Seedling Lifting, Packing, and Storage at the ArborGen Bluff City Nursery

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Outline

Facing Page: *The hardwood seedling harvesting process at the ArborGen Bluff City Nursery. (Photo courtesy of Chase Weatherly, 2017.)*

Nursery Description

The ArborGen Bluff City Nursery is located in Nevada County in southwest Arkansas, approximately 4 miles south of Bluff City and approximately 3 miles west of White Oak Lake. The nursery has an average elevation of 375 feet (ft) (114 meters [m]) (mean sea level). The dominant soil type falls within the Darden series. The nursery was developed in 1980 and currently grows approximately 40 million bareroot loblolly pine seedlings and over 4 million bareroot hardwood seedlings annually.

Cultural Operations To Improve the Lifting Process

Several cultural practices are used to condition hardwood seedlings for proper lifting and planting, including top pruning, undercutting, lateral pruning, and the use of water stress to condition seedlings for outplanting.

Top Pruning

Top pruning is performed during the months of June to September in order to improve seedling quality. This process slows the top growth of the taller seedlings, allows smaller seedlings to catch up in overall height, and results in a more uniform crop size by the end of the growing season. In addition, it is believed that when seedling stems are cut back, the lower portion of the stems, as well as the root systems, become more robust and produce a higher quality seedling. Care is taken, however, to ensure that top pruning is not too aggressive such that the cut extends into woody tissue, which can damage the seedling and prevent proper growth afterwards. Also, top pruning opposite branched species results in the undesirable characteristic of multiple main stems, while alternate branched species generally maintain the apical dominance of a single stem.

A final seedling height of 18 to 24 inches (in) (46 to 61 centimeters [cm]) will meet most customer seedling specifications. Seedlings that fall outside this range are not necessarily culls, but the target height will generally fall between this upper and lower limit. There are many cases where customers will accept seedlings shorter than 18 in (46 cm), and there are also cases where customers request seedlings taller than 24 in (61 cm). Good communication with customers helps the nursery be prepared for its seedling size requirements.

Top pruning requires a tractor with a high ground clearance so the belly of the tractor passes over the taller seedlings later in the year without damaging the stems. A 6 ft (1.83 m) finishing rotary mower, modified so that it can be leveled out at the desired cutting height in the seedbed is used for top pruning. The PTO shaft / gear box may need to be adjusted to prevent the power take-off (PTO) shaft from pinching or rubbing the frame of the mower due to the height of the mower on the tractor. The three-point hitch brackets on the mower can be adjusted to allow for a higher operational height. The blades of the mower can be altered from the manufacturer specifications by increasing the cutting angle to be more aggressive, as well as extending the edge of the blade further along the shaft. Altering the blade can be extremely helpful in creating a clean cut on the seedling stem. When hardwood seedling stems are cut while top pruning using a dull or improperly angled blade, the top of the stem "shatters" instead of producing a nice smooth cut. This shattering of the stem can cause further tip dieback and can hinder regrowth of new tissue.

Undercutting

Hardwood seedling roots tend to grow deeper than what is desired for proper lifting and outplanting success. Therefore, undercutting is normally done between October and early November with the use of a reciprocating blade machine. The target root length is generally 8 in (20 cm), which meets most customer hardwood specifications although the depth can be modified to meet customer requirements. It is believed that undercutting will create a more fibrous root system, which improves outplanting success. The process of running a reciprocating blade beneath the seedling will also break up the soil around the root system which aids in the lifting process by ensuring a looser soil to pull from.

Undercutting is best performed under wetter conditions so that the soil is able to give way to the blade as it passes through. Too wet and the tractor can create very deep tractor paths and roots could "pull" instead of being cut off by the blade. Too dry and the blades may break prematurely as well as ride up above any hard pans and cut root systems off too short. It is best to test various moisture conditions to determine what works best for specific combinations of soils and equipment. Usually 2 to 4 hours of watering, equaling 1/2 to 1 in of rainfall (13 to 25 mm) the night before undercutting will provide the proper moisture.

As with top pruning, a tractor with high clearance is used to minimize the potential for seedling damage when passing over the stems later in the season, when most seedlings have already reached a height between 18 to 24 in (46 to 61 cm). Reciprocating undercutters have a lot of moving parts that receive tremendous stress during operation, so proper calibration and maintenance is of utmost importance. A spare parts list is kept current so that operations are not shut down due to a lack of parts inventory. Items such as blades, bearings, blade brackets, gear boxes, and rebuild kits for gear boxes are primary items to have in stock. Blades are very sharp, so cut-resistant gloves are available and their use is required for any worker handling the blades.

Lateral Root Pruning

Lateral pruning is normally the last cultural practice completed before lifting season and is done during mid-November to early December. Cutting the lateral roots between drills produces a more compact seedling that lifts easier and helps the tree planters get the entire root system into the planting hole, which is essential for good survival. Lateral root pruning also results in a more fibrous root system. The specific lateral pruner used is made by Silver Mountain Equipment Inc. and has only been modified to lateral prune beds with five drills, which requires six blades. This lateral pruner can be steered from the rear so that the blades stay between the drills. A well-trained and seasoned tractor driver and lateral pruner operator are essential to this operation, as there is little room for error when cutting lateral roots between drills spaced so close together.

As with undercutting, lateral pruning is best done in moist soils, which allows the disc blades to fully penetrate through the root system. The amount of soil moisture necessary depends on the soil type and lateral pruner being used. Heavier soils may require more moisture as compared to sandier soils. The ArborGen Bluff City Nursery will usually require 1 to 2 hours of irrigation the day before lateral pruning a field so that the blades will penetrate to a depth of 8 to 10 in (20 to 25 cm). Care should be taken to ensure the disc blades cut to the depth where the undercutting blade previously passed. This will ensure that lateral roots are fully pruned between drills. Failure to do this could create issues during the lifting process, when longer-than-desired lateral roots intertwine with root systems from adjacent seed drills.

Water Stress Manipulation

Water stress can aid in the development of a more fibrous seedling root system, as well as help condition seedlings for the stresses of outplanting. This practice usually begins in late August and may continue through to lifting. The idea is to manipulate soil moisture so there are periods of wet and dry conditions through the top 10 in (25 cm) of the soil profile. Root systems growing in overly saturated soils tend to be less fibrous, lack adequate mycorrhizal formation, and are often diseased. Later in the growing season (mid-August to early September) and when weather conditions are favorable (warm and dry), soil moisture can be manipulated such that wet periods are followed by extended dry periods, which should trigger seedlings to push their root systems deeper in the soil horizon to look for available moisture.

Considerable knowledge of nursery soil conditions and the use of soil moisture probes and/or sensors at various depths is necessary to correctly manipulate water stress conditioning. The ArborGen Bluff City Nursery installs soil sensors at 3-, 6-, and 10-in (7.5-, 15-, and 25-cm) depth in a soil that represents average drainage conditions. The soil sensor used is a Watermark model 200SS that can be easily installed following the manufacturer's instructions. These sensors measure soil moisture tension in centibars by using electrical resistance. Once it is verified the sensors are working correctly (based on manufacturer instructions) and the seedling crop has reached the target size or is on track to reach target size, irrigation can be manipulated in such a way that the soil is quickly saturated through the soil profile to at least 10-in (25-cm) depth, thus mimicking a heavy rain event. Once the irrigation water has percolated to at least 10 in (25 cm), water is completely shut off and soil moisture monitored using the installed sensors. The process seeks to create very dry soil in the upper 3 in (7.5 cm) of the soil profile and moist soil at 6 to 10 in (15 to 25 cm) of the soil profile. This cycle normally takes 7 to 10 days and then should be repeated. There should be no irrigation other than the initial start to the cycle.

Creating water stress in a seedling crop can be very detrimental to seedlings if done improperly and requires experience, close supervision, and guidance. Soil moisture sensors/probes are critical to fully understanding what is happening in the soil profile, and daily observations are essential. Every nursery field and crop is different, and the above process should be adjusted to fit the site and the species being grown. Oaks and other large seeded species respond well, whereas smaller seeded species tend to need watering more frequently without being harmed. Anyone attempting to use the process of water stress manipulation should establish a protocol and proceed with caution while developing confidence in the process for his or her soil type and species.

Timing of Lifting and Outplanting

The timing of hardwood seedling lifting is determined by the dormancy of the species to be lifted. Seedlings that have not reached an acceptable level of dormancy in the nursery before they are lifted will be at more risk of having poor survival once outplanted. In the same way, seedlings that break dormancy in late winter through early spring can also have poor survival. Historically, the "window" for safely lifting, storing, and shipping hardwood seedlings for outplanting falls between early December and mid-March. This lifting window may vary somewhat based on weather conditions, so it is necessary to determine the level of seedling dormancy. Measuring the number of "chilling hours" has been used by nursery managers for decades to determine the level of crop dormancy. A chilling hour occurs when seedlings have been exposed to 1 hour of temperatures between 32 and 45 °F (0 to 2 °C) after October 1. There are many ways to effectively monitor ambient air temperature. Digital temperature monitors or weather stations can be used to calculate chilling hours. Many of these products have smartphone applications that allow for real-time data monitoring. It becomes safer to lift, store, and ship hardwood seedlings as their exposure to chilling hours increases.

Leaf color and leaf fall can also be used to help determine when hardwood seedlings can be safely lifted. This will vary by species, however, since some hardwood species hold on to their leaves much longer than others. For example, there are lifting seasons where species such as water oak (*Quercus nigra* L) may never lose all their leaves during fall and winter due to unusually mild temperatures. Leaf color changes and leaf fall should, therefore, be used along with other metrics like chilling hours and overall weather conditions. Table 1 provides a guide to help determine which species exhibit early or late leaf fall.

Soil moisture is also an important factor when determining when to begin hardwood seedling lifting. Although nurseries have some form of irrigation system, this is not the case for outplanting sites where droughts can become severe. Great care is needed to properly communicate with customers to monitor soil moisture conditions during times of drought. Customers are contacted weeks ahead of planned lifting dates to get a good understanding of conditions at outplanting sites. Many survival issues can be avoided by ensuring that customers understand the importance of proper site preparation, weather, and soil conditions during planting season, as well as proper seedling handling. When necessary, customers are advised not to plant seedlings on outplanting sites with extreme drought conditions and where seedling survival would be in question.

Lifting Equipment Selection, Preparation, and Maintenance

The general purpose and function of a hardwood seedling lifter is to safely loosen the soil around the root system while also bringing the seedlings to the top of the bed so they can be hand lifted, sorted, and packed (fig. 11c.1). Several hardwood seedling lifter models are available and manufacturers typically have options and accessories for each. Selecting the best model and options for a particular application depends on a number of considerations:

- The total volume of seedlings to be lifted annually, weekly, and daily, which will determine if only one lifter or more should be considered.
- The width of the seedling beds, to match available lifter widths to bed width.
- Seedling height, considering each lifter's maximum clearance measurements and limits
- Tractor type and size; some lifters are rated for certain tractor sizes and others have options of either PTO or hydraulic-motor-driven gears.
- Soil type; some lifters perform better in heavy and/or wet soils while others may not.

After the mechanical lifter has lifted seedlings from the bed, shaken the soil from the roots, and left the seedlings

Table 11c.1*—Time of leaf fall by genus (Williams and Hanks 1994). It is believed there is a relationship between the timing of leaf fall and the onset of dormancy.*

Early Sept. – Oct.	Intermediate Oct. – Nov.	Late Nov. – Dec.
Carya	*2.24*	*Alnus*
Catalpa	*Betula*	*Castaneu*
Cercis	*Celtis*	*Elaeagnus*
Diospyros	*Cornus*	*Quercus*
Fraxinus	*Liquidambar*	
Juglans	*Liriodendron*	
Morus	*Maclura*	
Nyssa	*Plantanus*	
Populus	*Prunus*	
Robinia	*Tilia*	
Robinia	*Ulmus*	

Figure 11c.1*—Fobro lifter showing the back tine tilt angle and height above bed. (Photo courtesy of Chase Weatherly, 2017.)*

on top of the bed, all further seedling handling, counting, sorting, bagging, and strapping at the ArborGen Bluff City Nursery is accomplished entirely by hand in the field (fig. 11c.2). An important step in this process is to spray the roots of seedlings with a gel slurry. This is accomplished using a trailer that has been altered to house a 500-gallon (gal) (1,892 liter [L]) poly tank with an attached hydraulic Ace pump that can deliver a gel slurry via a 75-ft (23-m) heavy-duty water hose directly to the roots of bundled seedlings laying on top of the bed. This trailer is long enough to hold up to 1,000 empty hardwood seedling bags and up to the same number of 36-in (91-cm) and 48-in (122-cm) plastic zip ties used for securing the bags once filled with seedlings (this method does not utilize mechanical strapping machines). Two haul-in wagons hold empty metal seedling racks that are taken to the field so that completely processed seedling bags can be stacked on them and taken to the cooler for storage.

Thorough planning is necessary to ensure all equipment has been properly prepared before lifting begins. Knowing the size and type tractor used for the lifter(s) and haul-in wagons is essential when developing an equipment list for the harvesting process. All tractors need to be inspected to ensure they meet the requirements for the equipment being used and all equipment, such as lifters, haul-in wagons, and strappers need to be inspected and any alterations made to fit any specific requirements.

Spare parts for all equipment should be on hand before lifting begins to avoid downtime if spares are not available. A yearly "prelifting" inspection program should be used to inspect all equipment and supplies to ensure they are ready for use, as well as verify spare parts inventories are in place. Consulting owner's manuals and calling other nursery locations can be very helpful. Finally, consideration should also be given to how workers are transported to and from the field. Trucks and/or RTVs should be available as needed to safely transport all workers.

Field Operations

Lifting

All lifting and packing activities at the ArborGen Bluff City Nursery are done in the field so there is no need for packing sheds or process lines. When packed seedling bags are transported from the field, they only need be placed in cold storage to await shipping. With a small crew size (3 to 6 workers), this method can yield anywhere from 10,000 to 20,000 seedlings packed in an 8-hour day. With a larger crew size (21 to 26 workers), this method can yield upwards of 250,000 seedlings in an 8-hour day.

When using either a Lundeby or Fobro style lifter, the tractor operator positions the blade of the lifter so that it is running at a slight angle with the front face of the blade slightly lower than the rear portion of the blade. This will cause the rear tines that help to separate the seedlings from the soil to be tilted upward slightly above the surface of the bed (fig. 11c.1). The more aggressive the angle of the blade in reference to the bed surface, the more the soil will be disrupted, the slower the tractor will need to travel, and the greater the potential for seedlings to clog the lifter instead of sliding over the blade. The less aggressive the blade tilt, the faster the tractor can travel, and soil disruption will be less. Blade tilt adjustments are made so there is adequate soil disruption and seedling separation without a lot of clogging. Once the lifter blade has been set to the desired angle, the depth of the blade is set to minimize the chance of roots being scraped as the blade travels under the bed. With a target root length of 8 in (20 cm) set by the previous undercutting operation, the depth of the lifting blade should be run close to 10 in (25 cm). Tractor speed depends on soil moisture, soil type, and the species being lifted and is generally between 0.5 and 1 miles per hour (0.8 to 1.6 kilometers per hour). Wetter conditions may require slower speeds to help soil separation from seedling roots. Drier conditions may allow for faster speeds. Sandier soils will allow for faster speeds as compared to heavier soils. The lifter operator must constantly check the tractor, lifter, and the quality of lifting so that adjustments can be made as soon as possible.

Packing

Immediately after the seedlings have passed through the lifter frame and once the lifter has moved down the bed far enough to allow for safe access, the crew members should assemble along both sides of the bed in equal numbers so that the seedlings can be hand counted and placed into bundles of either 25 or 50 seedlings. During this process, any culling or grading takes place based on seedling quality standards. The objective is to get the desired number of plantable seedlings into each bundle. If there are relatively few culls (5 percent or less), there is little need for removing the culls from the bundles, which would require additional time. The culls can be left in the bundles as long as the total number of plantable trees are also in the bundle. As the lifter moves along the bed lifting the seedlings out of the bed, the packing crew moves along behind counting and placing seedlings in bundles (fig. 11c.2).

Wet lifting conditions can increase the amount of soil clinging to the root systems. While excess soil on root systems during lifting and packing does not harm the seedlings, it increases the weight of seedling bags and makes them harder to handle. Removal of the excess soil clinging to roots may be accomplished by having the packing crew shake it from the root systems. This activity is time-consuming, particularly in heavier soils and wet conditions. There are no specific guidelines as to whether or not soil removal efforts are worthwhile. The decision is highly dependent upon local conditions and preferences when determining how much time the packing crew should spend shaking seedling bundles to remove excess soil.

Once seedlings have been placed in bundles, the roots are immediately sprayed with a gel slurry mixture using a water hose attached to the gel wagon. The water hose is long enough to reach up and down the bed for at least 50 ft (15.24 m) or more. This will allow a crew member to walk along the bed spraying the bundles as they are placed on top of the bed and before placement into bags. The gel mixture ratio is determined by the manufacture's mixing instructions. Gel mixtures that are too thick will not flow properly through the water hose and will not spread evenly inside the root bundle. The result will be a large portion of dry roots in each bundle. Gel mixtures that are too thin will not deliver enough gel to the roots and the water will simply fall out of the bundle of roots. The result will be a large portion of dry roots in each bundle. Depending on root fibrousness and the amount of soil left on the roots, seedling bundles may need to

***Figure 11c.2**—The hardwood seedling harvesting process at the ArborGen Bluff City Nursery, illustrating the sequence of operations perform11c.ed in the field: Lifting, sorting and bundling, gel application, bagging, loading, and transport to cooler. (Photo courtesy of Chase Weatherly, 2017.)*

be turned while being sprayed with the gel mixture to ensure the entire bundle gets adequately sprayed.

A 400- to 500-gallon (1,514- to 1,892-L) tank of gel mixture should be able to deliver enough gel for 150,000 seedlings or more. A large crew of 21 to 26 workers requires at least one refill during a complete day of hardwood lifting. The refilling process takes up to 30 minutes or more, depending on how far the gel wagon needs to travel to get to a water source and how fast the tank can be filled. The gel mixture should not be allowed to freeze, and when not in use, the tank may need to be stored in a building where temperatures do not fall below freezing.

Seedlings are ready to be placed in the seedling bag after the gel mixture has been applied. The two bags used at the ArborGen Bluff City Nursery are:

- 40.5 by 11 by 36 in (103 by 28 by 91 cm), 150 pound (wet strength) 3-ply kraft bags with a water-resistant interior lining. These bags are the most commonly used and can usually hold from 100 to 400 seedlings placed length-wise, rolled, and completely shut using a plastic zip tie.
- 25 by 10 by 36 in (63 by 25 by 91 cm), 150 pound 3-ply kraft with a water-resistant interior lining. These bags are used as needed when seedlings are too tall to fit into the wider bags and when packaging smaller quantities than 100 per bag. These bags will usually hold 100 but can hold 200 seedlings placed root system down and the stems sticking out of the top of the bag. A zip tie is also used to secure the bag.

There are a wide variety of bags and packaging options on the market. Nursery managers need to carefully evaluate these many possibilities when designing a packaging solution that best fits their local requirements.

As indicated, seedlings are either placed root systems down so the stems extend out of the top of the bag or seedlings are placed so they are oriented flat in the bag and the top of the bags are rolled down tight before being strapped shut. When placing the seedlings flat in the bag, bundles of seedlings are alternately placed so that half of the seedlings are pointing one direction and the other half of the seedlings are pointing the opposite direction. This allows for a more uniformly packed bag that stacks, stores and ships more efficiently. Bags will typically hold 100 to 200 seedlings when grown to normal specifications. There are rare occasions when seedlings are so large only 25 to 50 seedlings will fit in a bag. Similarly, small seedlings may be packed at 300, 400, or even 500 seedlings per bag. Plastic zip ties of either 36 or 48 in (91 or 122 cm) length are used to secure the bag. The 36-in (91-cm) long zip ties can be used on smaller diameter bags and the 48-in (122-cm) long zip ties are used on larger diameter bags. Using zip ties instead of poly straps that are applied with strapping machines eliminates the maintenance, adjustment, and repairs associated with those machines.

The bags that have been fully packed and secured with a zip tie are placed back on the seedling bed, where they await loading onto a haul-in wagon. Each bag should be properly labeled with species and seedling number before being loaded onto the haul-in wagon. There may be additional relevant information that could be put on each bag label: customer name, delivery location, lifting date, and any seedling treatments such as pest control applications, etc. All labels have heavy-duty freezer adhesive backing to ensure they do not fall off during transport to the cooler and handling by loading dock personnel and customers. Permanent markers are another option for bag labeling.

Transport

Once seedlings have been fully packed and labeled, they are ready for loading onto seedling racks (industry-standard Jarke style metal stackable racks) and taken to cold storage. A haul-in wagon is driven alongside the bed with workers stacking the bags on seedling racks on the haul-in wagon (fig. 11c.2). One haul-in wagon can hold three to four seedling racks. The seedling racks will have their legs inserted and stretch-wrap will be wrapped around each rack to keep the bags secure during transport to cold storage. Depending on the size of the bags, one rack should hold between 20 and 40 bags. This means that each metal seedling rack can transport 2,000 to 8,000 seedlings, and each haul-in wagon can transport 6,000 to 32,000 seedlings. Two haul-in wagons should keep up with the production of a full crew processing an average of 250,000 to 300,000 seedlings per day. Forklifts unload the full racks as they arrive at the cold storage facility, where each full rack is properly inventoried before going into cold storage. Empty racks are then placed on the haul-in wagons and taken to the field.

Grading

There is no single standard of seedling specifications meeting all State, Federal, and private customer requirements. Each grower should be aware of the needs of its customers as well as general industry standards for seedling size in their market area. All cost-share programs will have a unique set of seedling specifications. In general, the following standards should meet the majority of all hardwood seedling specification requirements:

- Average seedling height 18 to 24 in (46 to 61 cm)
- Average root length 8 to 10 in (20 to 25 cm)
- Average root collar diameter 1/4 to 3/8 in (6 to 9.5 mm)
- Disease and damage-free

Individual species need to be surveyed in August or September for any potential seedling quality and/or specification issues. When possible, customers are notified early of any potential seedling quality issues. This not only helps maintain good customer relations, but also provides time for them to evaluate and determine their minimum acceptable standards or possibly swap species, which is very common in the hardwood seedling market. Some customers have seedling specifications that can only be met by manually grading each seedling. A number of issues must be addressed in these cases. First, production will definitely slow down when field grading and, because the grading is done during field packing, the packing crew must be instructed as to the specifications and what causes a seedling to fall outside the range of acceptability. Prior planning is necessary to determine what should be done with seedlings too small to make the specifications. Will presumed inventory numbers be reduced and how does this affect sales numbers? Should undersized seedlings remain in the field to be later incorporated into the soil? Is there another customer who might be willing to accept the smaller seedling size? These issues need to be addressed in advance.

Seedling Storage

Storage Facilities

A cooler building 90 ft wide by 90 ft long and 20 ft high (27 by 27 by 6 m) with insulated panel walls and roof is used for seedling cold storage at the ArborGen Bluff City Nursery. Large electric insulated doors open to allow for forklift and rack entry and exit. Plastic curtain strips line the inside of each large insulated door to retain the cold air inside. There is adequate space for pedestrian traffic with an emergency exit away from forklift traffic. Seedling storage racks are laid out so that forklifts can safely and easily access all rows. The cooler allows for the storage of 1.2 million to 1.8 million hardwood seedlings. The number of metal seedling racks required to fill the cooler is 300 to 400. Extra racks are in place to meet shipping and satellite storage needs.

The target temperature for hardwood seedling storage is 36 °F (2 °C) and not allowed to fall below freezing. The humidity should be as high as possible, especially when using open-ended bags that allow for the top of the seedlings to extend outside the bag. Air circulation is sufficient to allow for quick cool down during times when the outside air temperature is high or the doors remain open for extended periods of time and warmer seedlings are being lifted and placed into the cooler. Wireless temperature monitors are employed that can be accessed at any time through cell phone applications or websites that download the data. In many cases, alarms can be set to notify the grower when the temperature falls outside a given range or if the humidity falls below a set point.

Storage Time

There are currently no universally accepted set of standards in the forest nursery industry for determining how long hardwood seedlings can be properly stored. Certainly, the personal species-specific experience of individual nursery managers is important. An assessment of seedling dormancy is also important. The ArborGen Bluff City Nursery has specific guidelines that compare the number of chilling hours with the amount of cold storage seedlings can withstand without significant declines in seedling quality.

A general rule that could be safely applied by most nurseries in the Southeastern United States would be the following:

- **Less than 200 chilling hours**

  Seedlings are considered to be very metabolically active. Any seedling lifting should be done with caution and planting should occur within 1 to 3 days.
- **Between 200 and 400 chilling hours**

  Most species can be stored for 1 to 2 weeks before outplanting.
- **Greater than 400 chilling hours**

  Most species can be stored for more than 4 weeks before outplanting.

The above should be taken as a guideline and modified by each nursery location to fit its specific circumstances and experiences. The guideline above also assumes that everything has been done correctly in the lifting and packing process before healthy seedlings have been placed in cold storage. Some species do not store well for long periods of time. Sweetgum (*Liquidambar styraciflua* L.) is one species that does not store as well as most other hardwood species. Growers should communicate with customers to ensure sweetgum is lifted, shipped, and planted in as short a timeframe as possible. When storage is required for sweetgum, reducing the storage times listed in the guideline above by half would be a safe starting point.

Reference

Williams, R.D.; Hanks, S.H. 1976. Hardwood nursery guide (formerly Hardwood nurseryman's guide, revised 1994). Agric. Handb. 473. Washington, DC: U.S. Department of Agriculture, Forest Service. 78 p.