Container Seedling Storage and Handling in the Pacific Northwest: Answers to Some Frequently Asked Questions

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Abstract: The paper contains a list of 20 questions that seem to arise often in discussions involving storage and handling of container (and bareroot) planting stock. Each question is stated, followed by a response. The questions span a wide range of topics including time of lifting, methods of storage, thawing rates, and effects of storage on seedling quality.

Keywords: freezer storage, cooler storage, carbohydrate reserves, root hardiness, stress resistance, lifting window, under-snow storage, chilling, dormancy

Introduction

For more than 25 years, I have been actively engaged in seedling quality research and operations. Every year the same questions seem to arise around lifting and planting time. These questions relate to various aspects of seedling handling and storage. This meeting of the Western Forestry and Conservation Nursery Association provides an excellent forum at which to provide responses to these questions to a wide audience. Further, their publication in these proceedings will ensure that they are both available and accessible to regeneration personnel in future years.

What Are the Main Methods for Storing Container Stock?

There are essentially 2 methods for storing both container and bareroot planting stock: cooler storage and freezer (or frozen) storage. In cooler storage, stock is held at slightly above freezing—typically +1 °C (34 °F). In contrast, in freezer storage, the temperature is slightly below freezing—typically –1 °C (30 °F). Although separated by only a degree or two, these 2 regimes can have profound effects on seedlings, as we shall see later. One method of cooler storage that was once popular in the Pacific Northwest was "open-bin" storage. Here seedlings were placed into open-topped bins, rather than storage bags or boxes, and held in a large cooler. Generally they were watered to keep them moist throughout the storage period. This method is seldom used today. A variant of freezer storage that is used in parts of Canada and Scandinavia is "under-snow" storage. Containers are placed outdoors on the ground in fall. When covered with snow they can be held at just below freezing throughout the winter months. This method can be very successful and involves low cost.

Is Under-Snow Storage Risky?

Yes, it can be. If snow fails to materialize, stock can suffer from cold damage—especially to the root systems. Although roots do attain a certain level of cold hardiness in winter, they do not harden nearly as much as shoots. Therefore, containerized seedlings are particularly vulnerable to this kind of damage. State-of-the-art snowmaking machines have greatly reduced this risk, but they are expensive. Other speakers at this meeting will address "under-snow" storage more completely.

Is Container Stock Stored Differently Than Bareroot Stock?

Not really. Although there are vast differences in equipment—storage bag designs, handling systems, and the like—the biology of both stock types is very similar. Therefore, storage methods and stock responses to storage are very similar. However, there is one important exception. Container stock tends to be more forgiving than bareroot stock.

How Is Container Stock Storage More Forgiving?

Assuming that container stock is stored with the plug mass intact, this provides a protective cushion around the root system. It buffers the sensitive roots from rapid changes and extremes in temperature and moisture. Further, the plug mass protects the roots to some extent from rough handling and other kinds of physical abuse. But perhaps the main advantage of container stock is that, since it is not grown in the ground, various weather-imposed lifting limitations can be avoided. Frozen ground, rain, mud, and other factors that close the lifting window for bareroot stock are not an issue with container seedlings. It should be possible for growers to lift and pack container stock at the optimum time.

How Do You Determine the Optimum Time for Lifting Container Stock for Storage?

Here are a couple of rough guides for determining the date of lifting for containers:

Freezer Storage

For long term freezer storage (2 to 6 months), wait until the stock has been exposed to about 350 hours of chilling (when temperature is below 42 °F [5.6 °C]). This will ensure that the roots are hardy enough to survive prolonged frozen conditions (Lindstrom and Stattin 1994; Stattin and others 2000). We'll talk more about this later.

Cooler Storage

For shorter term cooler storage, chilling time can be relaxed to about 300 hours.

No Storage

If storage is not involved (that is, lifting for "hot planting") these rules do not pertain and stock can be lifted when it is not actively growing.

In General, How Does Storage Affect Container Stock?

In order to answer this question we need to consider 2 things: 1) how environmental conditions in storage differ from those in the greenhouse or growing area; and 2) how these differences affect seedling physiology.

In greenhouse or outdoor conditions, seedlings are exposed to: 1) daily input of radiant energy as sunlight; 2) daily photoperiod; 3) strong diurnal variations in temperature; and 4) strong diurnal variations in humidity. Contrast this to storage where seedlings experience a prolonged period (perhaps several months) of constant darkness, low temperature, and high humidity.

How Do Plants in Storage Respond to Prolonged Constant Darkness?

First, there is no photoperiod signal to trigger plant growth responses to environmental cues. Fortunately, this does not seem to be a problem. The short day signal that induces dormancy in plants occurs in the greenhouse during summer (Perry 1971). Dormancy release in storage is triggered by chilling, not photoperiod, so the absence of a photoperiod in storage is of little consequence. Second, a far more important issue is the lack of radiant energy for photosynthesis. Seedlings, even when frozen, remain alive in storage. Therefore they continue to metabolize and respire energy (Ritchie 1982). With no photosynthesis occurring, this energy must be obtained from stored carbohydrates. Therefore, the plant must persist through storage on only the carbohydrate it has stored before it was lifted.

How Much Carbohydrate Reserve Is Present When Stock Is Placed in Storage?

Generally, seedlings contain between 150 and 200 mg/g dry weight (15 to 20%) of total nonstructural carbohydrate (TNC) at the time they are lifted in winter. TNC is the carbohydrate fraction that can be burned as food by seedlings. It includes mainly sugars and starch, and does not include cellulose or lignin. During winter, various plant tissues contain different levels of this material, with the highest concentrations occurring in the foliage (Figure 1).

How Rapidly Is This Food Reserve Depleted?

Rate of depletion depends largely on temperature, since respiration has a Q_{10} of slightly above 2.0. Even though cooler storage is conducted at only about 1 to 2 °C (2 to 4 °F) higher than freezer storage, this small temperature difference, over time, is enough to cause more rapid TNC depletion in the cooler than in the freezer. Coastal Douglas-fir seedlings that were held in freezer storage depleted 17 and 28% of their stored TNC after 2 and 6 months, respectively (Figure 2). Cooler-stored trees lost 28% after only 2 months.

What Carbohydrate Concentration Is Critical for Survival?

Unfortunately, I cannot give you a definitive answer to this question. However, there is evidence suggesting that levels as low as 10 to 12% may be near critical. Clearly, TNC levels this low will affect growth performance during the first year after planting. To what extent it affects survival is not known.

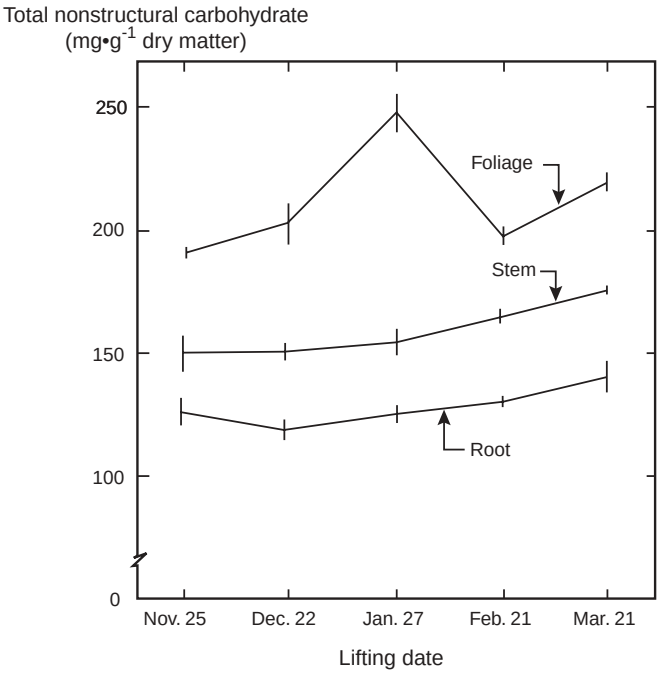

Figure 1—Total nonstructural carbohydrate concentrations in coastal Douglas-fir seedlings during a winter lifting season. Vertical bars are ± 1 SE (redrawn from Ritchie 1982).

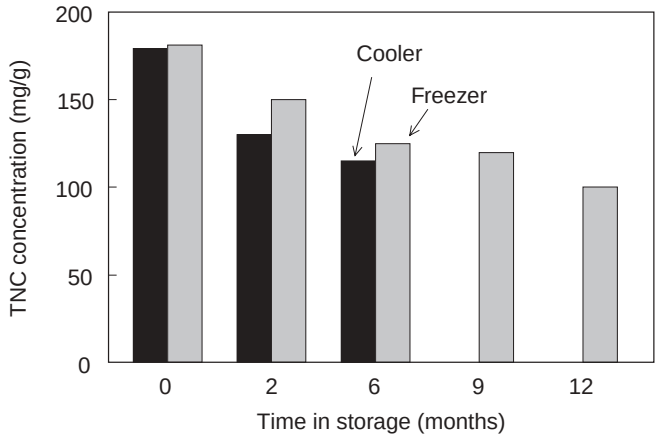

Figure 2—Concentration of total nonstructural carbohydrate in coastal Douglas-fir seedlings. Seedlings were lifted midwinter and placed in either cooler (+1 °C [34 °F]) or freezer (–1 °C [30 °F]) storage for 2, 6, 9, or 12 months (modified and redrawn from Ritchie 1982).

How Does Exposure to Prolonged Cold Affect Seedlings in Storage?

Prolonged cold acts as chilling and, therefore, promotes (van den Driessche 1977), but slows (Ritchie 1984) the release of dormancy. This is because the optimum temperature for dormancy release is 3 to 5 °C (37.5 to 41 °F) (Anderson and Seeley 1993), and storage occurs at a lower, hence less efficient, temperature (Figure 3). Because of this effect, seedlings taken out of storage in say, April, will be much more dormant and stress resistant than those growing in the nursery in April. This is a positive benefit of storage. The other side of this coin is that prolonged freezer storage can injure roots if the plants are not sufficiently cold hardy when they are placed into freezer storage (Stattin and others 2000).

How Does Freezer Storage Kill Roots if the Storage Temperature Is Above the Lethal Temperature for Roots?

Root tissues, like all plant tissues, are compartmentalized into what are called the "apoplast" and the "symplast." The apoplast consists of intercellular spaces, cell walls, and xylem elements. Water in the apoplast is nearly pure so it freezes rapidly. The symplast includes the tissues inside the cell membrane. Symplast water, or cell water, contains dissolved and colloidal material that give it a lower freezing point. When tissue freezes, ice crystals form in the apoplastic water. These crystals, having a very low water potential, draw water out of the cells. This lowers the freezing point of the symplast and both tissues enter an equilibrium state. When the tissue thaws, the ice crystals melt and water moves back into the cells. This is a natural process that can occur daily in winter and does not damage a hardy plant. But in freezer storage there is no thawing, so the ice crystals continue inexorably to grow. Over time this dehydrates cell contents to the extent that they are irreparably damaged. At this point root tissue begins to die.

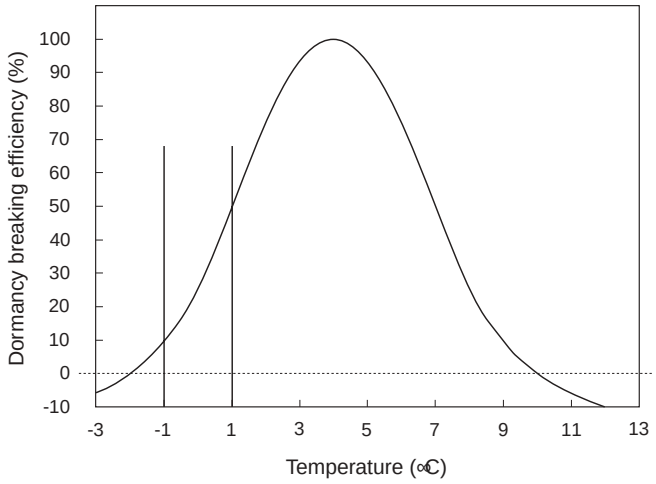

Figure 3—Relative dormancy-breaking efficiency of temperatures between –3 and +12 °C (27 and 54 °F). Seedlings are typically stored between –1 and +1 °C (30 and 34 °F). While temperatures in this range release dormancy, the rate of release is slowed owing to their low efficiency (modified and redrawn from Anderson and Seeley 1993).

How Does Constant High Humidity Affect Seedlings in Storage?

High humidity presents a "good news:bad news" situation to seedlings. The good news is that the constant high humidity in storage bags normally prevents the seedlings from desiccation. This, of course, is very important for stock quality. On the other hand, high humidity presents an opportunity for various storage molds and root diseases to proliferate and compromise stock quality. As a general rule, freezer storage arrests the proliferation of mold and disease on stored stock; cold storage does not.

How Does Cold Storage Affect Cold Hardiness?

This is a very important question because if storage impedes or arrests the development of winter hardiness, then stock lifted early and planted out in midwinter may not be hardy enough to survive low temperatures on the planting site. Unfortunately, I know of no published studies that address this question in a focused, systematic way, so I cannot give a definitive answer. This would make an excellent research topic for a Masters or Ph.D. student.

How Long Can Container Stock Be Stored?

Here are 2 "Rules of Thumb" that I have found useful in answering this question: 1) stock that is lifted early (say, before January) can be successfully freezer stored for up to 6 months; 2) stock should be cooler stored for no longer than 8 weeks no matter when it is lifted. This primarily reflects the mold/disease issue mentioned above.

What Factors Determine Whether You Should Freeze or Cooler Store Container Stock?

The most important factor is probably the availability of a freezer storage unit. Many operators do not have access to these expensive facilities. If such a unit is available, then the key factors are lifting date and desired storage duration. Stock that is lifted early can be either freezer or cooler stored. Late-lifted stock, having lost cold hardiness, is best stored at slightly above freezing. If the desired storage duration is more than 8 weeks, freezer storage should be used. For shorter term storage either method can be used.

How Rapidly Should You Thaw Frozen Container Stock?

The conventional wisdom on this subject is that stock should be thawed very slowly. This is wrong. Thawing rates of frozen stock are very uneven. Seedlings on the outer edges of boxes or pallets will thaw much faster than those in the middle. During this time detrimental things are happening to the thawed seedlings. Heat of respiration is building up; stock is dehardening and rapidly losing stress resistance, exhausting its already depleted remaining food reserves, and possibly desiccating. Also, storage diseases have a perfect environment in which to proliferate. So it is important to keep the thawing period as brief as possible (Camm and others 1995).

Can You Plant Frozen Plugs?

Yes. Studies on several species have shown that plugs can be planted in a frozen condition with no ill effects (Kooistra and Bakker 2002; Kooistra 2004).

Can Stock Be Refrozen Once It Has Been Thawed?

It is not uncommon for foresters to thaw frozen stock for planting only to find that the planting site has been snowed in, or that some other problem prevents the stock from being planted when planned. What to do—refreeze it or put it in the cooler? Neither option seems very tenable. However, my suggestion would be to refreeze the stock if the planting date is unknown or several weeks away. If it is certain that planting will be delayed for only a few days, then cooler storage may be preferable. This is based on assumptions only, and not on good research data. To my knowledge this specific question has not been addressed in a published report. This would make another good student research project.

How Should You Handle Late-Lifted Plugs?

Very carefully. In my experience, late lifting (generally after February) can become very risky. At this time stock is rapidly dehardening, losing stress resistance and beginning to grow (Ritchie 1989). If you find yourself in a situation when late lifting is unavoidable, it is critical to lift, handle, and store stock with extreme care.

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