Seedling Storage, Part II

In the January, 1996 issue we talked about the types of storage and how they must be tailored to the outplanting season. Now, let's take a look at how a knowledge of seedling physiology and some relatively simple measurements can be used to determine the proper time to harvest your seedlings.

Hardiness vs. Dormancy. Nursery managers must know how to harvest their crop at its peak of quality and how to maintain that quality until the seedlings can be outplanted. This means lifting seedlings when they are fully dormant and also resistant to stresses of harvesting, storage, shipping, and outplanting. In the forest nursery business we often use the terms "dormancy" and "hardiness" interchangeably, and yes, there is some overlap - both in physiology and in time. These conditions are NOT the same, however, and it is important that growers understand the differences.

In the temperate zone, seedlings go throu gh a seasonal pattern of active growth in the summer followed by a period of dormancy in the winter. Dormancy has a couple of common definitions:

"a state of minimal metabolic activity", or "any time that a plant tissue is predisposed to grow, but does not". Note that dormancy usually refers to a specific meristematic tissue. Hardiness, on the other hand, can be defined as "a condition of durability, or resistance to stress". Note that hardiness can apply to all types of plant tissues, but the term can also refer to a specific stress, such as cold hardiness. In operational use, however, we usually mean a hardy seedling is resistant to all the various types of stresses that will be encountered during lifting, handling, storage, and outplanting. Although there are some differences, seedlings that are cold hardy are also resistant to other types of stresses.

As we mentioned earlier, there is some temporal overlap between dormancy and hardiness and, in fact, dormancy is a prerequisite to deep levels of hardiness. Although non-dormant tissue can harden to some degree, seedlings cannot achieve full hardiness if they are still growing. In coastal Douglas-fir, the deepest levels of hardiness are reached after the plant has already passed the period of maximum dormancy and is actually coming out of it **(Figure 1).** Of course, in the tropics or semitropics where seedlings never really go dormant,

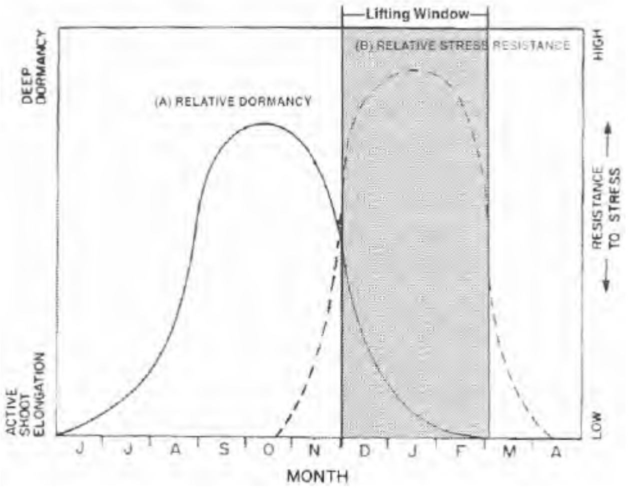

Figure 1. The period of maximum seedling resistance (hardiness) actually occurs after the period of maximum dormancy (Lavender 1985)

there is no lifting window as such but seedlings still can be cultured into a state of peak hardiness so that they can be harvested.

Scheduling the Lifting Window. Our objective then is to measure, or better yet predict, when seedlings are ready to harvest. In forest and conservation nurseries, three different methods of scheduling seedling harvesting have been used:

1. Calendar/experience—Scheduling the harvest according to the calendar is the most traditional technique, and when based on the combined experience of the nursery staff, can be quite effective. The procedure is simple - if it takes 4 weeks to harvest all the seedlings, then that amount of time is scheduled on the calendar based on past weather records and how well seedlings that were lifted on various dates have survived and grown after outplanting.

Unfortunately, the actual lifting window in bareroot nurseries is subject to the vagaries of weather and so will change from year to year. Container growers have easier, especially those with enclosed growing structures, because seedlings can be lifted irrespective of weather conditions. In tropical and semitropical nurseries where weather is not a factor, the seedlings can be harvested as soon as they are large enou gh and after they have been exposed to several weeks of hardening.

Experienced growers use several morphological indicators to help them determine when seedlings are becoming hardy:

- **Foliage characteristics:**

  Determining when deciduous species are ready to lift is easy, because the leaves change color and eventually fall off the seedlings. Even evergreen seedlings show signs when they are becoming dormant, however. For example, the cuticle of leaves or needles becomes thicker and waxier so that the seedling can tolerate desiccation during the winter. Experienced growers can feel when the seedlings are becoming hardy and the needles of some species even show a slight change in color. In spruces, the actively-growing foliage is bright green whereas the dormant foliage becomes bluer in color because of the waxy cuticle that develops on the surface.

- **Buds (presence, size, and number of primordia):**

  Even novice growers know that most seedlings form a bud at the end of the growing season. In the temperataure zone, most people look for large buds with firm scales as an indication of shoot dormancy. This is not the case for some Southern pines, however, where the presence of a bud is not considered necessary. Bud size and length has also been used as a good indicator of when seedlings are ready to harvest and counting the number of bud primordia is one of the ways that Ontario nurseries determine the timing of their harvests.

- **Presence of white root tips:**

  The root system is the last part of the seedling to go dormant and so growers often dig up bareroot stock or extract a few container seedlings to check for new root growth durin g the Hardening Phase. This technique is more useful in the Fall than in the Spring because the roots in postdormant seedlings will grow whenever the temperature allows.

Although it is not too scientific, the calendar/experience method of scheduling the lifting window is popular and widely used because it is simple and usually effective.

2. Time/Temperature—The technique of accumulating chilling hours, or degree-hardening-days (DHD) involves measuring the temperature each day and calculating the amount of time below some reference or threshold temperature **(Table 1).** Note that there can be both positive and negative degree days depending on your objectives. Positive degree days are used to determine insect development where the relative warmth is important, for example for insect development. For our purposes, we are interested in negative degree days (NDD) because we want to track the accumulated chilling below the base temperature. Soil temperatures have been used for base temperatures for bareroot seedlings in Ontario [<10 °C (50 °F) at 15 cm (8 in) depth] and air temperatures [< 5 °C (40 °F)] for container seedlings in Washington. The concept is logical enough - the cumulative exposure of seedlings to cold temperatures should help indicate when they are becoming dormant and hardy.

The chilling hours technique is relatively simple: record the daily temperatures, calculate the chilling hours, and then correlate this numerical index to some measure of seedling quality such as outplanting performance. Seedlings are harvested over the duration of the potential lifting season and outplanted to determine survival and growth. Because chilling hours will vary from year to year **(Figure** 2A), data should be gathered for at least 3 to 5 years. This seedling performance data is then plotted against the accumulated chilling hours, and the resulting graph shows when it is safe to begin lifting **(Figure 2B).** This example from Ontario shows how second year outplanting survival was correlated to DHD's for bareroot jack pine and white spruce, and how this information was used to predict the fall lifting date. Note that the different hardening patterns for the two species which shows that the white spruce seedlings could be lifted almost 3 weeks earlier than the jack pine.

Table 1. Calculating negative degree days with a 40 °F (4.5 °C) base temperature (NDD_{50})

NDD_{50} = 40 °F - [(Maximum daily temperature + Minimum daily temperature)/ 2]

Examples: Day One: 40 °F - (40 °F+ 20 °F)/2 = 40 - 30 = 10 Degree Days

Day Two: 40 °F - (45 °F+ 35 °F)/2 =40 - 40 = 0 Degree Days

Day Three: 40 °F - (50 °F + 40 °F)/2 =40 - 45 = 0 Degree Days*

"Note that average daily temperatures that are warmer than the base temperature still equal 0 negative degree days.

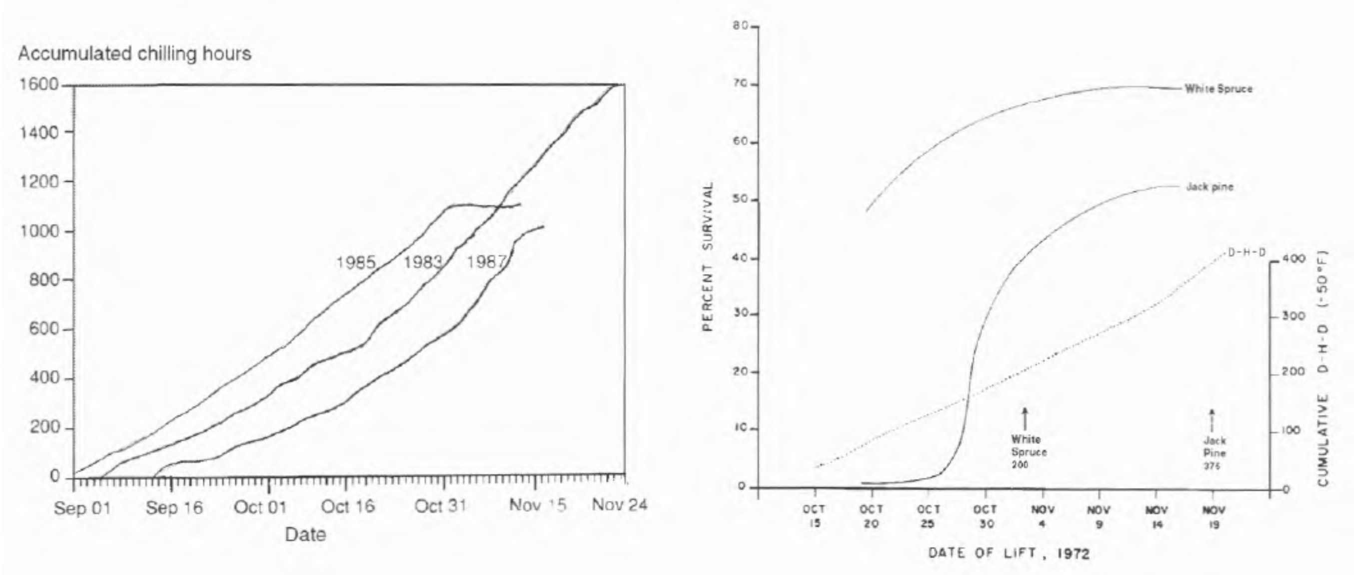

Figure 2 A/B. Accumulated chilling hours or Degree-Hardening-Days (DHD) can vary considerably from year to year as in this data from British Columbia (A), and when compared to seedling performance data, are an easy and practical way to schedule lifting dates: 200 DHD's for white spruce, and 375 DHD's for jack pine from Ontario (B). (A modified from Daniels and Simpson 1990; B from Mullin and Parker (1976).

3. Seedling quality tests—Other nurseries use some test of seedling quality as a index of when it is safe to harvest their stock. You hear so much about the various seedling quality tests that it is easy to forget that *you have to determine exactly what you are trying to measure before deciding on a specific test.* Seedling quality is very a complex subject, and some tests are more appropriate than others - it all depends on what you are trying to measure or predict. Since we are interested in determining lifting windows, then a short turn-around time is essential. You can't afford to wait 3 or 4 weeks for a test, especially for fall lifting in bareroot nurseries where the ground can freeze and put an abrupt stop to the entire season. Another important thing to remember is that many seedling quality tests only measure a certain tissue rather than the entire seedling. While a researcher may be primarily interested in a specific tissue or physiological function, we nursery folks have to deal with the entire seedling. For example, the entire root system of a container seedling could be killed by a unseasonable cold snap but the foliage will appear normal for days or even weeks. A seedling quality test that was run on the foliage buds may not indicate that they seedlings are critically damaged until it is too late.

Root growth potential (RGP), dormancy, and cold hardiness tests have all been used to try and predict lifting windows. RGP is the most famous (and, if you ask me, the most misused) seedling quality test. While it gives us an indication of vitality and relative vigor, RGP readings typically show too much variation to be a practical way of predicting when it is safe to lift.

Dormancy tests, such as the days to bud break and dormancy release index (DRI), are primarily concerned with the physiological status of the buds. While the DRI has been linked to lifting date, it is only being operationally used in a few nurseries. Because it is so closely related to overall seedling hardiness, I believe that cold hardiness tests are the best for the purpose of determining lifting windows.

There are several ways to measure cold hardiness: the whole plant freeze test (WPFT) and freeze-induced electrolyte leakage (FIEL) are the two that currently are in operational use to determine lifting windows. The WPFT consists of freezing seedlings over a range of temperatures, moving them to a greenhouse, and rating their cold tolerance by visible damage after a week. This test is being used operationally in British Columbia where conifer seedlings are considered ready to lift and cold store when they can tolerate freezing to - 18 °C (0 °F) with no more than 25% visible cold injury to the foliage. The FIEL test consists of immersing needle tissue samples in vials of distilled water which are then placed in a freezer where the temperature is gradually lowered. When the temperature reaches the killing point. the cell membranes rupture and the cell contents leak into the water which raises its electrical conductivity. An Index of Injury (I_{50}) is calculated by comparison to a relative scale in which the unfrozen control tissue reading rates 0 and heat-killed tissue rates 100. The USDA Forest Service is currently evaluating the FIEL test as a means to predict the lifting window in 8 different nurseries from across the US, and preliminary results appear very encouraging **(Figure 3).**

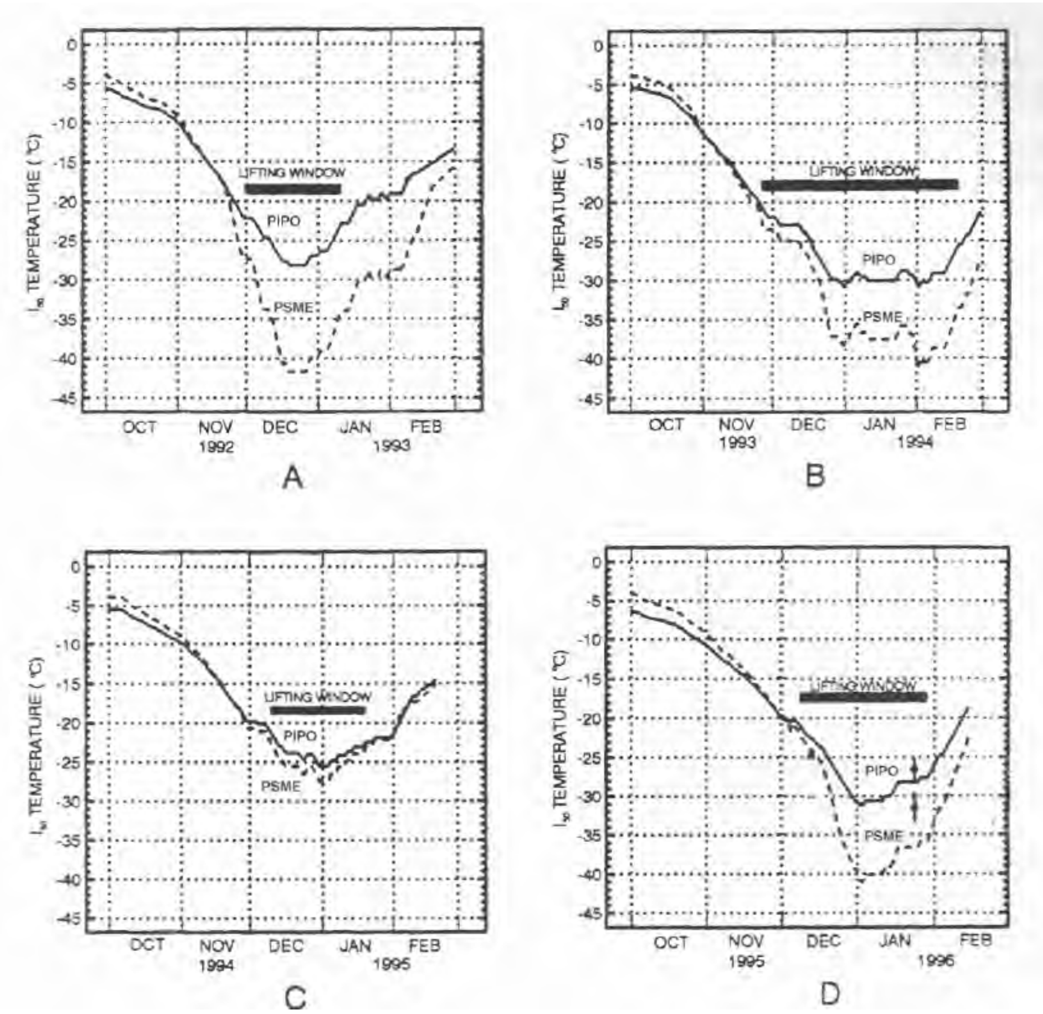

Figure 3. When the cold hardiness of Douglas-fir (PSME) and ponderosa pine (PIPO) seedlings were monitored over four consecutive winters using the Index of Injury (I_{50}) from the freeze-induced electrolyte leakage test, the lifting window was found to vary considerably (modified from Tinus 1996)

Chlorophyll fluorescence (Ch1F) is the newest seedling quality test which has shown promise in predicting the lifting window for some northern conifer species. The technique consists of exposing preconditioned seedlings to high light intensity and measuring the amount of light that is re-emitted or "fluoresced". The beauty of the Ch1F test is that it is immediate, non-destructive, and the newest equipment is portable. The major drawbacks are that ChIF doesn't work on all species, and that interpretation requires a skilled technician. Operational testing in British Columbia appears very promising, however, and it remains to be seen whether Ch1F will be accepted as a practical way to schedule seedling harvest.

Conclusions and Recommendations

Determining when it is safe to harvest seedlings so that they will maintain a high level of quality throughout the storage period is one of the most challenging parts of nursery management. Scheduling the lifting window based on calendar date and personal experience will continue to be used in operational nurseries, but the quality of the stock will occasionally suffer due to the year-to-year variation in seedling hardening rate. Chilling sums are relatively simple and inexpensive to develop but remember that they will vary by species and ecotypes. As far as seedling quality tests go, I recommend cold hardiness tests as the best way to schedule your lifting window each year. Some exciting new research is currently underway which will make cold hardiness testing even easier and faster and Ch1F tests also show promise. Stay tuned, because I'll be reporting on them in future issues of FNN.

Well, now that we have discussed the types of seedling storage and know how to schedule seedling harvesting, we will conclude this series in the next issue of FNN with a look at packaging, monitoring storage conditions, physiological effects of storage, and post-storage handling.

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