The Container Tree Nursery Manual

Volume Seven

Chapter 3
Harvesting

Contents

7.3.1 Introduction

Container nursery managers wait anxiously until they can begin to harvest their crop because, after plants are graded and placed into storage, the value of the crop is at its maximum. Scheduling the best time to harvest is critical because plants need to be at their peak of quality yet hardy enough to withstand the sequential stresses of packing, storage, shipping, and outplanting.

"Lifting" is a historical term adopted from bareroot nursery harvesting when seedlings are physically removed from the soil; the term is still used in container nurseries as an operational synonym for harvesting. "Lift and pack" is another bareroot nursery term that has been adopted by container growers when referring to the harvest operation.

When scheduling plant harvest, the first and most important consideration is whether the stock will be lifted and outplanted immediately ("hot-planted") or harvested when dormant and then stored for later shipment and outplanting.

Methods of harvesting container stock across North America are a function of nursery size and location, plant species, research input, and tradition. Many large nurseries in the Western United States and Canada remove plants from containers and package them ("lift and pack" or "pull and wrap"). They use refrigerated storage to handle large orders that must all be processed simultaneously. This is the case in much of the Pacific Northwest, where winter temperatures are variable and snow is absent or intermittent (for example, Kooistra 2004). In eastern Canada, however, temperatures remain cold enough that container stock can be stored outdoors or some nurseries use snowmaking equipment to supplement the snowpack (White 2004). The harvest and storage of other native plants can be considerably different from commercial conifers. Because of the sheer number of species, the wide variety of container sizes, and the fact that little or no research has been done on dormancy or hardiness, native plants may require special harvest and storage procedures (Burr 2005).

7.3.1.1 Hot-planting

Hot-planting is done during summer or fall, when plants are not completely dormant or hardy; plants must be handled with care throughout the process. This means that stock is lifted, held for a short time with or without refrigerated storage, and outplanted within a week or two. Greenhouse stock that will be hot-lifted is usually held for several weeks in a shadehouse or open compound to develop some degree of hardiness before outplanting (fig. 7.3.1). Some nurseries use moisture stress and/or artificially reduce day length ("blackout") to hasten the hardening process. (More information on hardening nursery stock can be found in Section 6.4.4 of Volume Six and on blackout in Section 3.3.4.6 in Volume Three of this series.)

Timing is the key to a successful hot-planting program, and it is critical to minimize the time from when stock is harvested to when it is outplanted. This tight timeline and the fact that the stock is not fully hardy mean that most hot-plantings must be relatively close to the nursery.

When the customer notifies the nursery that the outplanting sites are ready, the stock is graded to specifications and a final "shippable" inventory is calculated. Plants should be packed standing up in boxes to encourage air exchange and allow for possible irrigation on the outplanting site. Do not pack in plastic liners that restrict air flow and can trap the heat generated by plant respiration. Packed stock

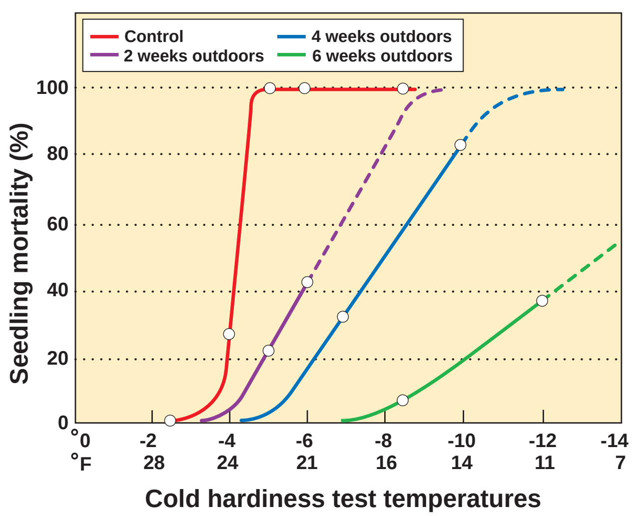


Figure 7.3.1—*All nursery stock must be properly hardened before outplanting, especially those being "hot-planted." The longer these loblolly pine seedlings were hardened in an outdoor compound the more cold hardy they became (modified from Mexal and others 1979).*

should be placed immediately in cooler storage at approximately 4.4 °C (40 °F) (Fredrickson 2003).

For larger planting projects, stock is held for a short period in refrigerated shipping vans at the nursery until the entire order can be shipped. With southern pines, seedlings harvested for summer hot-planting are generally stored at 4 to 21 °C (40 to 70 °F) for a week or less (Dumroese and Barnett 2004). (More information on hot-planting in summer and fall outplanting windows can be found in Section 7.1.2.5.)

7.3.1.2 Dormant stock

Most container nursery stock is harvested during the winter dormant season and stored until it can be shipped for outplanting. Storage methods are discussed in Chapter 7.4. The key consideration in harvesting is whether plants will be placed in open, sheltered, or refrigerated storage. The type of storage dictates not only the time of harvest but also the type of packaging. In open compounds and sheltered storage, plants remain in their containers, whereas, for refrigerated storage, they are typically removed from their containers, graded, and packed in cardboard boxes.

7.3.2 Scheduling the Winter Harvesting Window

Nursery managers must harvest their crop at its peak of quality and know how to maintain that quality until plants are delivered to the customer. This means harvesting when plants are fully dormant and resistant to the stresses of harvesting, storage, shipping, and outplanting. This time period is known as the "lifting window" or "harvesting window."

Foresters and other nursery customers have observed that stock harvested during winter dormancy survive and grow better than plants lifted a few months earlier or later. Numerous inhouse studies and research trials have confirmed these observations. Although most of this research was done with bareroot stock, the same principles apply to container stock. Whereas harvesting bareroot plants at their peak dormancy is usually restricted or compromised by too muddy or frozen soils, container plants can be harvested throughout the winter dormant season. Given this potentially wide harvest season for container stock, let's discuss some ways that growers determine the proper lifting window.

7.3.2.1 Calendar and visual clues

Using calendars and visual clues are the most traditional techniques for scheduling and harvesting, 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 the crop, then that amount of time is subtracted from when the crop becomes fully dormant or is scheduled to be shipped for outplanting. One calendar technique for deciding when to harvest is known as the "F-date," which is based on the average date of the first fall frost. Harvesting can begin 30 to 45 days after this date (Mathers 2000).

Experienced growers also use several morphological indicators to help them confirm when plants are becoming dormant and hardy and ready to harvest.

Foliage characteristics. Determining when deciduous species are ready to lift is relatively easy, because their leaves change color and eventually fall off. Even evergreen species can show foliar signs when they are becoming dormant. For example, the cuticle of leaves or needles becomes thicker and waxier so that the plant can tolerate desiccation during the winter. Experienced growers can feel a difference in foliage texture and rigidity when plants become hardy, and the needles of some

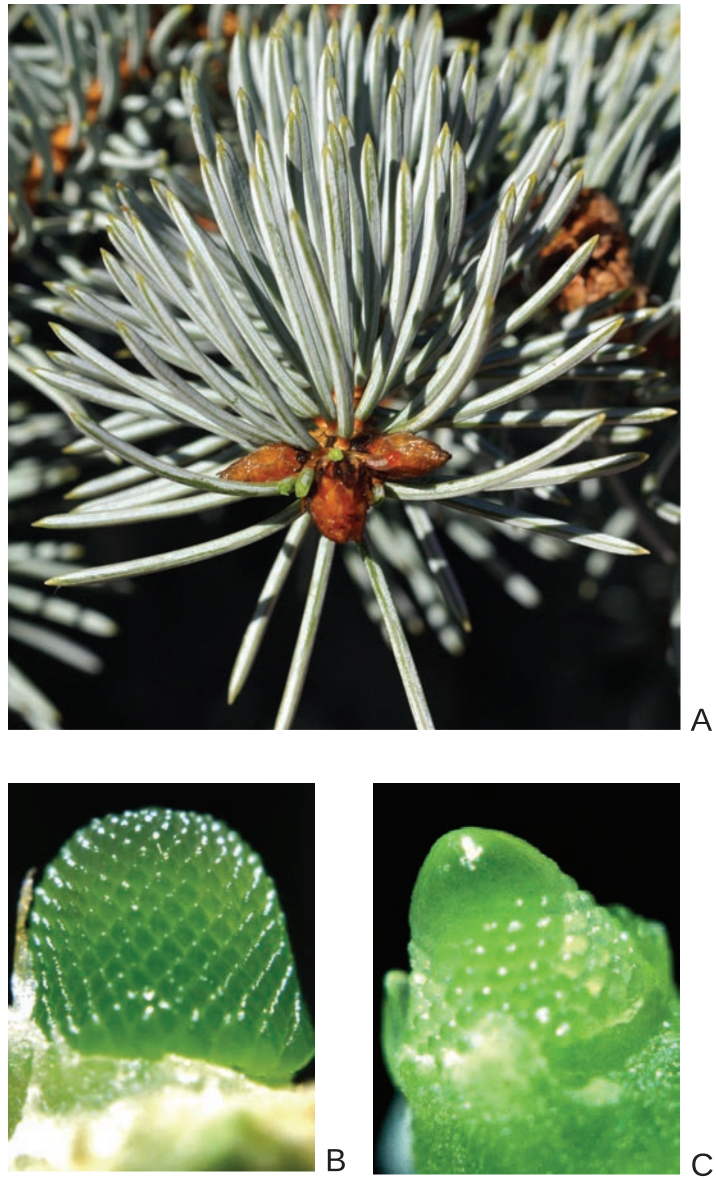


Figure 7.3.2—*Plants develop visible signs of dormancy and hardiness, such as bluish wax deposits on their foliage (A). Bud size and development are also signs of dormancy and plant quality; large buds containing many leaf primordia (B) are superior to smaller, less developed buds (C) (B&C, courtesy of Steve Colombo).*

species exhibit a slight change in color. For example, the actively growing foliage of Engelmann spruce (*Picea engelmanii*) is bright green, whereas dormant foliage becomes bluer in color because of the waxy cuticle that develops on the surface (fig. 7.3.2A).

Buds (presence, size, and number of primordia). Plants with determinant growth patterns, such as pines and spruces, form a bud at the end of the growing season. In the temperate zone, most people look for large buds with firm scales as an indication of shoot dormancy and plant quality. Other plants, such as junipers and cedars, have indeterminant growth and a terminal bud is not formed. Some semitropical pines, such as longleaf (*Pinus palustris*) in the southern United States, also do not form buds in the nursery (Jackson and others 2007). (See section 6.1 in Volume Six for more information on determinant and indeterminant growth patterns).

Bud size and length have traditionally been used as good indicators of when plants are ready to harvest. In Eastern Canada, counting the number of bud primordia is one way that nurseries determine the timing of their harvests (fig. 7.3.2 B&C). KBM Forestry Consultants, a private seedling testing laboratory in Thunder Bay, Ontario, offers bud dissection on a fee basis (Colombo and others 2001).

Presence of white root tips. Some growers consider the presence or absence or white root tips as a sign of plant dormancy. Roots never go truly dormant, however, and will grow whenever temperatures are favorable. Therefore, the presence of white root tips has little value in predicting dormancy or hardiness, but numerous long, white roots indicate that plants have been exposed to temperatures above 10 °C (50 °F) (see figure 7.2.41C).

So, although it is not too scientific, scheduling the lifting window by the calendar and visual clues can be effective if based on actual nursery and field experience with specific plant species.

7.3.2.2 Outplanting trials

Another traditional method of determining when it is safe to lift nursery stock involves outplanting performance. Over a period of years, nurseries can determine their lifting windows from observations on plant survival and growth after outplanting. This technique has been used for bareroot stock, but few results have been published for container plants. In a comprehensive study of four bareroot conifer seedlings from northern California, samples were collected at monthly intervals throughout the winter and then outplanted and evaluated for first-year survival (Jenkinson and others 1993). The resulting data show that lifting windows can vary significantly between species and between seedlots within a species (fig. 7.3.3). Outplanting trials are effective in establishing lifting windows, but the drawback is that it takes from 5 to 10 years to accumulate enough data to account for seasonal weather variation. In addition, separate trials would be needed for customers from different climatic regions.

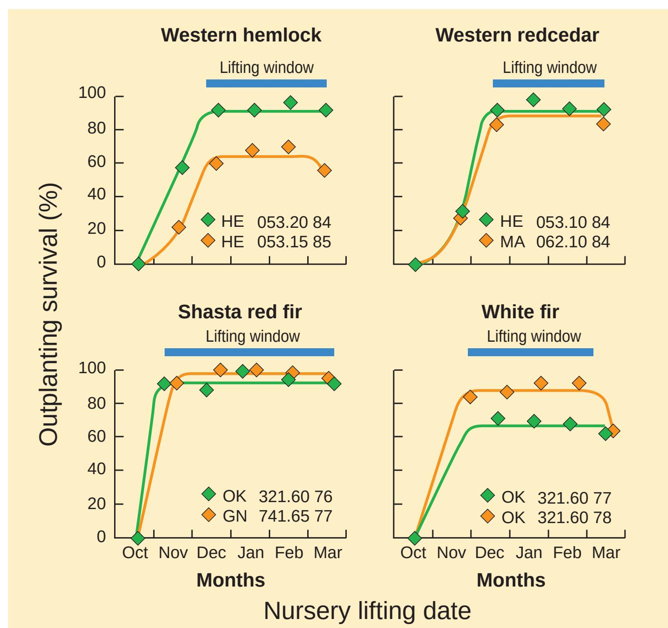


Figure 7.3.3—*An effective but time-consuming way to establish lifting windows is to lift plants throughout the harvest season and monitor their performance after outplanting. These results show that the lifting window for all four conifers was from late November to the end of February. Because they became dormant sooner, high elevation species such as Shasta red fir (*Abies magnifica*) had a wider window than species from lower elevations (modified from Jenkinson and others 1993).*

7.3.2.3 Plant quality tests

Plant quality testing is discussed in detail in Chapter 7.2, and several tests have been used to determine when container stock is ready to harvest. Root growth potential (RGP) is the most widely known quality test, and many experiments have attempted to correlate RGP with lifting windows. Although this test provides an indication of vitality and relative vigor, RGP readings typically vary too much from year to year to be useful.

Estimating bud dormancy with chilling sums. All growers know that plants should be harvested when they are dormant. Unfortunately, growers lack a quick-and-easy test to determine dormancy status—current tests measure only bud dormancy. Therefore, the easiest and most practical method for estimating intensity of bud dormancy is based on the chilling requirement. The concept is logical enough—the cumulative exposure of plants to cold temperatures controls the release of dormancy. Therefore, by measuring the duration of this exposure, it is possible to estimate the intensity of dormancy indirectly.

The operational application is known as chilling sums, or degree-hardening days. The process involves measuring the temperature throughout the day and calculating the duration of time below some reference temperature. This chilling sum can be calculated with several different formulas, and environmental monitoring equipment is available that will calculate chilling sums automatically (see Section 7.2.5.1 for more details).

Cold hardiness testing. It is traditional knowledge that plants should be hardy enough to withstand the stresses of harvesting, storage, shipping, and outplanting. There are many types of hardiness, but cold hardiness has proved to be easiest to measure and the best predictor of when to lift container stock. For more than 20 years, cold hardiness tests have been used to determine lifting windows and estimate storability in Canadian container nurseries. Their critical threshold is when plants exposed to cold temperatures show less than 25 percent visible cold injury to the foliage (Burdett and Simpson 1984). For open storage, plants must be able to tolerate two consecutive frost hardiness tests at –15 °C (5 °F) (Colombo and others 2001; White 2004), whereas for long-term freezer storage, tolerating two consecutive hardiness tests at –15 °C (5 °F) or one at –40 °C (–40 °F) is considered adequate (Colombo and Gellert 2002).

Growth chamber measurements of cold hardiness of Douglas-fir and ponderosa pine container seedlings were modeled against weather data to establish lifting windows (Tinus 1996). Freeze-induced electrolyte leakage tests demonstrated the year-to-year variation in lifting windows that can be expected. Comparing the four years modeled, the starting and ending dates and the duration of the lifting window were significantly different (fig. 7.3.4).

7.3.3 Prestorage Fungicide Treatments

Storage molds are a serious concern during overwinter storage, especially from the fungus *Botrytis cinerea* that is commonly found on lower senescent foliage (fig. 7.3.5A). Therefore, just prior to packing plants for refrigerated storage, some nurseries treat their stock with foliar fungicides.

Unfortunately, both nursery workers and tree planters have complained about skin rashes and other allergic symptoms after handling fungicide-treated stock. The only comprehensive study of fungicide effectiveness and pesticide residue was conducted at container nurseries in British Columbia (Trotter and others 1992). Two fungicides, benomyl (Benlate 50WP) and captan (Captan 50WP), were sprayed on conifer seedlings prior to refrigerated storage using an irrigation boom. In one treatment, both pesticides were applied through a backpack sprayer. They found both fungicides were effective when applied to species predisposed to Botrytis mold. Seedling samples were collected before and after the standard storage period to determine pesticide residue levels. Captan was found to be more persistent than benomyl, and levels were significantly higher when a backpack sprayer was used (fig. 7.3.5B). This short residual effect means that the fungicide is effective only immediately after application and that highly susceptible seedlots may still be infected if predisposing conditions exist during or after storage (Trotter and others 1992).

Therefore, the decision on whether to apply protective fungicides to control storage molds should be considered from both cultural and safety standpoints. Species and seedlots that are already infected prior to harvest may benefit from protective fungicides, but heavily infested or stressed lots may still develop mold problems during or after storage. (See Volume 5, Section 5.1.6.2 for more discussion of molds and other storage problems.)

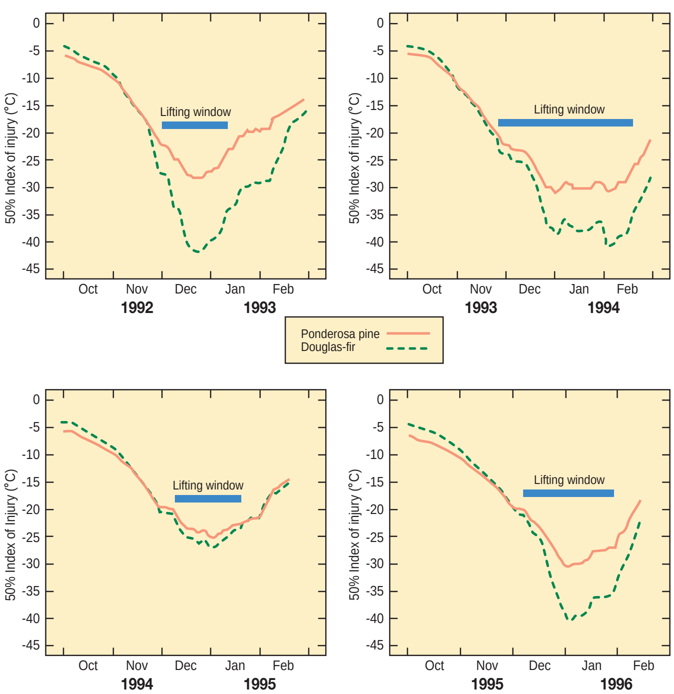


Figure 7.3.4—*Cold hardiness, measured as the 50-percent index of injury from freeze-induced electrolyte leakage tests, was used to model the lifting window for two southwestern conifers over four winters from 1992 to 1996 (modified from Tinus 1996).*

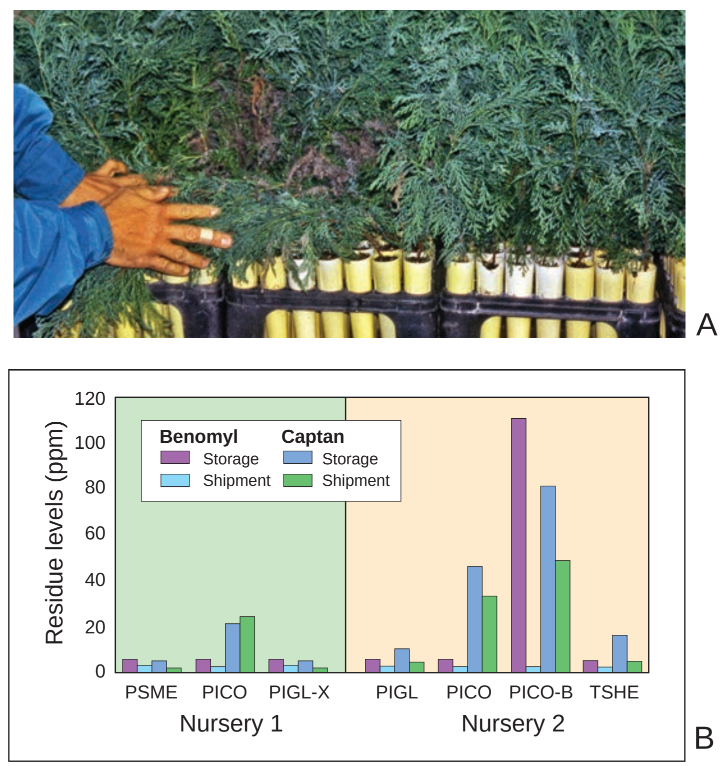


Figure 7.3.5—*Plants grown at high densities often develop Botrytis mold on the lower senescent foliage (A); pesticide residue levels on foliage of stored plants varied by nursery and by application method. All treatments were applied in the greenhouse through an irrigation boom except PICO-B in nursery 2, which was applied with a backpack sprayer (B, species codes: PSME =* Pseudotsuga menziesii, *PICO =* Pinus contorta, *PIGL =* Picea glauca, *PIGL-X =* Picea glauca x engelmannii, *TSHE =* Tsuga heterophylla) *(modified from Trotter and others 1992).*

7.3.4 Processing Speculation and Contract Crops

The manner in which container stock is processed depends on how the crops will be sold and shipped.

7.3.4.1 Small speculation orders

Some nurseries, such as State government and private nurseries, service many, perhaps thousands, of customers who order a few plants of many different species. Plants to satisfy these orders are usually grown on speculation, and orders are accepted throughout the winter and spring shipping season. To facilitate filling and processing orders, plants are usually harvested, graded, packaged into discrete quantities (for example, 5 or 25; usually the minimum number that can be ordered), and then stored in bulk bins in a cooler. As orders come in, workers pull plants from the bulk bins and combine the various species for shipping, often by mail or parcel service.

7.3.4.2 Large contract orders

Many Federal government and forest industry nurseries grow all or most of their container plants on contract and so grade, package (often 100 to 500 plants per box), and store their stock in the same operation by customer. Depending on the customer preference and the length of storage, these orders may be held in cooler or freezer storage.

7.3.5 Grading and Packaging

Regardless of whether container plants are going to be hot-planted or outplanted as dormant stock, they are graded for size and appearance according to established standards or, in the case of contract stock, standards agreed to with the customer (see Volume 1, pages 147–149). "Culls" are plants that do not meet the grading criteria. Sometimes these criteria are adjusted during the grading process based on other cull and shipping factors that become apparent during the process. Typical grading criteria include shoot height, stem diameter at the root collar ("caliper"), and root plug integrity (fig. 7.3.6). In addition, plants are inspected for physical injury or disease, especially for gray mold (*Botrytis cinerea*) that can spread in storage.

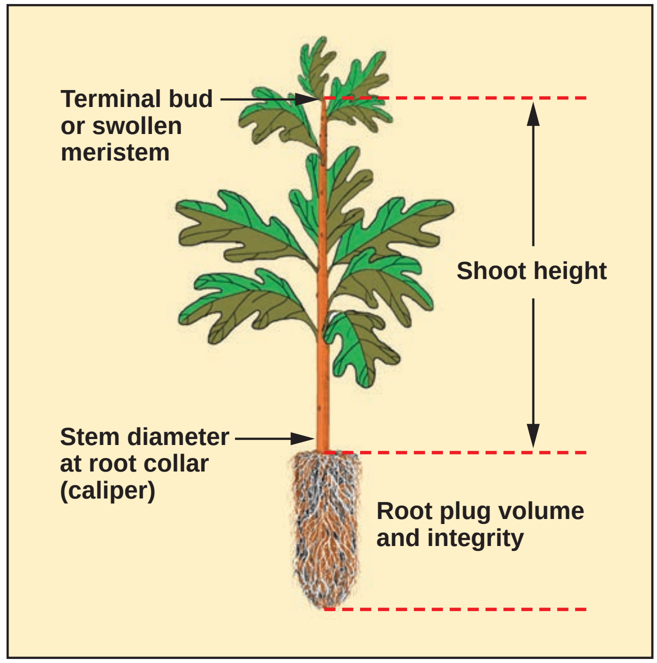


Figure 7.3.6—*Common grading standards include shoot height, stem diameter at the root collar ("caliper"), and root plug integrity.*

The timing of the grading operation depends on the harvesting methods. To minimize volume and reduce disease during storage, most container nurseries grade their stock as part of the harvesting process. Some nurseries that store in open compounds ship ungraded stock to the outplanting site, where they are graded immediately before outplanting (Dionne 2006).

Container size and the way plants will be packaged and stored determine the best processing system. For smaller volume containers, plants can be processed two ways: (1) grading, storing, and shipping plants in the growth container; or (2) extracting ("pulling" or "lifting") plants from the growth container and subsequently grading, packaging, and placing them into storage and/or shipping containers (Landis and McDonald 1981). Because of their size and weight, larger volume single containers are graded and handled individually.

7.3.5.1 Storage and shipping in growth container

This process is generally limited to container types with individual soft plastic "cells" or "tubes" that are held in hard plastic racks. The most popular containers of this type are Ray Leach "Cone-tainers"™ and Deepots™ (fig. 7.3.7A). The harvesting process consists of removing each container from the rack, grading the plant within it, and then placing the container into either a "shippable" or "cull" rack (fig. 7.3.7B). Racks of shippable plants are stored outside either in shadehouses or under white plastic sheeting (see Section 7.4) until they can be shipped for outplanting. Cull racks are emptied as time permits. Because the plastic racks are brittle and can be damaged during handling and shipping (fig. 7.3.7C), some nurseries group shippable containers into bunches secured by a rubberband or put them in plastic bags (fig. 7.3.7D), which are then placed in cardboard boxes for refrigerated storage.

Some nurseries using block containers also leave graded plants in the growth containers for storage and shipping to the outplanting site. This is particularly common with the more durable hard plastic blocks, such as the Hiko™ tray, IPL Rigi-Pots™, and Ropak Multi-Pots™. In some nurseries, cull plants are pulled from containers during the grading process but, in others, no grading occurs and all plants are shipped to the outplanting site, where the planter makes the final decision regarding plant quality (Dionne 2006).

7.3.5.2 Plant extraction

As mentioned earlier, container plants are typically extracted from their growth container when they will be stored under refrigeration, but often hot-planted stock is

A

B

C

Figure 7.3.7—*Harvesting nursery stock in the growth container is popular for soft plastic cells that can be removed from their racks (A), graded, and consolidated into "cull" or "shippable" racks (B). Containers shipped to the outplanting site must be returned to the nursery, which can result in damage (C), so some nurseries pack the individual cells into plastic bags (D) and cardboard boxes.*

D

extracted as well. "Pull and wrap" is most common with large block containers, such as the Styroblock™ because extracting plants reduces the volume of space needed during storage and shipping. Harvested, dormant plants can be stored for up to 6 months, so extraction allows the used containers to be cleaned and sterilized for the next crop.

In smaller nurseries, the process of extracting plants from their containers, grading them, and packaging them is often done at individual workstations. Each station is equipped with a rack or clamp that holds the container block or tray in place while the workers pull and grade plants (fig. 7.3.8A). In larger nurseries, however, the sequence of tasks is combined into "grading and packing lines." Different workers, connected by conveyors (fig. 7.3.8B), are responsible for extracting, grading, and packaging.

Grading and packing has become more mechanized in order to reduce both labor costs and the high incidence of workplace injuries. Many forest and conservation plants have aggressive root systems and develop a firm plug by the end of the growing cycle. Roots of some species even grow into small holes in the walls of the container cavities, especially with Styrofoam™ blocks. This makes extracting plants by hand difficult, and nursery workers on the packing line often develop tendonitis and other chronic wrist and lower arm injuries. To facilitate extraction, some nurseries use mechanical "thumpers" that use a jolting motion to loosen the plugs from their containers (fig. 7.3.8C).

Another reason that plants are difficult to remove from containers is that roots often grow out of the drainage hole and form a mat (fig. 7.3.8D). To facilitate extraction, some nurseries run the container blocks over a rotating blade to sever the root mat (fig. 7.3.8E). It is much easier to prevent this by designing greenhouse benches that promote air-pruning of roots.

The extent of mechanization of the packing line varies by nursery size and sophistication. Larger nurseries often use pin or rod extractors to physically push one row of plants at a time out of the container and onto a conveyor belt, where they are graded (fig. 7.3.9A). Culls are discarded on the floor, whereas shippable plants are counted into bunches of 5 to 25. At the end of the conveyor, another worker collects the bunches and packages them.

7.3.5.3 Packaging plants

Three common packaging systems are used for native plant nursery stock.

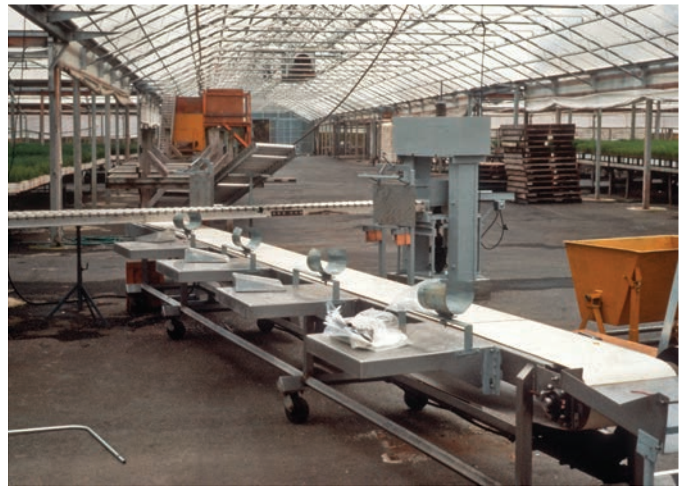
Jellyrolling. In this first packaging system, bunches of plants are placed in a cradle and their root plugs are tightly wrapped with a protective material (fig. 7.3.10A). The jellyroll bundles are then stacked into carboard boxes for storage and shipment to the outplanting site (fig. 7.3.10B). Jellyrolling has been used for decades to protect the fine roots of bareroot stock from desiccation (Dahlgreen 1976), and research has shown that moisture stress is lower for jelly-rolled conifer stock (fig. 7.3.10C). Wet burlap and absorbent paper toweling was traditionally used, but cellophane is preferred for native plants that do not form a durable root plug. A field trial with *Ambrosia dumosa* seedlings found that jellyrolling improved their moisture status during shipping and outplanting, and that they survived and grew as well as plants shipped in containers (Fidelibus and Bainbridge 1994). The most obvious advantage of jellyrolling is that containers are not damaged or lost during the outplanting process. For polybag plants grown in native forest soil, shaking the soil from the root system, dipping the roots into a superabsorbent slurry, and jellyrolling greatly reduced the volume and weight of pine seedlings. In addition, it allowed the soil-based media to be sterilized and reused, saving the cost of procuring more media and reducing the impact on the forest environment (Mexal and others 1996).

With the recent interest in shipping frozen nursery stock to the outplanting site, jellyrolling single plants keeps them from freezing together.

Bagging and boxing. In the second packaging system, automatic bagging machines hold a supply of plastic bags that are automatically inflated by a flow of air, making it easier to insert plants (fig. 7.3.9C). In general, when bags of plants will be placed into plastic-lined boxes for storage, as is the usual case for contract crops, then the bags are just deep enough to enclose the root plugs to facilitate handling. When bundles of plants will be stored in bulk bins (fig. 7.3.11A), as is often the case for speculation crops, then the bags are large enough to enclose the entire plant, especially for evergreen crops, to retard desiccation (fig. 7.3.11B).

A

Figure 7.3.8—*Each grading station in the "pull and wrap" operation has a rack to secure the containers (A). In larger nurseries, grading stations are part of grading and packing lines, which increase efficiency (B). Because plants are often difficult to pull from containers, such as the Styroblock™, they are first run through a "thumper" that loosens the plugs (C). If roots have formed a mat at the drainage hole (D), they must be trimmed to ease extraction (E).*



B

C

D

E

Figure 7.3.9—*In more mechanized nurseries, plants are pushed from their container one row at a time by a pin extractor (A). After grading, plants are counted into bundles that are either wrapped in cellophane (B) or placed into a plastic bag (C). In the final step, bundles are placed into cardboard or plastic boxes that protect the stock during storage and shipping (D).*

Boxing. In the third packing system, which is commonly used in the southern United States, container plants that are going to be hot-planted are often extracted and placed directly into shipping boxes without any type of plastic bag (Dumroese and Barnett 2004). These plants are lifted, stored for a very short time in a cooler, and outplanted before transpiration and desiccation reduce plug moisture to an unacceptable level.

The final step in the grading and packing process involves placing the plant bundles into storage or shipping boxes or bins (fig. 7.3.9D), and marking them with the species, seedlot, number of plants, and other important information.

7.3.5.4 Processing large-volume container stock

Because of their size and weight, large container stock are typically processed one at a time and accumulated in a shadehouse or open compound until they can be shipped (fig. 7.3.12A). Although large ornamental nurseries often store their stock under refrigeration, this is not common in forestry or native plant nurseries. Square containers, such at Treepots™, are graded and stored in special metal pallet racks or in plastic crates (fig. 7.3.12B) until they can be shipped for outplanting.

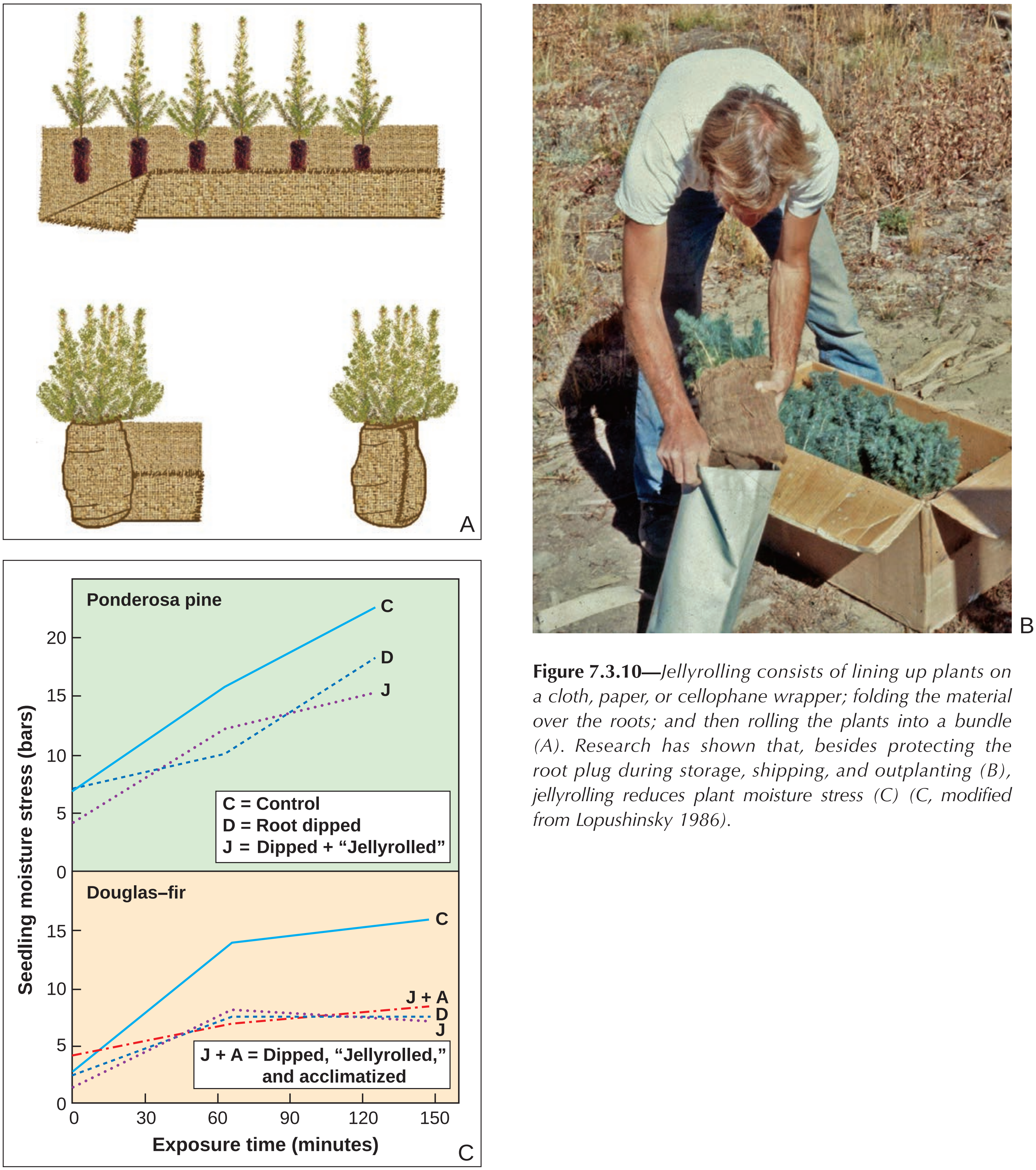


Figure 7.3.10—*Jellyrolling consists of lining up plants on a cloth, paper, or cellophane wrapper; folding the material over the roots; and then rolling the plants into a bundle (A). Research has shown that, besides protecting the root plug during storage, shipping, and outplanting (B), jellyrolling reduces plant moisture stress (C) (C, modified from Lopushinsky 1986).*

Figure 7.3.11—*When crops will be bulk-stored for later repacking and shipping (A), plants are completely inserted into deeper plastic bags to retard desiccation (B).*

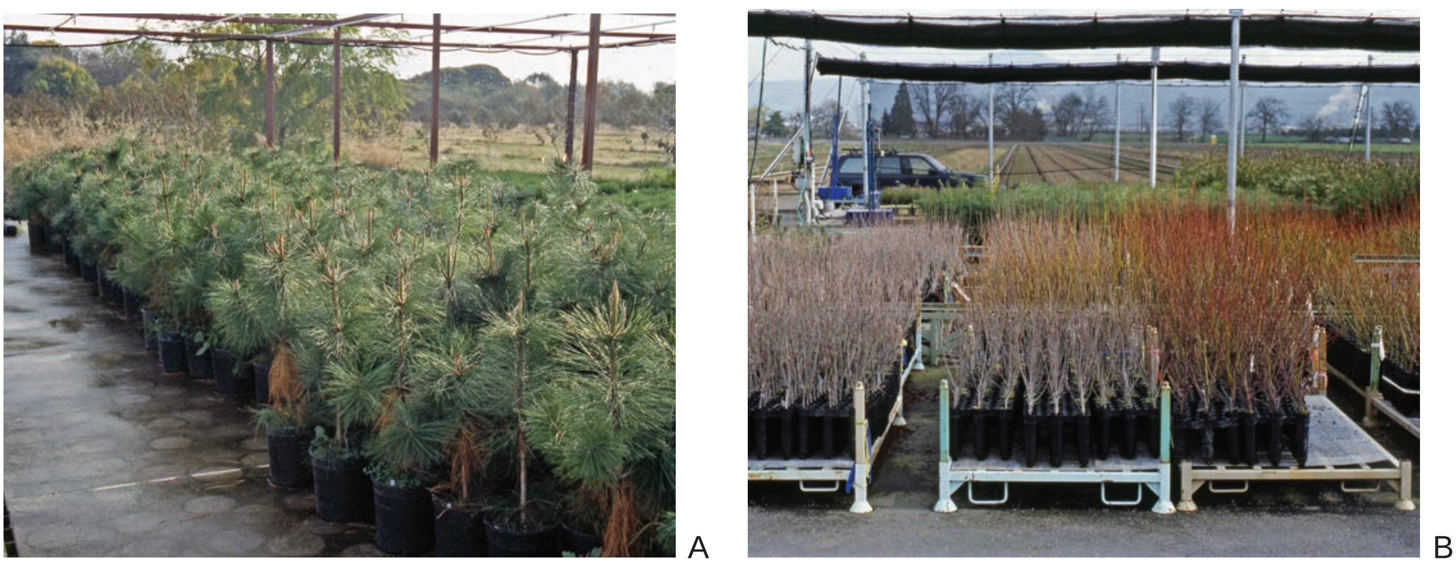


Figure 7.3.12—*Large container plants are often graded in the shadehouse (A) and stored on racks until they can be shipped (B).*

7.3.6 Packaging for Storage and Shipping

Figure 7.3.13—*Waxed cardboard boxes make handling easier and storage more efficient (A). A plastic bag liner (B) is absolutely essential for long-term freezer storage because moisture is drawn out of plants and condenses on the side of the containers (C).*

The typical storage box is made of corrugated cardboard that has been treated with plastic or wax to make it waterproof (fig. 7.3.13A). Some nurseries use corrugated plastic boxes that, although they are more expensive, are reusable (fig. 7.3.13B). Even nurseries that ship stock to the outplanting site in the growth container often put stock in boxes for additional protection against mechanical injury. Boxes are the standard for refrigerated storage of pull-and-wrap container stock but, because they are not moisture-proof, a thin (1 to 2 mil) plastic bag liner is needed (fig. 7.3.13B). With freezer storage, this thin plastic bag liner is mandatory to prevent desiccation injury because refrigeration equipment continually removes excess moisture from the storage rooms (fig. 7.3.13C).

7.3.7 Processing Cull Seedlings

Figure 7.3.14—*Cull plants can be ground in a tub grinder and composted.*

At each grading station, cull plants are dropped on the floor or tossed into a bin. If there is a market, undersized but otherwise healthy plants can be transplanted into larger containers. This is common with cultivars that can be outplanted over a large geographic area or with threatened or endangered species, when every plant is valuable. Most forest and conservation plants come from a specific seed zone ("source-identified"), however, and so are only adapted to a rather restricted area. In addition, most forestry and native plant projects outplant all their stock in one season, so there is no market for holdover plants.

Therefore, most nurseries compost their culls for reuse as a soil amendment. Because the woody stems and roots would take years to decay, culls are run through a hammer mill or tub grinder to hasten decomposition and speed up the composting process (fig. 7.3.14).

7.3.8 Summary and Conclusions

Plants may be harvested, graded, packaged, and stored in a variety of ways depending on the timing of the outplanting window, the type of container used to produce the plant, and the convention used in a particular locale developed through research and/or experience. Plants harvested during the growing season with minimal dormancy and stored for just a few days with or without cooler storage are said to be "hot-planted." More often, plants are harvested when dormant and are stored for a few weeks to months in refrigerated storage. Nursery managers can determine when plants are dormant using the calendar, visual clues of the plants themselves, outplanting trials, or plant quality tests. Calculating chilling sums for a crop and correlating those with the results of plant quality tests is probably the best way for managers to ensure crops are dormant prior to harvesting.

Many factors influence the harvesting process, including nursery size and mechanization, customer base, container type, plant growth form, whether plants are extracted and subsequently placed in bags or jellyrolled, storage conditions, and local success derived from research and/or experience. For example, State and private nurseries often grow plants on speculation; those plants are extracted from containers, bundled in groups consistent with minimum orders, bulk-stored in coolers, and then packaged for shipping as orders are received. Conversely, large, reforestation nurseries usually grow plants on contract, extract them from containers, and store them in coolers or freezers until outplanting, unless those nurseries are in the Maritimes of Canada, where plants are retained in containers and stored in outdoor compounds. Many native plant nurseries grade and ship plants in their containers, particularly for species that do not produce robust root systems. As is evident, the harvesting process is dictated by many variables, but the goal of harvesting is always the same: get the crop from the nursery to the field without reducing plant quality.

7.3.9 Literature Cited

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