% germination confidence intervals (Fig. 2). Although not a perfect comparison it is clear that abnormal germination is a larger source of variability than repeatability in HM, HW, and CW (all resin vesicle species). In the remaining species the variation within seedlots is a greater source of variability than the number of abnormal germinants. I have not looked at repeatability of Abnormal counts between replicates, but suspect they would show much wider 95% confidence limits compared to germination and perhaps that is the appropriate comparison.

Damage

This influence is intended to cover any mechanical damage that might occur during handling or processing of cones or seeds. This can result in crushing or cracking of the seed coat which can damage internal tissues or allow for easy entry of fungi. It is not very common in current seedlots, but can be seen in some of our older seedlots. Mechanical damage to the seedcoat can be quantified through x-ray analysis as it is far more obvious than with the naked eye. The rest of this section will specifically cover resin vesicle damage that potentially can affect several BC species.

Resin vesicles are pockets of resin contained in the seed coats of CW, HW, HM and *Abies* species in BC. They appear as small bumps on the surface of the seed. The actual purpose of these resin vesicles is uncertain, but there is ample evidence indicating damage to resin vesicles will result in reduced germination. The mechanism by which resin vesicle damage results in seed deterioration is not known and these structures, which are found in quite divergent genera, have not received very much attention. Damage can usually be avoided, but we are left with the legacy of past experiences and hopefully have learned something along the way.

Quantification of resin vesicle damage may be possible or useful as a means of explaining why those BL tests (for example) are so variable over time and/or of such poor quality. This isn't something we currently quantify, but could be useful to explain to owners why some seedlots perform so badly and/or display high variability over time. It may be a further rationale to dispose of poorly performing seedlots. Initial

work in this area focused on characterizing seed into four groups representing % of resin vesicles damaged (i.e., Category 1= 0-25% damaged). It is not an exact science and is subjective but can clearly identify seedlots with a high degree of resin vesicle damage. I'm very interested in others experience or ideas in quantifying resin vesicle damage.

Pests

My first thought about seed pests focuses on fungi and not insects. With the exception of *Dioryctria* spp. all other insect have completed feeding prior to cone collection. Insects such as *Megastigmus* spp. can be found in seedlots, but they consume all the contents of the seed and are usually removed during final cleaning. The same can be said for *Leptoglossus* damaged seed in which the seed contents are wholly or partially consumed. Although insects can certainly have a large impact on crop yield they are not considered to be a significant factor influencing germination.

Fungi can be a significant factor and three seed-borne fungi have been identified as problematic: *Caloscypha fulgens*, *Siroccocus conigenus*, and species of the *Fusarium* genera. *Sirococcus* arises from an infection within the seed and does not affect germination *per se*, but rather causes a shoot blight that can be initiated as early as cotyledon emergence and can eventually kill the seedling. Fortunately seed-borne levels are relatively low and restricted to a few species (SS, SXS, and SX), BUT cross contamination to other species such as PLI can occur in the nursery. *Caloscypha* is another infecting fungus which results in seed death and can infect adjacent seeds in multiple-sown cavities. *Abies* spp. and SS show the highest levels of *Caloscypha*. *Fusarium* probably is the most serious fungal threat as it can attack before germination, after emergence, or as a serious threat as a root pathogen in the later stages of the seedling crop cycle. It has caused significant losses in FDC, LW, and PW, but occurs in nearly all species as a contaminant which we try and reduce through our use of running water soaks in operational seed preparation. Fungal assay testing of susceptible species is performed on contract and results of infection and contamination made available.

Origin

This vague term is intended to identify any influences pertaining to differences between natural stand and seed orchard crops. The primary characteristic that is different between wild stand and seed orchard seed is seed size measured on a weight basis or the more commonly used seeds per gram (SPG). In all species, seed derived from seed orchards is heavier than seed derived from natural stands (Table 2). This is most pronounced in PLI in which orchard seed is on average 36% heavier and this phenomenon ranges down to orchard seed being only 5% heavier in CW (Table 2). The original germination varies between wild and seed orchard collections for some species. This may be an artifact in some species (SX, PW, LW, and FDC) with well established seed orchard programs that are meeting most reforestation needs; the wild seedlots represent much older collections in these species. Origin also has the ability to influence original quality in terms of access to labour, monitoring, and potential for more refined post-collection handling practices.

Operational Preparation

The influence here moves from the realm of tests to implementing the same procedures and results on vastly larger quantities of seed. The actual environment surrounding each seed in a test dish which is physically separated from other seeds is different from a mass of stratifying seed in intimate contact. Potential for fungal cross contamination is greater and for deeply dormant species with long pretreatments standardized monitoring is critical. Our operational pretreatments also utilize a running water soak to try and remove seed-borne contaminants and seeds are surface dried to maintain seeds in a 'free-flowing' condition while still maintaining maximal internal moisture. The running water soak is only used for YC, PW, BA, and BL in testing. Operational seed preparation is often less standardized in terms of duration and seeds are left under stratification conditions until sowing, often extending the actual pretreatment. In general this will be beneficial by increasing germination speed, but there is a critical level at which megagametophyte reserves could be depleted past the point of having the energy to support germination.

Quantification is provided by our Quality Assurance program which tests a subsample of seedlots at shipping for germination. This value is then compared with the latest test information to evaluate whether a falldown (if negative) or gain (if positive) occurs and use this information to improve the agreement between the two. Moisture content is also evaluated at shipping (non-destructively) and this method is also used

to target specific moisture regimes for pretreatment (i.e., PW at 37%). These calculations are also used to calibrate the surface drying of seedlots.

Nursery Conversion

Converting the seed to seedlings in the nursery is like a replication of the test environment. How close can you get under operational conditions and constraints? This influence can be greatly affected by the actual environment in terms of the temperature regime during germination. Are conditions warmer or colder than the daily average of 23.3°C which is supplied by the standard 30:20 regime in the controlled germination chamber? Temperature will play a key role in determining germination speed, but heating for germination is probably the largest cost of seedling production. With seedling costs not rising we have seen crops being sown later to reduce the energy required to heat a greenhouse.

The moisture regime can also influence the efficiency of conversion in relation to moisture status at and following sowing. If seed is too dry then germination can be delayed and if conditions are too moist then fungal proliferation is promoted. In the greenhouse there are also many more sources of pathogen spores (especially *Fusarium* spp.) and disease issues, even at germination, that are not necessarily tied to a pathogen being seed-borne. At the nursery the criteria for evaluating germination (often at seed coat shedding) is later than in the laboratory where the radicle being 4X the seed length is used. There may be additional factors during the interim which are not identified through current testing practices. Part of our sowing request Quality Assurance program involves obtaining feedback on germination at the nursery. This allows for a comparison between germination test results: in the laboratory, on operational sowing requests as the seed leaves our facility, and on the same requests at the nursery. This allows for an identification of the source of any germination reductions and helped to guide improvements at the appropriate stage.

Discussion

This started out as the standard five-year review of our species deterioration rates to update our germination retest frequencies to a review of seed characteristics and a more efficient strategy for our retesting program. Factors like Deterioration Rate have been looked at by genetic class and with our current proportion of orchard seed use (and number of wild seedlots for some species) it became obvious that a new strategy is required to provide an appropriate balance between providing good information for sowing and maintaining our stewardship responsibilities. This review also resulted in some critical thinking on our important tests to include and for some species (or even specific seedlots) it may be worthwhile introducing additional test results (i.e., resin vesicle damage assessment for poorly performing *Abies* seedlots).

The text focuses on species differences, but variability exists within each species and I believe the seedlot-specific quantification of these influences can help improve seed-use efficiency. It is certainly still a work in progress and I appreciate feedback you may have on the presentation, identified influences, and any other influences you may quantify at your facility.

Dave Kolotelo
Ministry of Forests, Lands and Natural Resource Operations
Tree Seed Centre
18793 - 32nd Avenue
Surrey, BC V3S 0L5
E-mail: Dave.Kolotelo@gov.bc.ca

ISO 9001:2008 CERTIFICATION OF THE BERTHIER TREE SEED CENTRE

Since November 2011, the Berthier Tree Seed Centre (CSFB) has been certified **ISO 9001:2008**. To our knowledge, it is the first forest tree seed centre in Canada to obtain this certification. ISO 9001:2008 specifies requirements for a quality management system, where an organization needs to demonstrate its ability to consistently provide products, materials, and services that meet the needs of its clients.

Why be certified ISO 9001: 2008?

Our Branch (Direction générale des pépinières et des stations piscicoles) expressed the desire for CSFB to undertake the certification process to demonstrate the quality of our product. The ISO certification obtained by the CSFB is the result of an extensive team effort, coordinated by Normand Brault until his recent retirement in September 2012. A company specializing in this area has been hired to conduct an evaluation and validation of our compliance with the ISO standard.

What does a ISO 9001: 2008 quality management system include?

At the beginning of the certification process, CSFB management established a quality policy and defined quality objectives consistent with this policy. The CSFB quality policy statement is: "By continuously improving its procedures, the Berthier Tree Seed Centre intends to actively contribute to the Ministry of Natural Resources' strategy of sustainable forest management, notably to increasing forest yields, by ensuring the production of quality seeds and meeting the expressed needs of customers at the lowest cost."

CSFB's mission is to provide the highest quality seed possible to all Quebec forest nurseries producing seedlings for reforestation. The scope of the CSFB ISO system is the production of forest seeds, which encompasses the extraction of coniferous and deciduous tree seeds, as well as their processing, analysis, stratification, storage, and shipment.

The system is based on a Management Manual that is divided into three types of activities: support, implementation, and improvement. The Manual creates an interface between the reality of the business and the requirements of the ISO standards. The procedures and instructions contained in the Manual assure the planning, operation, and control of processes. Monitoring reports permit the initiation of quality objectives and the introduction of corrective and preventive actions, in the interest of continuous improvement. Internal audits and management reviews are conducted annually to verify functioning of the quality system.

1. Support activities

All ongoing tasks at CSFB, regardless of their nature, duration, and importance to overall activities, were outlined in the Management Manual procedures (from the receipt of cones to shipping seeds to nurseries). These procedures are designed to ensure monitoring and implementation of the various stages of the production, storage, and shipment of conifer and hardwood seeds, as well as the records, analyses, and controls that ensure traceability.

Each staff member is responsible for the compliance of his/her own activities and is invited to suggest improvements at any time. Thus, CSFB employees indicate any element of non-compliance or any possible improvements to the production process. Monitoring of corrective and preventive action is recorded in a register which shows that when problems are identified measures are taken to eliminate them and that the results obtained are verified.

A support committee ensures that the system procedures are established, implemented, and maintained. The committee is composed of Branch representatives, a quality coordinator, and CSFB employees. Detailed procedures are regularly updated and available to all employees on both the common server and the "Système SEMENCES" computer system.

2. Implementation activities

To ensure compliance and improvement of procedures, the Branch determines, in consultation with the support committee, requirements in terms of installations, equipment, materials, infrastructure, IT, etc. A survey is also sent to customers (nurserymen) annually to assess their satisfaction and identify areas for improvement.

3. Improvement activities

CSFB staff defines, plans, and implements activities and monitoring measures to ensure the conformity of products and procedures. In addition, the quality system promotes the establishment of mechanisms for continuous improvement.

Assessment after 1 year of certification

It is certain that the first year of implementation of such a system requires a lot of effort from the whole team as well as a change in work habits. After a year of certification, CSFB staff better understand the benefits of such an approach. Thus, the implementation of a quality system facilitates employees' work and contributes to operational improvements. Updating production procedures greatly facilitates the replacement of a staff member, over the short or long term, while promoting the flexibility of employees'

tasks. Finally, we recommend that any organization that wants to promote quality production and customer satisfaction undertake certification. However, a quality management system will only be successful if the entire staff is involved.

Michèle Bettez
Centre de semences forestières de Berthier
Direction générale des pépinières et stations piscicoles
Ministère des Ressources naturelles du Québec
1690 chemin Grande-Côte
Berthierville, Qc J0K 1A0
E-mail: michele.bettez@mrn.gouv.qc.ca

Fabienne Colas
Direction de la recherche forestière
Ministère des Ressources naturelles du Québec
2700 rue Einstein
Québec, Qc G1P 3W8

ROBB BENNETT BECOMES A FELLOW OF THE ENTOMOLOGICAL SOCIETY OF CANADA

Dr. Robb Bennett is exemplary in his scientific contributions and dedicated service to entomology in Canada. As an entomologist with the British Columbia Ministry of Forests, Lands and Natural Resource Operations (1992–2010), he created and expanded a major research program in cone and seed pest management that had international collaborative spread and influence. His successful lobbying for provincial support garnered $400,000 in annual funding and the establishment of the Pest Management Technical Advisory Committee of the BC Forest Genetics Council, which he initially chaired (2003–2010). During this period, his participation was critical for ground-breaking research that produced the first ever description of a cecidomyiid fly pheromone (named "Bennettin" in recognition of his work) and the use of infrared radiation by a herbivore in host-finding (*Leptoglossus occidentalis*). Dr Bennett also is highly respected as one of Canada's leading spider systematists and has shared this expertise through volunteer curation of the spider collections at the Royal British Columbia Museum (Victoria), where he is a Research Associate, and the Canadian National Collection of Insects, Arachnids and Nematodes (Ottawa) (CNC). The results of his scientific efforts are 45 peer-reviewed papers, 44 technical publications, 3 on-line arthropod identification guides, and the mentoring of many undergraduate and graduate students. He also has been an active advocate in conservation entomology where he has volunteered on various committees as a Specialist, Member or Chair: for example, BC Ministry of Environment Invertebrates-at-Risk Team (2001–2006) and Committee on the Status of Endangered Wildlife in Canada, Arthropods Specialists Subcommittee (2006–present). Of particular note have been his contributions to the Entomological Society of Canada, for which he has served on several committees starting in 1998 and as Editor-in-Chief of *The Canadian Entomologist* (*TCE*) (2007–11). In the latter role, he is to be commended especially for elevating the quality of the journal, thereby setting a solid stage for its move to electronic publication and a new publisher.

Jim Corrigan
Ministry of Forests, Lands and Natural Resource Operations
Tree Improvement Branch
3401 Reservoir Road
Vernon, BC V1B 2C7
E-mail: Jim.Corrigan@gov.bc.ca

MICHAEL CARLSON RECEIVES AN AWARD

Dr. Michael Carlson, a well known forester and emeritus scientist with the BC Ministry of Forests Lands and Natural Resource Operations (FLNRO), was honoured with an Achievement Award from the Forest Genetics Council of British Columbia.

Dr. Carlson joined the FLNRO in 1982 and has worked out of the Kalamalka Forestry Center. During his years with the FLNRO, Dr. Carlson led a comprehensive genetics research program with lodgepole pine, BCs primary reforestation species. This work led to many scientific and applied accomplishments that have guided seed choice for the approximately 90 million

lodgepole pine seedlings planted each year in BC. Dr. Carlson was also active as a member of the Forest Genetics Council of BC from 1998 to 2009. He is well known in the Vernon area for his environmental initiatives and for his work with poplar planting as a means of increasing the capacity for treated effluent disposal through irrigation on commonage lands. Dr. Carlson is well known by foresters throughout BC for his involvement, mentoring, and practical support of silviculture operations. He retired from the FLNRO in 2010 but continues to make significant contributions as a non-paid emeritus scientist.

The Forest Genetics Council of BC is a cooperative representing the forest industry, provincial and federal government agencies, and universities. The Council coordinates provincial genetic resource management activities, and advises the provincial government on policy matters with respect to tree seed, genetic conservation, and associated research. Objectives include genetic conservation and improving forest productivity. These activities do not include genetic engineering, and no genetically modified trees are planted in British Columbia.

Presentation of the award was made January 15, 2013 at Vernon, BC by Mr. Dave Peterson, Provincial Chief Forester with the FLNRO.

Jack Woods
Forest Genetics Council
3250 West 15th Avenue
Vancouver, BC
V6K 3A9
E-mail: jwoods.fgc@shaw.ca

PEST MANAGEMENT TECHNICAL ADVISORY COMMITTEE – 2012 REPORT

The Pest Management Technical Advisory Committee (PMTAC) manages the disbursement of annual funding allocations that come from the Forest Genetic Council of British Columbia. This support is intended to fund pest management research on how to best protect, maintain, and increase crop production in BC seed orchards. Committee members come from the Tree Improvement Branch of the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), the Canadian Forest Service, private and provincial government seed orchards, and the Forest Genetics Council.

The PMTAC establishes research priorities and sets budgets through an annual process of proposal development and evaluation. In 2012, the PMTAC supported pesticide trials targeting the Douglas-fir cone gall midge, the fir coneworm, the western conifer seed bug and the Sequoia pitch moth (Tables 1 and 2). Attempts were made to develop a technique to detect feeding damage caused by the western conifer seed bug on individual lodgepole pine (*Pinus contorta* var. *latifolia*) seeds. Support was provided for operations of the seed and cone pest management research laboratory, and for the operational and extension activities carried out by the Ministry's cone and seed pest management biologist.

Table 1. PMTAC-supported projects for fiscal 2012/13.

Project	Species impacted	Budget ($)
Pesticide trials to identify new products to control *Contarinia oregonensis* and to support Federally-sponsored Minor Use trials targeting *Dioryctria abietivorella* and *Leptoglossus occidentalis*.	Douglas-fir, spruce, and lodgepole pine	49,000
Synanthedon sequoia pitch moth control attract-and-kill trial.	Lodgepole pine	16,800
Synanthedon sequoia pitch moth control bole spray trial	Lodgepole pine	8,400
Detecting *Leptoglossus occidentalis* seed bug feeding punctures on lodgepole pine seeds.	Lodgepole pine	7,000
Operational support for MFLNRO cone & seed pest research laboratory.	All species	6,300
Operational support for MFLNRO cone & seed pest biologist.	All species	25,000
Total PMTAC budget for fiscal 2012-13		112,500

Through the last quarter of fiscal 2012–13, the Committee will receive final reports for projects undertaken in 2012 and generate a list of projects recommended for PMTAC funding support in the upcoming fiscal year.

Table 2. Highlights from the PMTAC-supported projects for fiscal 2012/13.

Project	Highlights
Pesticide trials.	Progress is being made to compile the data needed to register Delegate WG (spinetoram) for control of the fir coneworm, *Dioryctria abietivorella*, on Douglas-fir. Screening trials targeting the Douglas-fir cone gall midge, *Contarinia oregonensis*, may have found an effective product. Movento (spirotetramat) appeared to significantly reduce the number of Contarinia galls found in cones when observed in mid-season half cuts.
Synanthedon sequoia attract-and-kill trial.	Droplets that combined the sex pheromone for the Sequoia pitch moth with a pesticide were applied in a grid inside lodgepole pine seed orchards. These treatments appeared to significantly reduce pitch moth attack rates at several Interior locations.
Synanthedon sequoia bole spray trial	Results from this trial failed to show that the pesticide Delegate, registered for use as a bole spray against Apple clearwing moth, significantly reduced the number of pitch moth attacks observed on the ramets used in this trial.
Detecting *Leptoglossus occidentalis* seed bug feeding punctures.	The seeds from all treatments have been extracted and empty seeds have been separated from the filled ones. Samples of empty and full seeds have been put through several staining processes. We found a process of staining heated seeds with ruthenium red that can successfully be used to identify individual lodgepole seeds that have been attacked by seed bugs.
Operational support for MFLNRO cone & seed pest research laboratory.	This support contributed to the work required to conduct both the PMTAC and the Federally-sponsored Minor Use pesticide trials undertaken in 2012.
Operational support for MFLNRO cone and seed pest Biologist.	This funding was used to support: the regular extension duties of the Biologist, including site visits and the provision of pheromone-based and other monitoring supplies to seed orchard operations; the Operational Reporting Meeting (Oct. 30, 2012) for field personnel from the Interior locations; the spray/no-spray trial that used Sevin to attempt to protect lodgepole pine cones from seed bug attack in Kalamalka Pli 307; a Btk spray trial targeting the European pine shoot moth (*Rhyacionia buoliana*) on lodgepole pine. Three Btk sprays applied during the adult flight (and oviposition) season failed to appreciably reduce the number of transplants attacked by EPSM in Kalamalka Pli 230 in 2012. Each seed orchard manager has been asked to respond to a survey asking about the history and current status of pest problems and pest-based losses experienced at their respective locations. The Biologist is using these surveys to update the list of pests of concern to seed orchard production in the province.

Jim Corrigan
Ministry of Forests, Lands and Natural Resource Operations
Tree Improvement Branch
3401 Reservoir Road
Vernon, BC V1B 2C7
E-mail: Jim.Corrigan@gov.bc.ca

STORAGE POTENTIAL OF SPRUCE AND PINE SEED[1]

Storage of tree seed is important for reforestation programs, research, and conservation. Physiological quality of the seed must be maintained during storage for rapid germination and subsequent development and growth of healthy, normal seedlings. The two principal factors influencing seed storage are seed moisture and storage temperature. Drying seed to an equilibrium of 5–20°C and 15–25% of relative humidity (moisture content of 4–7%, depending on species), and storing seed at -18±3°C are considered to be the minimum storage standards (Anon. 2011).

The National Tree Seed Centre targets seed moisture less than 8% and stores seed at -20°C. Seed is germination tested to monitor viability. Testing has been conducted for over 30 years using standardized procedures. Some older seedlots have been in storage for over 50 years and many seedots have been tested many times. Hence, a sizeable dataset has been built up over the years and has been used to demonstrate the long-term storage ability for a number of species (Simpson et al. 2004, 2007).

Germination retest frequency at the Seed Centre is 10 years. Retesting of all previously tested seedlots was completed over a three-year period, 2009–2011. The data provided the opportunity to evaluate the storage potential for spruce and pine species by identifying individual seedlots that exhibited higher or highest germination following the most recent tests. Examples are provided for two species to demonstrate how these data may be used to predict the trend in germination over a 100-year time period.

Methods

Seed moisture was determined by the oven method whereby seed in aluminum containers was dried for 17 ± 1 hr in a force draft oven set at 103°C. Containers were then weighed and moisture content was calculated on a wet weight basis.

Seed that are dormant were treated to alleviate dormancy before germination testing. The most common treatment is moist chilling for 21 days for *Picea glauca*, *P. sitchensis*, and *Pinus contorta* var. *latifolia* while *P. strobus* seed were chilled for 28 days. Germination testing was carried out by placing four replicates of 50 seed each on moistened Versa-Pak™ in Petawawa Germination Boxes. Boxes containing seed that required moist chilling were placed in a walk-in cooler at 4°C for the appropriate duration. Seed were germinated in a Conviron G30 germination cabinet set at 20°C for 16 hours with no light and 30°C for 8 hours with light and a constant relative humidity of 85%. The testing duration was 21 days except 14 days for *Pinus banksiana* and 28 days for *Pinus strobus*. Germination was assessed regularly and a seed was considered to have successfully germinated when the cotyledons were visible and the radicle and hypocotyl were well developed.

Results and Discussion

The data were evaluated to identify one older seedlot from each species that had the higher or highest, current germination. Once this was done the data were searched to find the first germination test result for each chosen seedlot. As well, the current moisture content for each seedlot was obtained. If no current value was available, then the most recent value was used. Data are presented in Table 1.

Age of seedlots in storage ranged from 25 to 55 years. *Picea mariana* and *Pinus resinosa* seed had the highest germination (96.5% and 98.0%, respectively) for seed in storage for 40 years. *Pinus rigida* seed had 100% germination after 25 years. Seed quality declined little for species

[1] This article is in part found in: Simpson, J.D.; Daigle, B.I. 2012. National Tree Seed Centre annual report, 2011. Nat. Res. Can., Can. For. Serv.- Atl. For. Cen. 23 p.

such as *Picea mariana*, *Pinus banksiana*, *Pinus contorta* var. *latifolia*, *Pinus resinosa*, and *Pinus rigida* where the test interval was more than 20 years. Germination of *Picea glauca* seed declined at a more rapid rate. Simpson et al. (2007) showed that germination of *Picea glauca* seed, from a number of seedlots, stored at -20°C for 25 and 28 years did not decrease or declined slightly.

The results demonstrate the potential for storing seed of these species for many decades. Simpson et al. (2004) suggested that seed of some conifer species can be stored for up to 100 years while maintaining a germination greater than 60%. In order to evaluate the longer-term storage potential (up to 100 years), germination test results of *Picea glauca* and *Pinus banksiana* were further evaluated.

Table 1. Impact of storage time on seed germination for a single seedlot of four spruce and five pine species. Seed moisture content (MC) is presented for current or most recent tests.

	Initial testing		Current testing		
Species	Yrs in storage	% Germ.	Yrs in storage	% Germ.	% MC
Picea glauca	16	96.0	42	81.0	6.21[2]
Picea mariana	24	97.2	40	96.5	6.79
Picea rubens	33	81.2	55	75.5	7.14
Picea sitchensis	29	82.0	39	89.0	7.52
Pinus banksiana	25	95.0	50	92.0	8.88[1,2]
Pinus contorta var. *latifolia*	2	93.5[3]	35	90.0	-[1]
Pinus resinosa	0	97.5	41	98.0	5.60[1,2]
Pinus rigida	0	100.0	25	100.0	4.60[1,2]
Pinus strobus	23	97.0	32	96.5	7.17

[1] small quantity of seed

[2] previous MC value

[3] seed not moist chilled

Germination data from these two species were subjected to a simple linear regression analysis. Datasets were created by retaining seedlots with germination at or greater than 70%. A germination of 70% was considered to be a threshold whereby seedlots with germination at or above this value represent seed of high physiological quality that may be capable of maintaining high germination for a long period of time. Seed age was the other consideration as it related to having a sufficient number of germination tests. For *Picea glauca* the cut off age was 40 years while for *Pinus banksiana* the cut off was 38 years. The data were analyzed and the resulting intercept and constants were used to generate a curve representing the change in germination of seed for each of these species over a 100 year time span.

The graph for *Picea glauca*, produced using data from 3,572 germination tests of 1,501 seedlots, shows that the long-term seed storage potential is very good (Fig. 1). Germination does not fall below 70% until seed is over 80 years of age. In contrast, *Pinus banksiana* seed shows even greater storage potential using data from 1,986 germination tests of 1,096 seedlots (Fig. 2). Here, germination is just below 80% at 100 years. *Pinus banksiana* seed is probably genetically predisposed for long-term storage owing to the serotinous characteristic of the cones where seed must remain viable for many decades and be capable of germinating when heat from wild fire opens the cones and the seed fall onto a fresh seed bed.

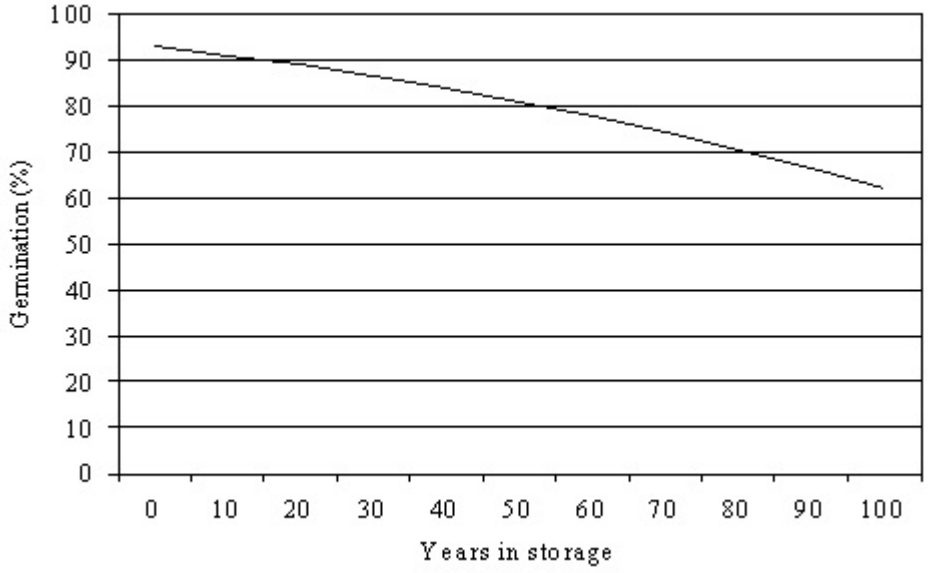


Figure 1. Estimated germination over time of high quality *Picea glauca* seedlots.

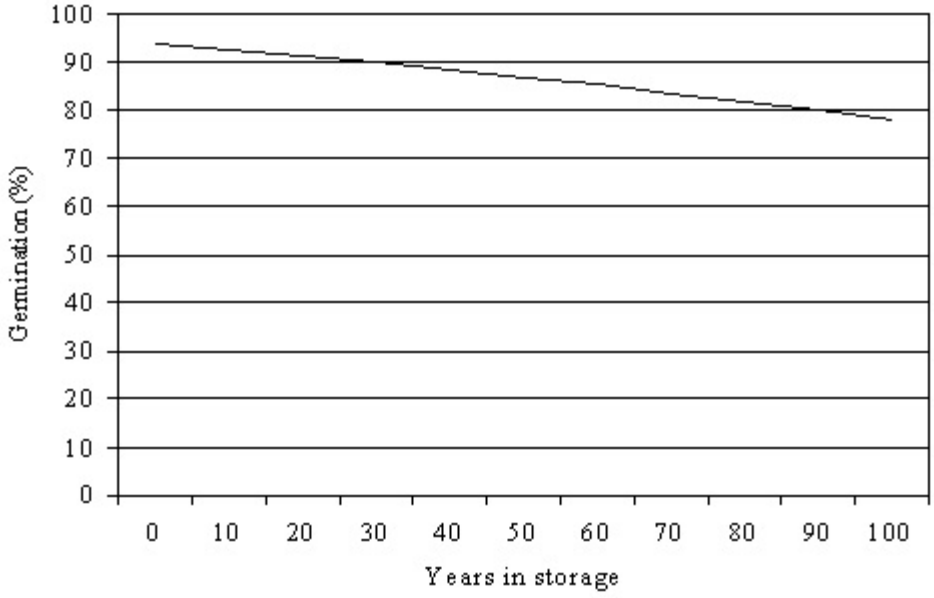


Figure 2. Estimated germination over time of high quality *Pinus banksiana* seedlots.

These graphs show, based on the datasets, that *Picea glauca* and *Pinus banksiana* seed from good quality seedlots has the potential for good to excellent storage, respectively, under conventional conditions. This, plus the data presented in Table 1 for high quality seedlots, demonstrates that seed from these spruce and pine species has good storage potential which is important from a genetic conservation point of view.

Literature Cited

Anonymous. 2011. Draft updated genebank standards: Minimum standards for conservation of orthodox seeds. FAO, Rome, 40 p.

Simpson, J.D.; Wang, B.S.P.; Daigle, B.I.; 2004. Long-term seed storage of various

Canadian hardwoods and conifers. Seed Sci. Technol. 32:561–572.

Simpson, D.; Daigle, D.; Hayes, D. 2007. Impact of storage on viability of white spruce seed. Tree Plant. Notes 52(2):4–8.

Dale Simpson and Bernard Daigle
Natural Resources Canada
Canadian Forest Service
National Tree Seed Centre
PO Box 4000
Fredericton, NB E3B 5P7
E-mail: Dale.Simpson@nrcan.gc.ca

UPCOMING MEETINGS

30th ISTA Congress
June 12–18, 2013 Antalya, Turkey
www.seedtest.org

Canadian Forest Genetics Association
July 22–25, 2013 Whistler, BC
www.forestgenetics2013.ca/

RECENT PUBLICATIONS

Brown, K.R.; Antos, J.A. 2012. Seedbanks, germination and early survival of bitter cherry (*Prunus emarginata*) in coastal British Columbia. For. Ecol. Manage. 282: 92–104.

Ellwood E.R.; Temple, S.A.; Primack, R.B.; Bradley, N.L.; Davis, C.C. 2013. Record-breaking early flowering in the Eastern United States. PLoS ONE 8(1):e53788. doi:10.1371/journal.pone.0053788

He, T.; Pausus, J.G.; Belcher, C.M.; Schwilk, D.W.; Lamont, B.B. 2012. Fire-adapted traits of *Pinus* arose in the fiery Cretaceous. New Phytol. 194:751–759.

Kong, L.; von Aderkas, P.; Owen, S.J.; Jaquish, B.; Woods, J.; Abrams, S.R. 2012. Effects of stem girdling on cone yield and endogenous phytohormones and metabolites in developing long shoots of Douglas-fir (*Pseudotsuga menziesii*). New For. 43(4): 491–503.

Potter, K.M.; Hargrove, W.W. 2012. Determining suitable locations for seed transfer under climate change: a global quantitative method. New For. 43(5-6): 581–599.

Rosenberg, O.; Almqvist, C.; Weslien, J. 2012. Systemic insecticide and gibberellin reduced cone damage and increased flowering in a spruce seed orchard. J. Econ. Ent. 105(3): 916–922.

von Aderkas, P.; Nepi, M.; Rise, M.; Buffi, F.; Guarnieri, M.; Coulter, A.; Gill, K.; Lan, P.; Rzemieniak, S.; Pacini, E. 2012. Post-pollination prefertilization drops affect germination rates of heterospecific pollen in larch and Douglas-fir. Sex. Plant Repro. 25(3): 215–225.

Walker, X.; Henry, G.H.R.; McLeod, K.; Hofgaard, A. 2012. Reproduction and seedling establishment of *Picea glauca* across the northernmost forest-tundra region in Canada. Global Change Biol. 18(10): 3202–3211.

Yakovlev, I.; Fossdal, C.G.; Skroppa, T.; Olsen, J.E.; Jahren, A.H.; Johnsen, O. 2012. An adaptive epigenetic memory in conifers with important implications for seed production. Seed Sci. Res. 22(2): 63–76.