Seedling Storage and Handling in Western Canada

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Abstract: Seedling storage and handling techniques are similar across western Canada. Understanding seedling physiology permits management of the prestorage phase and assists in preparing seedlings for storage. Careful handling and packaging, appropriate storage conditions and management, as well as careful thawing and subsequent storage are essential to seedling vigour once outplanted. Outplanting seedlings while frozen has been investigated with favourable results. This new technique is seen as a new way to improve seedling survival and performance.

Keywords: seedling handling, seedling storage, outplanting frozen seedlings

Introduction

Seedling storage and handling are similar in their operations and concerns across western Canada. However, a wide array of issues must be considered based on a great number of nurseries spread across a large and diverse landmass with an equally diverse forest community. In this paper I will attempt to present an overview of the current handling and storage practices across western Canada, and trace the concepts and operational steps followed in handling and storage of seedlings. I will conclude with a report on the research work we are doing on an alternative to thawing seedlings after storage by outplanting the seedlings while still frozen.

State of Seedling Storage in Western Canada

Western Canada is comprised of the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba as well as the Yukon and Northwest Territories. These provinces/territories represent a productive forest land area of 121.4 million ha (~300 million ac) (Lowe and others 1996). In 2002, approximately 291 million seedlings were outplanted on forest land (Table 1) (Canadian Council of Forest Ministers 2003).

Efforts to restore forests to lands denuded by logging, pests, and/or fire have demanded the development of a large forest nursery industry (Table 1). These nurseries were initially established by the provincial governments, but are now largely in the private sector. Nursery production, although initially bareroot, is now overwhelmingly container focused. The container system of choice in western Canada is the Styrofoam container production system initially developed by the BC and Canadian Forest Services.

Most outplanting in western Canada occurs in the spring. As spring arrives across the west at quite different times depending on geographic location and elevation, almost all seedlings are overwintered in frozen storage. This practice permits the availability of seedlings that have been thawed just prior to outplanting. These seedlings have not yet flushed, and are thus in a physiologically appropriate condition to withstand the stress of outplanting and to commence growth. In some locations, such as Manitoba, snow caches are used in conjunction with cold storage. Caches are developed in February and populated with seedlings from frozen storage for local availability once spring arrives in the area.

Storage Preparation and Seedling Storage

A number of planning steps are necessary prior to seedling storage. We are fortunate to be dealing with conifers in that these plants are cold adapted and capable of handling frozen conditions for months at a time. To be able to successfully handle and

Table 1—Number of nurseries and seedlings planted in western Canada (2002).

Province/Territory	British Columbia	Alberta	Saskatchewan	Manitoba	Yukon and NT
Nurseries by Province	30	12	3	1	0
Seedlings planted (million)	205.5	53.0	15.7	16.0	0.8

store seedlings over winter, a good understanding of physiology is necessary (Ritchie and Landis 2003). As conifers move through their annual growth cycles, they respond to a number of triggers that prepare them for winter. Plant processes move from growth to frost hardiness and dormancy. Some of the external changes during this period include cessation of new foliage extension and stem elongation, budset and development, stem lignification, and, finally, cessation of root growth. Internally, cuticle walls in the foliage are thickening, developing waxes on foliage surfaces, translocating soluble sugars, and moving water from cells to the intercellular spaces. Knowledge of these processes and their roles in overwintering allows the nursery manager to induce dormancy and prepare seedlings for storage. Development of dormancy and cold hardiness can be hastened by manipulation of nutrition, by use of short day treatments to trigger budset, and by gradual exposure to lower temperatures.

Across western Canada, nurseries use a testing procedure to determine if seedlings are physiologically ready for lifting, packaging, and cold storage. A "storability" test for this condition was developed by Simpson, Binder, and l'Hirondelle of the BC Ministry of Forests, Research Branch, to determine whether seedlings are sufficiently hardened to withstand the 6 or more months of cold storage (Simpson 1990). The storability test takes samples of seedlings from various geographic locations and elevations of origin and freezes these plants in a controlled freezer to a predetermined temperature threshold (–18 °C [0 °F]). Plants are then assessed for damage to the foliage or cambium. Current testing utilizes the measurement of variable fluorescence to determine if tissue damage has occurred. This gives us results up to 6 days earlier than visual observation.

Some nurseries also track indices such as chilling hours to aid in the determination of appropriate lifting dates. The storability test, however, tests seedling samples directly. This incorporates the response of the plant to the environment and thus has been our preferred method, and has proven a reliable predictor of poststorage health and vigour.

To be able to carry our seedlings through cold storage, especially the nonfrozen periods of this storage, we pay attention to the presence or potential of storage mould. Each crop is assessed prior to packaging to determine if there is a risk of storage mould development. The density of the crops, the fall weather conditions, and the susceptibility of certain species, western redcedar for example, are all taken into consideration (Figure 1). Managers may space crops in the nursery to aid in air circulation and thus lower humidity in order to make it more difficult for *Botrytis* spp. to establish. As a last resort, a fungicide spray may be applied prior to storage to protect the susceptible foliage from mould.

Once the seedlings have reached a physiological condition acceptable for storage, the lifting and packaging can begin.

Figure 1—To prevent storage mould, as illustrated on these western redcedar seedlings, a prelift risk assessment is required, and a fungicide treatment may be required.

Dormant seedlings can withstand some level of stress during the lifting process, but stress in plant tissues is cumulative. Every part of the lifting and packaging process must be designed and managed in a manner to minimize these stresses (McKay 1997). In addition, it is necessary to keep seedlings cool during this process; some species may start to lose frost hardiness and dormancy if exposed to warmer temperatures.

During packaging, the seedlings are bundled and roots are plastic wrapped in groups of 6 to 25 seedlings, depending on stock type size. Bundles are then packaged by placing seedlings in a plastic bag inside a waxed carton. Some nurseries use a paper bag with an inner, poly-lined layer. The reason for the plastic bag or poly layer is to ensure that seedlings do not desiccate in frozen storage over winter. Care is given to properly close the bags to ensure an adequate vapour barrier around seedlings inside the carton (Figure 2).

The storage facilities used in western Canada are of 2 types (Figure 3). Most storage facilities are buildings designed and built primarily for seedling storage, and most of these units are racked. Racking allows palletized storage of seedling cartons from floor to ceiling in the building and thus a very efficient use of space. Other types of storage units are buildings originally designed to store fruit. These buildings are not palletized and thus are usually limited to stacking the cartons 5 high, as more layers would crush the bottom cartons.

All refrigerated buildings have circulation fans to distribute the cold air and keep the temperature as uniform as possible. The normal freezing temperature for seedling

Figure 2—Packaging considerations. An intact and carefully closed vapour barrier, as supplied by this poly bag, is critical to seedling health in cold storage.

storage ranges from –2 to –5 °C (28 to 23 °F) in the refrigeration room and an inside box temperature of –2 °C.

Freezing of seedlings is done as rapidly as possible to minimize carbohydrate reserve losses and reduce the risk of storage mould development. The process of freezing can be accomplished rapidly by dropping the room temperature to –8 °C (18 °F), or spacing the cartons so all have good exposure to the cold air. If the temperature is dropped rapidly, monitoring the inside carton temperatures is important. Temperatures should not drop below –5 °C to avoid damage to seedling roots.

Monitoring of seedlings in storage is critical. Frequent and repeated checking is necessary to assure that seedlings are actually freezing and remaining so. This allows for quick action if problems occur. The performance of the refrigeration equipment needs to be monitored to ensure it is delivering the proper temperatures and airflow. Temperature needs to be recorded throughout storage to ensure the proper ranges of ideal frozen storage are maintained (Kooistra and Bakker 2002a).

Seedling Thawing

Seedling packaging involves grouping plants into bundles. As root plugs freeze together in these bundles, thawing is required prior to outplanting to facilitate seedling separation. Some of our research also suggests that the seedlings are preconditioned through the thawing process, and thus may develop more rapidly once outplanted (Kooistra and Bakker 2002a).

The process of thawing tends to be rapid, taking place over a 5- to 10-day period at temperatures in the thawing facilities of 5 to 15 °C (41 to 59 °F). Once stock is thawed, it is either shipped to the field for outplanting or placed in cool storage (2 °C [36 °F]) until it can be sent to the field. The temperature and condition of the stock is monitored throughout this

Figure 3—Examples of cold storage.

process to ensure that seedlings do not experience adverse conditions, and to detect if storage mould is developing.

Thawing of seedlings is not without its difficulties and can negatively impact seedling quality. Due to operational logistics, seedlings that may be thawed to meet a certain planting date may not be able to be planted on schedule. When this occurs and seedlings are placed back into cool storage, seedlings will use a portion of their carbohydrate reserves during this period, with negative consequences on subsequent growth (Silim and Guy 1998). If plants have been activated sufficiently due to the thaw, the buds may break in the cartons and flushing may occur. This flush is not light adapted, and plants are now much more susceptible to stress. Survival and performance on the outplanting site will therefore be reduced (Figure 4). The risk of storage mould development also increases. Conversely, if the outplanting date is moved ahead, the seedlings will need to be thawed more rapidly. To accomplish this, higher temperatures in the carton will be experienced during thaw, with resultant loss of carbohydrate reserves to fuel higher respiration rates.

Seedlings sent to the field are also handled with care to reduce stress. Transportation can consist of refrigerated trucks, temperature insulated units on pickup trucks, or short distance transport under reflective tarps. Once in the field, some storage may be provided by spotting and operating highway refrigerated trailers, with daily supplies removed as needed. More commonly, a field cache is created where cartons are placed in a shady cool spot with a reflective tarp suspended above the cache.

If the whole process, from preparation for storage in the nursery through the cold storage and thawing phases to the final handling in the field, goes well, then we have all experienced success in the resultant successfully established and performing plantation.

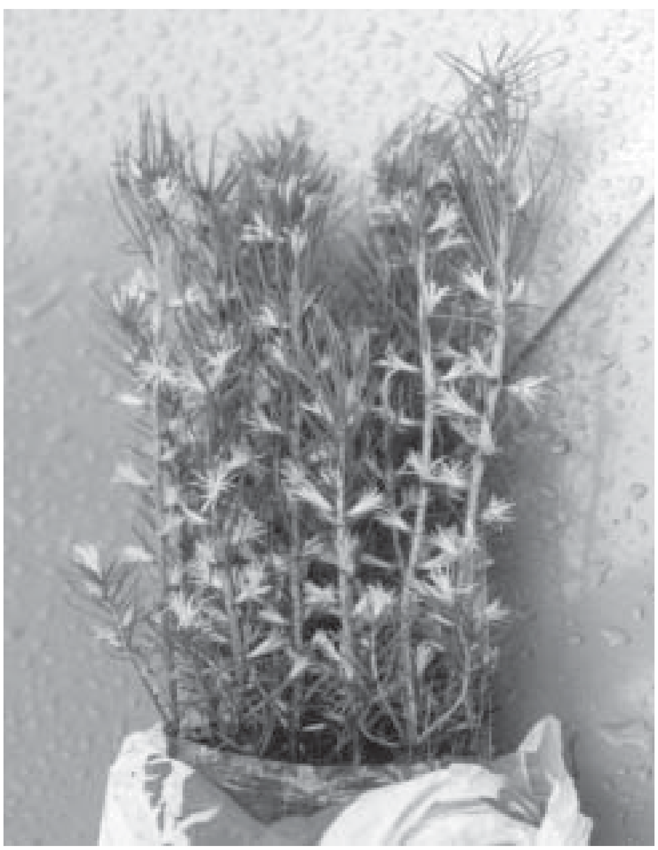

Figure 4—Careful thawing of seedlings and managing of nonfrozen storage are critical to preventing flushing and in minimizing carbohydrate losses, as illustrated in these western larch seedlings.

Another Approach?

The most difficult part of the storage and handling of seedlings from nursery to outplanting site is often seedling thawing and maintenance of seedling quality in the face of operationally changing logistics. In 1998, having determined that it would be possible to package seedlings so separation was possible while still frozen, a study was undertaken to determine if there would be any negative impact on seedlings if outplanted frozen. An example of how these seedlings are wrapped to achieve separation while still frozen can be seen in Figure 5.

The results of the study are reported in Kooistra and Bakker (2002b). I encourage you to read this paper rather than repeat the results here. If you cannot obtain a copy, please contact me at the address above. Briefly, we observed no detrimental effects from outplanting seedlings while frozen. This study was done in a farm field plot. Some argued that it may not be representative of true forest outplanting conditions. Therefore, the study was repeated on 2 forest sites in 2002. The preliminary results to date support the results of the 1998 study. It appears there are few to no detrimental effects to outplanting seedlings while they are still frozen.

In these trials, we measured variable fluorescence before outplanting and for a number of days after outplanting to determine if frozen seedlings were under different stress levels than thawed seedlings. Variable fluorescence measures the fluorescence signature plants emit when the photosynthetic system is stimulated by light. If plants are under stress, variable fluorescence responses (QY) will be lower;

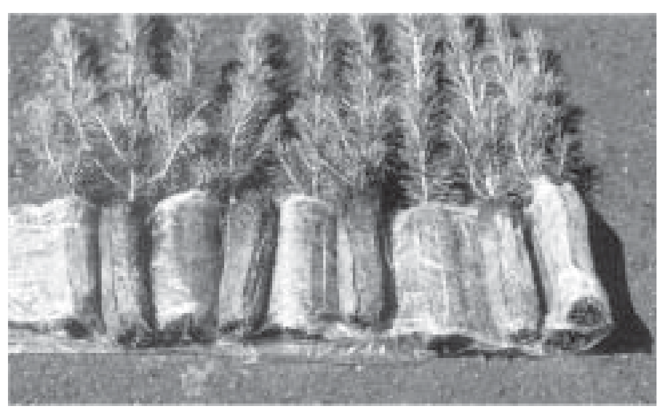

Figure 5—A bundle of “wrapping for planting frozen” seedlings illustrating how the wrap separates each seedling.

this measurement is a good, nondestructive way to determine stress levels in seedlings. It should be noted in the results presented below (Figures 6 and 7), larch (Lw) readings are lower than spruce (Sx) or pine (Pli). This is not due to higher stress levels in Lw, but rather that the measurement taken in this species is of cambial chlorophyll fluorescence as opposed to needle chlorophyll fluorescence in Sx and Pli. The readings for Lw are in the normal range for this type of variable fluorescence measurement.

As in the 1998 study, the 2002 results in Figures 6 and 7 show very little difference among the variable fluorescence readings of either type of seedling. It should be noted that in both studies, the QY readings were slightly higher for thawed seedlings. This is likely due to thawed plants becoming somewhat active by the thawing process, and thus giving slightly higher readings in the first few days. By day 6, there is no difference between thawed and frozen seedlings.

The preliminary data from the end of season measurements are illustrated in Figures 8 and 9. Seedling height (Figure 8) and root collar diameter (RCD) (Figure 9) showed no significant differences between the frozen and thawed treatments across the various trial sites. Initial height and RCD did influence results, as can be seen in the Lw-T results. The differences that were observed in the data so far

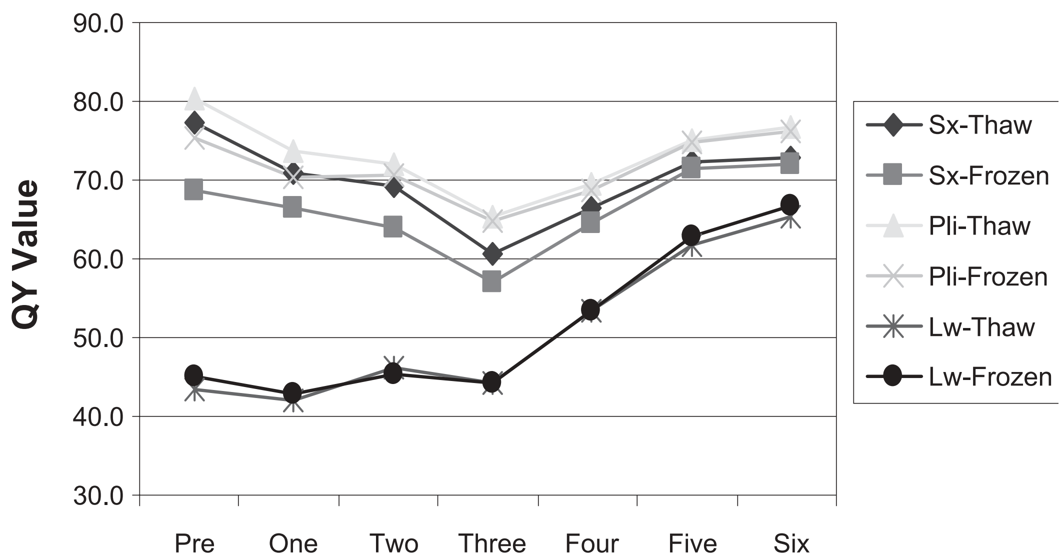

Figure 6—Variable fluorescence for frozen and thawed seedlings in the 2002 Styx Creek outplanting site (Sx = spruce; Pli = pine; Lw = larch).

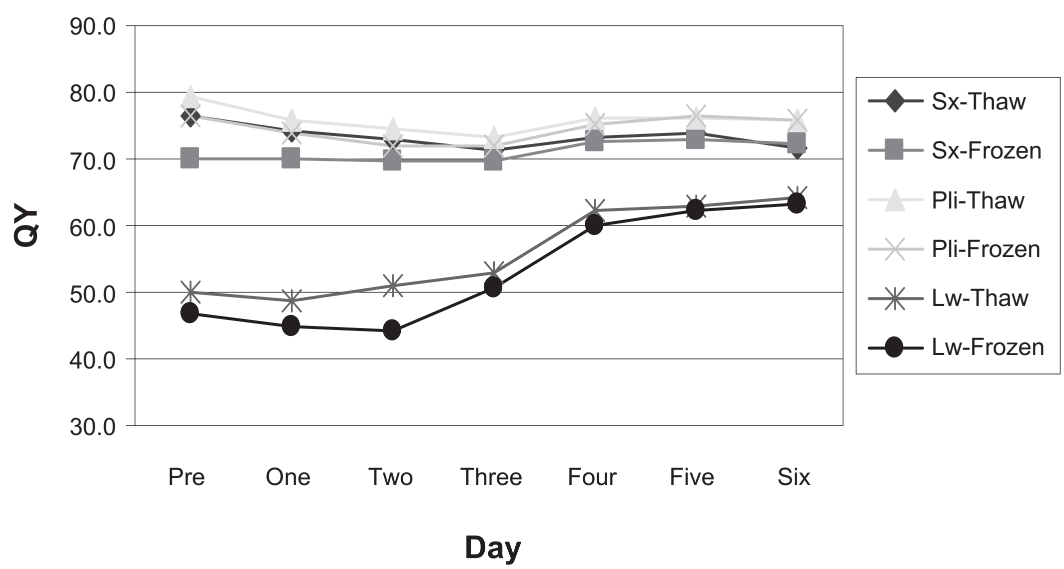

Figure 7—Variable fluorescence for frozen and thawed seedlings in the 2002 South Fork Creek outplanting site.

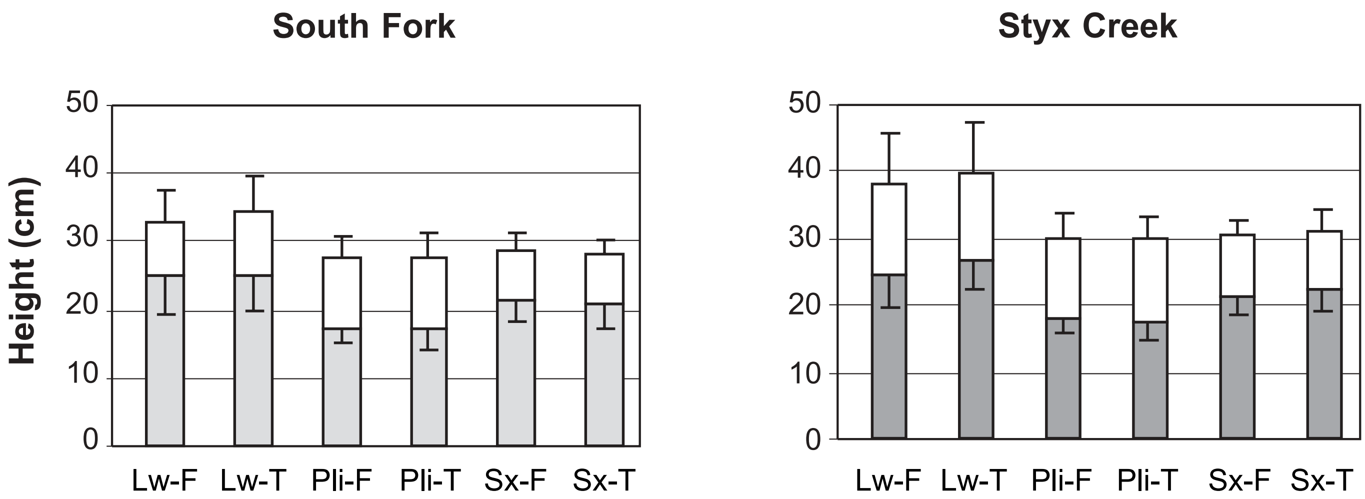

Figure 8—Seedling height for frozen and thawed seedlings at the end of the first growing season in the South Fork Creek and Styx Creek outplanting sites.

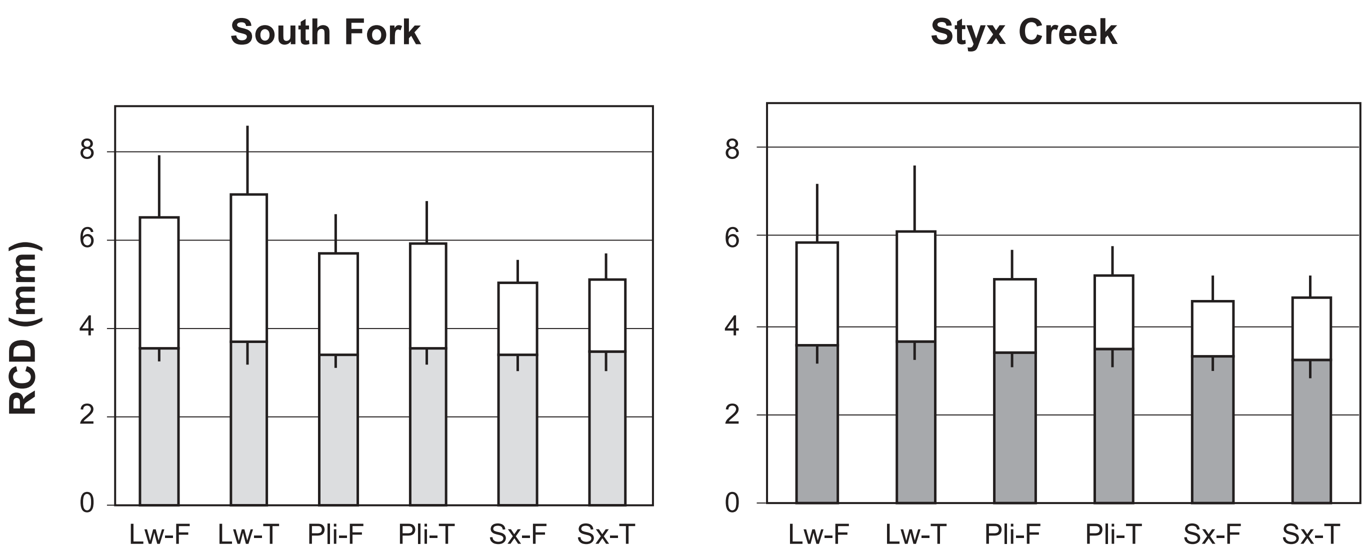

Figure 9—Root collar diameter for frozen and thawed seedlings at the end of the first growing season in the South Fork Creek and Styx Creek outplanting sites.

can be attributed to site differences across the trial plots. It must be stressed this trial is still being analysed and these are preliminary results.

The data from these 2 trials, and the experience from 5 years of increasing operational outplanting of frozen seedlings, indicate that outplanting seedlings while frozen has no significant detrimental effect on survival and performance. It is more likely that this practice may enhance seedling performance through the reduction of stress, while at the same time simplifying spring outplanting logistics. Once operational packaging procedures have been further developed, it is expected that, in western Canada, the practice of outplanting frozen seedlings will continue to expand and become another operational technique employed by those involved in reforestation to ensure and enhance the survival and performance of outplanted seedlings.

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