Mountain Pine Beetle Seed Planning

TREE IMPROVEMENT BRANCH

BULLETIN 05

MARCH 2008

Lodgepole Pine Cone Collections

In response to the mountain pine beetle (MPB) outbreak in the interior of BC, there is a large and ongoing lodgepole pine (Pli) cone collection effort. This is to ensure that those with reforestation obligations have a supply of seed into the future. Those contemplating a cone collection should:

1. review their seed inventory
2. review the expected production of seed orchard crops
3. review the overall supply of seed for the area of interest before initiating a collection.

Bulletin 04[1] provided a provincial overview, with suggested analysis assumptions, using this three-step view of seed available for interior seed planning zones. Individuals are encouraged to perform their own analysis in reaching collection decisions, as they have the best information concerning their specific inventory, their specific needs and, at least initially, access to orchard-produced seed.

This bulletin provides the best information available concerning Pli cone crops, including reproductive biology, serotiny, cone and seed evaluations, collections from dead trees, cone classes, and long-term trends in collection volume, yield and germination. This is not an exhaustive literature review, but references provided offer the opportunity to dig deeper.

Reproductive Biology

Lodgepole pine reproductive biology continues to be an area of study because seed orchards have not met initial seed production targets and numbers of filled seed per cone continue to be low at some orchard sites. The best reference for details on Pli crop development from bud differentiation to seed maturation is provided by Owens (2006) and is available online,[2] but a few characteristics will be reviewed here.

Lodgepole pine cones require two growing seasons to mature after pollination (26–27 months after bud differentiation). Fertilization takes place in the season after pollination and is followed by growth and development of the embryo,

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1 **Interior Seed Supply Analysis and Planning**
http://www.for.gov.bc.ca/hti/pinebeetle/Pli_Bulletin04.pdf

2 **The Reproductive Biology of Lodgepole Pine**
http://www.fgcouncil.bc.ca/ExtNote7-Final-web.pdf

seed coat and megagametophyte (nutritive tissue). Lodgepole pine can begin to form seed cones at 10–15 years of age. The cones can contain between 100 and 130 cone scales.

Hellum and Wang (1985) have divided the cone scales into three classes:

1. **basal** – accounting for 65% of the scales and sterile
2. **middle** – accounting for 25% of the scales and the most fertile
3. **apical** – accounting for the remaining 10% and exhibiting half the fecundity of the middle scales.

With the potential for 2 seeds per scale, the average maximum seed potential is 40–60 seeds per cone.

Cone Serotiny

Lodgepole pine is characterized by serotinous cones – those that remain closed on the tree when seed maturation is complete. Not all trees within a stand will possess serotinous cones, although stands may be predominantly serotinous or non-serotinous. The coastal variety (var. *contorta*) of Pl produces mainly non-serotinous cones. In serotinous cones, the cone scales are sealed together with resin and require a temperature of between 45 and 60°C for the bond to be broken (see Tinker et al.1994 for a thorough review). Once the bond is broken, flexing of the cone scales depends on the moisture content of the scales – the higher the moisture content, the greater degree of cone scale flexing and seed release (Hellum and Barker 1980). This is due to differential shrinkage of the top and bottom of the cone scale (Harlow et al 1964).

Depending on cone scale moisture content and atmospheric conditions, seed release may be instantaneous or may occur over several years. Yes, once the serotinous bonds are broken, the cone scales can open and close with changes in atmospheric conditions. A serotinous, non-serotinous and a fully reflexed cone are presented in Figure 1. Note how the sterile, basal cone scales do not reflex backwards, as there are no viable seeds to disseminate.

Figure 1. A serotinous, non-serotinous and fully opened Pl cone.

The seeds will remain viable within the cones until fire or high temperatures break the resin bond. Cone serotiny and the associated traits of asymmetry and thickening of cones scales exposed to weathering (or fire) are considered to be more evolved characteristics of the genus *Pinus* (Shaw 1914). It has been hypothesized by Teich (1970) that cone serotiny is controlled by a single gene.

Without fire or extreme temperatures, the annual production of serotinous cones will contribute to the canopy seed bank. Decreased serotiny has been correlated with increased elevation (Tinker et al. 1994) and with increased latitude (Koch 1996). A trend of decreased serotiny has also been observed moving from east to west within the interior of BC (M. Carlson, pers. comm., March 2008). It has been observed by many that cone serotiny is rare in young stands, but far more common in older stands. The age of transition is variable, but has been estimated at between 15 and 30 years (Crossley 1956; M. Carlson, pers. comm., March 2008). The proportion of serotinous cones in a stand has also been linked to the most recent disturbance type. Stands originating from severe fires showed a high proportion of serotinous cones, and those originating from other disturbances showed a high proportion of non-serotinous cones (Muir and Lotan 1985).

With all of these interacting factors, it is difficult to define a consistent pattern of cone serotiny across the landscape. Cone serotiny is a highly evolved characteristic allowing the species to take advantage of a wide variety of sites and conditions. Young stands produce less serotinous cones and seed is released annually to take advantage of gaps in stand stocking. As stands mature and stocking stabilizes, trees generally become more serotinous and start to build up the canopy seed bank for future regeneration following fire or other disturbance events.

Cone and Seed Evaluations

Cone evaluations are primarily performed to determine if there is a collectable crop, whether there are any problems (i.e., insects or disease), and to determine the most appropriate time for collection. With a canopy seed bank, only a small portion of the crop is maturing in any one year and, as long as the developing olive-green cones are avoided, immaturity is not a common problem in Pli.

Given that cone insects and diseases are generally not a problem for natural stand Pli, immature cones can be avoided visually or by not collecting during the seed maturation period. Then, Pli cone evaluations can focus on getting an accurate estimate of filled seeds per cone and assess proportion of cones by cone class (discussed later). Determinations of filled seeds per cone are best done using whole cones, as transverse cone cuts explain less than half the variability in filled seeds per cone (Eremko et al. 1989, page 23). To properly estimate filled seeds per cone, it is important to obtain a sample that will be representative of what one intends to collect.

The serotinous bond first needs to be broken. This can be easily accomplished by immersing cones in boiling or near-boiling water for one minute, or until the cracking sound stops. The cone scales then need to be reflexed to extract the seed, which can be done by heating cones in a microwave oven for 1–1.5 minutes or in a convection oven overnight at 60°C.

The number of filled seeds should be determined by cutting them, although the very small sterile 'seeds' are easily separated from the viable seed visually without cutting (Figure 2). A filled seed should contain a completely elongated embryo and firm white nutritive tissue [megagametophyte] (Figure 3). The embryo is often white, making it difficult to differentiate from the megagametophyte. Variation in filled seeds per cone is quite high and, over the past few months, we have observed a range of between 0 and 67 filled seeds per cone. Collection averages are lower and are generally in the 15–30 filled seeds per cone range.

Figure 2. A comparison between a seed derived from a) fertile and b) sterile cone scales.

Figure 3. Filled lodgepole pine seed showing a fully enlarged embryo and firm nutritive tissue [megagametophyte].

There is no magic number for when a cone crop is collectable in terms of cones per tree or seeds per cone. Cone crop ratings are quite general and subjective with regards to total cones on a tree and the proportion of trees having a good crop (Eremko et al. 1989). The individual cone standard was 20 filled seeds per cone (Eremko et al. 1989), but there are many crops being collected that do not meet this standard. The seed need, and whether orchard crops will become available for an area, will drive the need for seed and whether a crop is collectable, but an evaluation will provide an indication of what can be expected from the crop and the total volume of cones required.

Collections from Dead Trees

Many of the current Pl collections are taking place in stands killed by the MPB. There is little concern about the seed viability of serotinous Pl cones from dead trees. We generally consider the serotinous cones to be discrete, closed units isolated from the tree and the environment as long as serotiny is maintained. Viability of seed within old, serotinous cones was noted as early as 1880 when Sargent reported germination of seed from 10-year-old serotinous cones. There have subsequently been many similar observations (see Kamra 1982 for a review), and in 2006 we looked at the viability of seed from trees that had been dead for 10 years. We were able to find viable seed in all collections investigated.[3]

Although most MPB-killed Pli stands may initially have a canopy seed bank, serotiny is being lost on many sites because of the increase in direct and indirect solar radiation reaching the defoliated crowns. Cones closer to the ground will achieve high temperatures sooner and, therefore, open first. Conditions within many of these killed stands are limiting the window of opportunity to secure the canopy seed bank. Whether the disseminated seed will form a stand is uncertain and highly variable by site. Considerations include the rate of seed release, degree of mineral soil exposure, predation, and the environmental conditions of the site.

The probability of natural regeneration can be increased by spreading the cone-bearing branches uniformly across the site (Crossley 1956). Bancroft (1996)[4] describes post-harvest survey procedures and drag scarification basics for naturally regenerating Pl stands. Conifers are generally not components of the soil seed bank, but there is some evidence with eastern species that seed may still be disseminated during the second season following fire (Thomas and Wein 1985).

Lodgepole Pine Cone Classes

For Pl, serotinous cones have been categorized into four classes to assist collectors in deciding which cones to include and exclude (Eremko et al 1989). Classification is based on whether serotiny is maintained and on the degree of cone weathering (Figure 4). Note that weathering varies by site and with the portion of the cone exposed to the elements.

Class 1 cones are serotinous, show no weathering and have been recently produced on the tree, but not necessarily in the last year cones were produced. Class 4 cones are identified by their loss of serotiny and/or damage to the cones.

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3 Seed from Dead Lodgepole Pine Trees
http://www.for.gov.bc.ca/hti/publications/misc/DeadPLiSSEN.pdf

4 Fundamentals of Natural Lodgepole Pine Regeneration and Drag Scarification
http://www.for.gov.bc.ca/hfp/publications/00096/NatPlregen.pdf

Pli Cone Classes

Class 1

Class 2

Insets illustrate cone weathering variation on opposite sides of the same Class 2 and Class 3 cones

Class 3

Class 4

Figure 4. The lodgepole pine cone classes illustrating average appearance and variability by cone aspect.

Portlock (1996) suggested that five classes be used, with the fifth indicating damaged cones, but, for simplicity, we will combine damaged and non-serotinous cones together in class 4 as cones that should not be collected. Classes 2 and 3 are more subjective, as they are based on the proportion of the cone that is weathered. Class 2 cones have partial weathering (up to 66%) and class 3 cones have between 67 and 100% weathering.

Historically, when cone supply was considered endless, it was recommended that collections should be restricted to classes 1 and 2 and that one should NOT collect class 3 cones (Eremko et al. 1989). We have been conducting many of our cone and seed evaluations for Pli by cone class. The results for filled seeds per cone and moisture content are presented in Figure 5 for 30 Pl seedlots processed at the Tree Seed Centre in 2006. On average, class 1 and 2 cones had 20 seeds per cone, class 3 had 16 seeds per cone and class 4 about 7.5 seeds per cone. The moisture content of the cones also decreased with increasing cone class, making it more difficult to get complete scale reflexing and seed extraction from the lower moisture content cones.

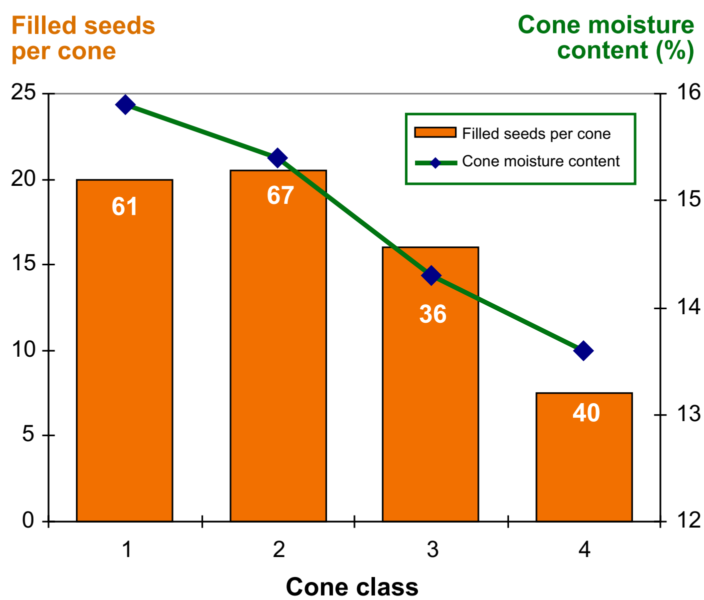

Figure 5. A comparison between filled seeds per cone and cone moisture content by cone class. Numbers within bars indicate the cone class sample size, which is based on 30 seedlots processed in 2006 from a variety of sources.

It is recommended that individuals do not automatically reject class 3 cones, as in some cases, we find they can have more filled seeds per cone than class 1 or 2 cones. Filled seeds per cone is a function of the pollination, fertilization and development success in any crop year and conditions optimizing these can vary greatly by year. For example, it should not be surprising that cones that are 12 years old can have more filled seed than three-year-old cones.

Pli Cones to Avoid

Opened cones

Insect damaged cones

Very small cones (2 – 2.5 cm)

one normal cone for reference

Resin covered cone

Figure 6. Examples of the types of Pl cones **not** to be collected.

It is worthwhile discussing in greater detail class 4 cones, or those that should not be included in collections (Figure 6). First, opened cones should not be included unless one can ensure significant quantities of filled seed remain in the cones. It is possible that the serotinous bond has recently broken, but no seed dispersal has occurred. If these cones make up a large proportion of the potential collection site, it is worthwhile evaluating them. It still may be possible to collect these cones, but it is also possible that the seed will be lost during the cone harvesting activity. Therefore, collecting opened cones should only be considered when there is no alternative.

Insect-damaged cones should also not be included in collections. These cones may still contain viable seed, but they are problematic to open and, therefore, few filled seeds are generally extracted from them. Small cones can still contain some seed, but it is probably best to avoid cones that are under 2 cm in length. Other cones to exclude are mechanically damaged cones, immature cones and resin-covered cones.

Lodgepole Pine Collection History

There has been a large increase in Pl cone collections in response to the MPB (Figure 7). A dip is indicated in 2007, but this simply reflects the fact that not all seedlots collected in 2007 have been processed, tested and registered yet. The 2006 calendar year represents almost a three-fold increase in cone processing in BC compared to the 10-year average. Seed orchards began producing small quantities of seed in 1982, with a high of 727 hl collected in 2006. There has been a large increase in Pl orchard capacity in the last few years and production should increase considerably once these begin producing regular crops.

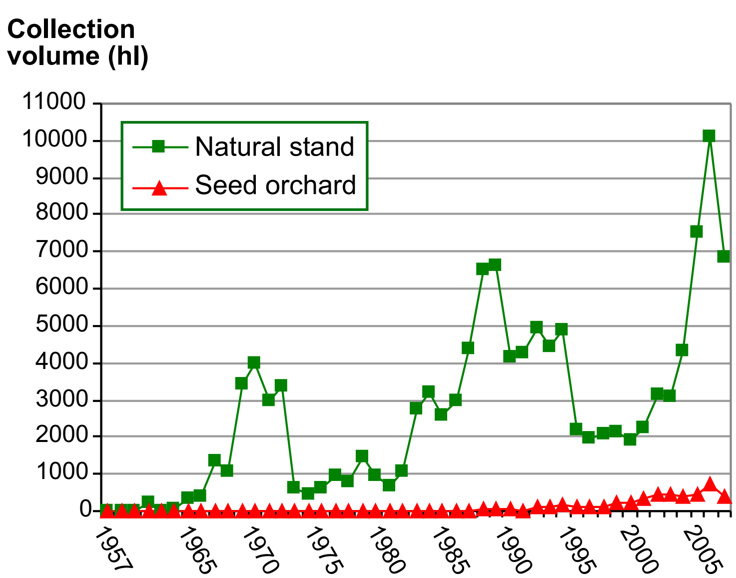

Figure 7. The trend in collection volume (hl of cones) for natural stand and seed orchard produced Pl seed. (Note that some data are unavailable for the earlier years.)

There is considerable discussion about the quality of current Pli cone crops. Certainly as people become more desperate for seed, it is possible that collection quality will decrease, but this needs to be put into perspective with the long-term averages for natural stand Pl seed germination and seed yield. In Figure 8, the initial seedlot germination capacity and year of production are plotted to show that Pli germination has been relatively stable over the past 20 years. There was a slight drop from 95% in 2004 to 93% in 2007, but these seedlots still possess excellent germination characteristics.

In terms of seed yield (kg of seeds per hl of cones), there has been a trend towards decreased yield in the 2006 and 2007 collection years (Figure 8). Average yield increased from 2001 to 2005, but has subsequently dropped. The most reasonable explanation for this apparent drop in seed yield is the greater proportion of class 3 and class 4 cones appearing in seedlots. There is ample justification for including class 3 cones, in most cases, but collectors should try to eliminate shipping class 4 cones to the extractory.

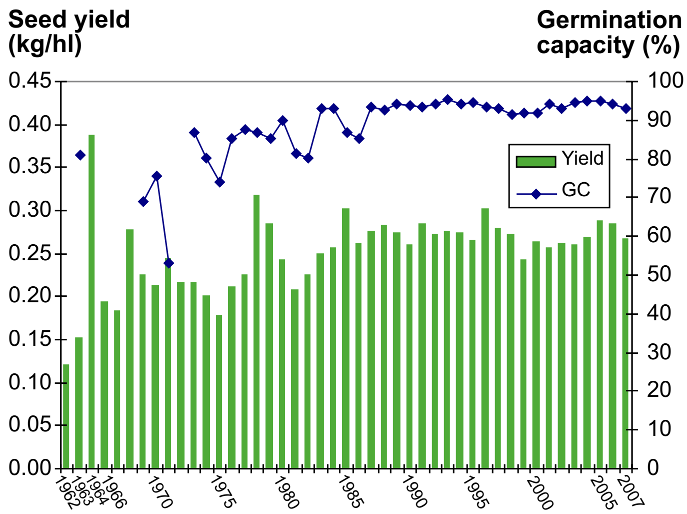

Figure 8. The average seedlot yield (kg of seeds per hl of cones) and germination capacity (%) of Pl collections by collection year. (Note that some data are unavailable for the earlier years.)

Another concern expressed pertains to the storage characteristics of Pli. We have observed and quantified excellent storage characteristics with this species and estimate an average linear decrease in germination capacity of only 0.05% per year or 1% in 20 years.[5] There should not be any significant concerns regarding the longevity of the large-scale collections taking place today.

This bulletin provides some readily available information about Pl cone collections and some general considerations are provided below. We will continue to accumulate and analyze data on Pli cone crops and will provide updates in the future. If there are specific issues or concerns that have been omitted, please bring these to my attention.

5 **Conifer Seed Longevity**
http://www.for.gov.bc.ca/hti/publications/misc/ConStorTSWG45.pdf

General Lodgepine Pine Cone Collection Considerations

Here are some basic considerations regarding Pl cone collection. Some of these are common sense, but warrant repeating.

1. Perform an evaluation on the potential of a cone crop before initiating cone collections. Most seed extractories will do this for you if they will be processing the cones.
2. Use good quality, tight-weave burlap sacks. For serotinous cones, fill to 40 L per sack, and for non-serotinous cones, 25 L of cones per sack to allow for cone expansion.
3. Make an appointment with your extractory for cone delivery. Do not show up at the extractory without an appointment nor call only the day before and expect that they can receive your shipment. They may already have shipment appointments for that day.
4. Advise the extractory if the collection is complete or ongoing. With some large Pli collections, several truckloads of cones are delivered over time, and it is important to know when cone delivery is complete for processing efficiency.
5. Cone sacks should be protected from the weather during and after collection. It is preferable that they are moved from the field to a temporary storage area daily.
6. Serotinous Pl cones can be transported to the seed extractory without a period of field conditioning and without racking.
7. Specific guidelines for Pl shipments to the Tree Seed Centre are provided at http://www.for.gov.bc.ca/hti/publications/misc/Pli_Cone_Shipment_Recommendations.pdf.

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