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Hardwood Seedling Growth and Development and the Impact of Pruning and Environmental Stresses

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Outline

Facing Page: *Beautiful elderberry seedlings during irrigation. (Photo by Greg Hoss.)*

Introduction

The environment and genetics control the growth and development of all hardwood and conifer seedlings. While a nursery manager has no ability to manipulate the genetics of the seedling once a seedlot is chosen, a manager can manipulate the phenotypic expression of seedling genetics by utilizing different cultural management tools. These tools can modify the seedling environment to a limited extent and influence seedling development to achieve a specific seedling morphology and/or physiology. When applied at the correct time and in the correct manner, cultural activities such as irrigation, fertilization, weed control, and pest control have significant effect upon seedling growth and development. This chapter discusses the typical seedling growth and development pattern, the "target seedling" concept, the effect of pruning on seedling development, and the potential effects of abiotic stresses.

Seedling Growth Phases

The Growth Curve

When seedling growth is measured and plotted over a nursery season, the growth line will typically take the form of an "S-shape" curve (fig. 7.1). Any number of morphological parameters follow this pattern: height, root-collar diameter, root weight, shoot weight, and probably any other morphological growth parameter. Each parameter may not follow the same time reference, but they will typically follow the S-shape development pattern. For example, root growth and shoot growth are not always synchronized, with one happening faster than the other for brief periods of time.

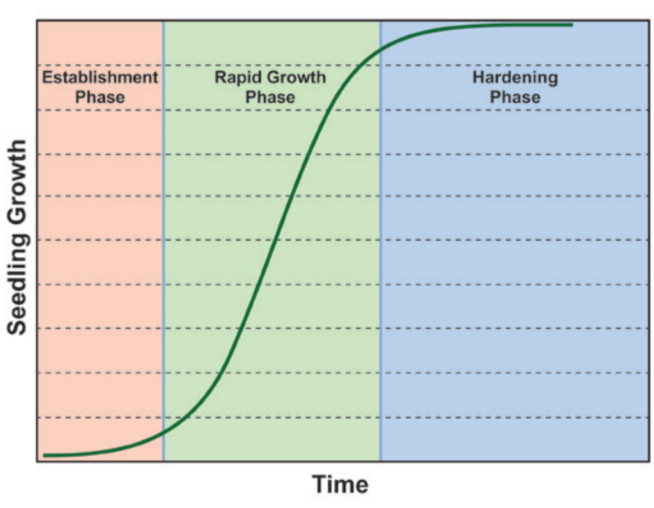

Figure 7.1—Three phases of seedling growth on an S-shaped growth curve.

Three different phases of growth can be used to describe the S-shaped curve; the establishment phase, the rapid growth phase and the hardening phase (Landis et al. 1998). The duration of each phase may vary, depending upon such factors as species, sowing date, environmental conditions, amount of fertilization, and other cultural practices. Although the characteristic shape of the growth curve is generally accepted, this exact shape is rarely seen in reality. Nevertheless, the three growth phases are always present, although the duration of the phases and the shape of the curve may vary. The nursery manager needs to understand these phases and their duration, because the timing and impact of cultural activities will vary within each growth phase.

Establishment Phase

This phase begins with the sowing of the seed and ends with the development of the first true leaves. In hardwoods, the establishment phase may last 6 to 12 weeks (Jacobs and Wilkinson 2009), depending on time of sowing and species. This phase is critically important since it establishes the seedling in the nursery bed or container. Failure to establish the seedling results in an empty space in the nursery bed or an empty cavity in a container, allowing weeds to grow. Temperature and moisture are important during this phase in order to facilitate germination and prevent disease (Landis et al. 1998). It may appear from monitoring top growth that little is happening during this growth phase. In reality, rapid root growth is occurring in both hardwood and conifers.

Rapid Growth Phase

Both stem and leaf biomass begin to increase rapidly during this phase and become the bulk of total seedling biomass. The rapid growth phase begins with the appearance of true leaves and continues at an accelerated or exponential rate of growth and ends in the fall as growth begins to slow due to the cooler weather and/or cultural practices of the nursery manager to reduce fertilization and/or irrigation. This is the period when seedlings add significant biomass and require adequate supplies of nutrients and water for proper development. Stress during this phase may stop or slow the growth of the seedling, resulting in reduced growth or, in some cases, cessation of all top growth. It is important that during this growth phase the seedlings be protected from stresses such as high temperatures, drought, or nutrient limitations. Typically, the duration of the rapid growth phase is greater than the other two and extends through the late spring and summer months in the Southern Region.

Hardening Phase

In the hardening phase, seedling growth begins to slow down naturally during the late summer and early fall with the advent of cooler temperatures and shorter days. Deciduous seedlings will lose their leaves in late fall/early winter. However, in late August and September and while seedlings are still photosynthesizing, a nursery manager must make the determination if the seedlings have reached their target size. If the target size has been achieved, a nursery manager may begin to reduce fertilization and adjust irrigation cycles to promote less frequent but deeper irrigation (see chapter 11c). This prevents the seedling from exceeding the target size and physiologically stresses the seedling to reduce transplant shock and better prepare it for outplanting (Jacobs 2011). Although top growth may be shutting down, this is a period of continued root and diameter growth albeit at a reducing rate until the leaves of the hardwoods die or fall off. On the other hand, if a species has not reached target size by late August/September, a nursery manager will need to "push" that species with additional fertilization into the fall.

The hardening phase, whether it occurs before or at the same time as natural leaf fall, gradually conditions the seedling for optimum performance after outplanting. During the rapid growth phase, the seedling shoot can be very fleshy and succulent. Any cultural manipulations to achieve hardening should be a gradual preparation of seedling physical and physiological characteristics for outplanting. This is particularly important if individual seedlots must be "pushed" to achieve target size before leaf fall. The reductions in photoperiod and lower fall temperatures, along with cultural activities such as reducing irrigation to induce moisture stress and changing the fertilization rates, will properly harden seedlings when done over a period of time (Landis et al. 1998, Jacobs and Wilkinson 2009, Jacobs and Landis 2009, Jacobs 2003).

Utilizing Growth Curves in Nurseries

The use of growth curves and data collected from history plots (chapter 10) allows the nursery manager to determine if the current seedling crop development is ahead or behind that of previous years. Any given parameter of seedling growth is plotted on the Y-axis, while time is plotted on the X-axis of a graph. Although any number of seedling growth parameters can be followed over time, the more commonly applied parameters are seedling height, in either inches or centimeters, and root-collar diameter, expressed most commonly in millimeters. Time units on the X-axis may be either the number of days from sowing or actual calendar date.

The data collected from history plots over several growing seasons can be used to generate a target growth curve. Growth curves will vary from year to year, according to changes in the natural environment and the influence of cultural practices. A theoretical growth curve can be generated by averaging the data over multiple years for any one species. When seedling measurements are made at any point during the growing season, they should be compared to growth curves generated using data from previous years to determine if the current seedling growth is on target. Based on the results, fertility and/or irrigation practices can then be altered to bring the growth in line with targeted levels.

The "Target" Hardwood Seedling

The Target Seedling Concept

The concept of a target seedling has been defined as "targeting specific physiological and morphological characteristics that can be linked with reforestation success" (Rose and Haase 1995). The concept of a target seedling began in the late 1970s and early 1980s and became more popular following a symposium on the subject in 1990 (Rose et al. 1990, Rose and Haase 1995, Landis 2003). At that time, nursery managers and researchers grew more interested in seedling quality and acknowledged that a quality seedling is made up of both morphological and physiological characteristics. In addition, and perhaps more importantly, the evolution of the target seedling concept recognized the need for communication between nursery managers and regeneration foresters regarding the ideal seedling qualities needed to maximize seedling survival and development on planting sites (Rose and Haase 1995). Even so, it may not be feasible to implement cultural practices specific to a single species to achieve the morphological seedling characteristics requested by individual customers, unless the request is for a particularly large order.

Matching seedling quality to specific site conditions is not common with reforestation seedlings in the Southern Region. In the central hardwood region, however, providing seedlings to match site conditions has been done (Jacobs 2011). Research has shown that improving root morphology for outplanting on droughty sites can increase survival (Jacobs et al. 2005, Jacobs et al. 2009). Nutrient-loaded seedlings and the use of container hardwood stock have proven to be successful on mine reclamation sites (Davis and Jacobs 2004, Birge et al. 2006, Salifu 2009). Providing tall container-grown hardwoods to reduce deer browse has prompted interest in the central region (Morrissey et al. 2010). This last technique may have application in the Southern Region, where a nursery manger can withhold top clipping on a portion of the seedlings to provide taller, more competitive seedlings.

Morphological Targets for Hardwood Seedlings

The most frequently measured morphological traits for hardwood seedlings include height, root mass, and root-collar diameter (caliper) (Jacobs and Wilkinson 2009). Other less-common traits that have been considered include leaf weight, number of branches, and bud size or appearance, which are more frequently employed by researchers than by growers (Rose and Haase 1995). Target seedling traits utilized today are, for the most part, determined by either State or Federal organizations.

Many States and/or regional organizations have established hardwood seedling specifications for their geographic area. These specifications are generally set by either a State organization, such as the forestry commission, or by a Federal Government entity, such as the U.S. Army Corp of Engineers. For example, the following are the 2017 specifications for "large stock plantings" of the Corp of Engineers Rock Island District of Mississippi.

- 5/8 inch (in) (9.5 millimeters [mm]) caliper at 6 in (15 centimeters [cm]) above the ground.
- A minimum of 4 feet (ft) (1.2 meters [m]) tall.
- Local ecotype seed should be used from the progeny where the trees are going to be planted.

In this case, "large stock plantings" are container hardwood seedlings produced in 1- or 3-gallon (gal) (3.7 liter [L] or 11.3 L) pots or unpruned bareroot seedlings, both of which may surpass 4 ft. Taller seedlings are often desired when planting in areas of heavy deer browse or bottom lands prone to flooding. By requiring a "local ecotype seed," the guidelines specify that the seed source (i.e., genetics) used for seedling production must match the environmental conditions of the planting site.

However, specifications for hardwood planting stock can vary by organization as well as by State and region. The following are hardwood planting stock criteria established by USDA's Natural Resources Conservation Service for the State of Arkansas (2013).

- A minimum root collar diameter of 1⁄4 in (6 mm) above the swell is required for all oak species and desired for all other hardwood species. Nonoak species may be smaller so long as all other specifications are met.
- A minimum tap root length of 6 in (15 cm) below the root collar.
- The ratio of the length of the shoot to the length of the tap root should be from 1.5 to 2.5, unless top pruned at the seedling nursery. Seedlings top pruned at the seedling nursery are acceptable. No top pruning should be done at the planting site. Tops should be proportional to the tap root length; e.g., 9 to 15 in (23 to 38 cm) above the root collar for a 6 in (15 cm) root.
- Healthy first-order laterals and fibrous roots must be present.
- Roots must be moist, not moldy, with NO overabundance of lenticels, and not discolored (inside or out). The outside of the roots should not be black, the cambium cannot be discolored, and the internal part should be white or creamy in color.

The Alabama Forest Commission (2011) provides the following hardwood specification guidelines: "Seedlings are perishable; keep seedling roots moist at all times. Plant only dormant seedlings and plant promptly after being received. Discard seedlings that are obviously small, diseased, dried out or damaged. Acceptable hardwood seedlings for planting should be a minimum of 18 in (46 cm) tall and 3/8 in (9.5 mm) in root collar diameter."

Other planting guidelines, such as no root pruning of seedlings after they leave the nursery, vary from State to State. Although reforestation foresters are beginning to realize that allowing onsite root pruning by tree planters may reduce survival and initial establishment, some States are reluctant to take a firm stand on root pruning or remove outdated online information allowing root pruning. The specifications in these examples indicate that height and root collar diameter are the most common morphological parameters utilized. Root collar diameter (RCD) is considered the single best indicator of seedling quality, since it is correlated with other morphological parameters such as height, seedling dry weight, root biomass, and field performance (Mexal and Landis 1990, Rose and Haase 1995). Hardwood seedlings with larger root collars, regardless of height, perform better on outplanting (Webb 1966, Jacobs 2011, McNabb and VanderSchaaf 2005).

Height, by itself, is a poor indicator of seedling quality. However, when combined with other morphological parameters, the usefulness of height improves. For example, the height/diameter (mm/mm) ratio can provide a relative indication of how spindly a seedling may be. For example, comparing a seedling with an RCD of 10 mm (0.4

in) and a height of 500 mm (20 in) to one with an RCD of 10 mm (0.4 mm) and a height of 300 mm (12 in) would have a height/diameter ratio of 50 for the first and 30 for the second. The seedling with the height/diameter ratio of 50 would be spindlier than the seedling with the height/diameter ratio of 30. In areas where seedling height may be desired to get above brush competition, a tall seedling with a large root collar (and large root system) would be more desirable (Rose and Haase 1995) than a tall seedling with a smaller RCD and smaller root system.

Tap root length is another commonly mentioned morphological parameter in hardwood seedling specifications. This is an important parameter since many hardwoods can have rather extensive root systems which require careful tap root undercutting at the nursery prior to seedling lifting and shipment. Root volume/mass has been recognized as an important factor in seedling outplanting survival. Although root volume/mass is not generally measured by nurseries due to its difficulty, managers recognize the importance of a fibrous root system for survival. A 6 in (15 cm) tap root, although important to get the roots deep in the soil, says nothing about the root mass or fibrosity (Rose and Haase 1995). To calculate and express the root biomass in an easier way, the Southern Forest Nursery Management Cooperative uses the root/weight ratio, which is defined as the weight of the root system compared to the total seedling weight expressed as a percentage. For example, a root/weight ratio of 30 percent means that 30 percent of the total weight of the seedling is in the root system. The root/weight ratio is easier to calculate and understand compared to calculation based on volume. Although research has established root/weight ratio guidelines for conifers, acceptable ranges of root/weight ratios for hardwoods have yet to be defined.

Monitoring Seedling Nutrient Levels

Work remains on how to use the physiological characteristics to develop target seedling parameters for hardwoods. Even so, nursery managers should consider the development of specific nutrient levels. In conifers and species that retain their foliage, a poor nutrient level may appear in the seedling crop as chlorosis. However, with hardwoods, which typically change color in the fall and then lose their leaves in early winter, the presence of a nutrient problem in the crop will not be evident to a nursery manager or customer. Since good nutrition is vital to seedling establishment and rapid spring growth (Jacobs et al. 2004, Jacobs et al. 2005), nursery managers should consider collecting foliar analysis before color change and leaf fall. The data can be used as part of the history plot information to target nutrient levels for specific hardwoods and may help explain survival or establishment difficulties.

The idea of exponential nutrient loading—that is, gradually increasing seedling nutrition levels over the growing season, before outplanting, on mine reclamation and other nutrient-poor soils—has been done with conifers (Jacobs 2011). Some outplanting trials with hardwoods show the applicability of this concept on these special sites (Birge et al. 2006, Salifu and Jacobs 2006, Salifu et al. 2008, 2009a, 2009b).

Impact of Seedbed Density on Seedling Morphology

The density at which hardwood seedlings are grown affects all aspects of seedling morphology, more so than any other cultural decision a nursery manager may make. Seeding density has a direct and visible effect on stem caliper, as caliper generally decreases as density increases. Producing a large-caliper seedling is important because increasing seedling root biomass has been associated with increased field survival and growth for some species (Jacobs et al. 2005, Weigal and Johnson 1998). Growing each species at the proper bed density can directly increase the number of permanent roots. However, accurate seed testing data are often lacking, and the decision as to what density to sow hardwoods relies heavily on the nursery manager's experience with that species. This can make growing hardwoods a challenge. One nursery manager recently reported that, based upon poor seed bed densities of a particular species the previous year, he decided to increase the seed density the following year. He commented, "This was a bad mistake, since it appeared that every seed germinated." Seedling quality that season suffered due to excessive seedling density.

Although the relationship between density and caliper is consistent, the relationship of density with height is complex and variable (Mexal and Landis 1990). Hardwood seedlings are grown at lower densities than conifers because their branching structure and leaf size require more space. Although there is a general consensus that increasing density results in a decrease in hardwood caliper (Schultz and Thompson 1990), no consistent relationship between density and height can be found in the research literature.

The number and size of first-order laterals appear to be useful indicators of survival and early growth for hardwoods (Gould et al. 2009, Schultz and Thompson 1990, 1996). These researchers stated that a "competitive" northern red oak seedling should have at least five permanent first-order laterals. Other species require eight or more first-order laterals for good field survival (Schultz et al. 1990). Nursery practices that encourage root development, such as undercutting and root-wrenching, are important to developing a large fibrous root system (Weigal and Johnson 1998).

Growth Manipulation Through Pruning

Uses of Root and Top Pruning

The decision to adopt a nursery practice should ultimately be based on whether it increases survival and growth after outplanting. In a survey of southern nurseries, Vanderveer (2005) received a range of responses as to what cultural manipulations were used to grow hardwoods for the reforestation market. Responses indicated some nurseries always top pruned while others never top pruned. Some nurseries always laterally pruned, while others did not even own a lateral pruner. The survey indicated the decision to use cultural practices such as top pruning, undercutting, lateral pruning, and root wrenching was based most commonly on customer specifications. Hardwood seedlings are typically sold to either the horticultural or reforestation market. Those nurseries that grow seedlings for the horticultural market must produce a larger seedling with more rigid specifications than nurseries that provide seedlings for reforestation. Most of the hardwoods sold for reforestation are used for wetland mitigation or wildlife food plots and are grown in nurseries that also grow conifers for reforestation. The implementation of certain cultural practices to increase survival and growth after outplanting was not specifically reported in Vanderveer's 2005 survey.

It is this author's experience that most nurseries currently top prune, lateral prune, and undercut, while not all root wrench. A large part of the decision to adopt any of these options focuses on facilitating the lifting, packing, and shipping process. McNabb (2004) reported that root culturing of hardwoods in southern nurseries was primarily used to control shoot height. Top pruning allows nurseries to more easily handle and ship seedlings. Lateral pruning cuts the lateral roots between drills and facilitates lifting. Undercutting many times is done to meet customer specifications for a tap root length, but it also facilitates the lifting process. Just as these procedures aid in shipping, however, when done at the right time and for the right reasons, they can increase seedling outplanting performance. One nursery manager who regularly root wrenches does so on the belief that it provides a more fibrous root system, in addition to improving soil aeration. This same manager reports that root wrenching in combination with water management between July and September offers the greatest benefit.

Root Pruning

Root pruning primarily includes lateral root pruning, undercutting, and root wrenching (Landis 2008). Table 7.1 provides a comparison of these three common root pruning methods used in the Southern Region. The objectives of root pruning are to encourage the development of lateral roots, control taproot length to facilitate lifting, and provide a seedling that will have a competitive advantage when outplanted. Root manipulation is intended to produce first-order laterals greater than 1 mm, since those less than 1 mm are probably lost in lifting and planting (Schultz and Thompson 1990). Nurseries that use root pruning methods only to aid in lifting should consider their use at other times during the growing season as a method to increase root biomass, which ultimately can increase field survival.

Top Pruning

When surveying nurseries that top pruned hardwood seedlings, South (1996) found that 9 of 13 nursery managers did so on a regular basis. Three reasons were provided for the decision to top prune: (1) to reduce lifting, packing, and shipping costs, (2) to reduce stem dieback after planting, and (3) to increase outplanting survival. Being able to control the height of the seedling by top pruning produces a seedling better suited to the environmental conditions after outplanting in reforestation areas, wetland mitigation, and wildlife food plots. Sufficient research has proven that survival is often increased and shoot:root ratio improved when seedlings are top pruned (South 1996, South 2016). Tall seedlings are not only more difficult to lift and pack and cost more to ship, they also stand a greater chance of going through transplant shock because sufficient roots may not have been lifted to support the top growth.

Top pruning occurs primarily from June to September in the Southern Region where the growing season can be 6 to 7 months long. The frequency of top pruning depends upon how fast the species grows. There does not appear to be a consensus in the literature as to the number of prunings necessary, although twice is most commonly reported. One nursery manager first top prunes when seedlings are between 18 in (46 cm) and 20 in (51 cm) of height, with a second top clipping no later than August, when seedlings are 24 in (61 cm) to 26 in (66 cm). Top pruning is done more frequently with a sickle bar mower than a rotary bush-hog mower, as is used in conifer nurseries. Nursery managers using the sickle bar mower report a cleaner cut. Top pruning hardwoods in the fall after leaf fall does not appear to have any adverse effect on survival and may reduce handling costs, while allowing the root system to continue growing in the nursery (Briscoe 1969, South 1996).

The Management of Abiotic Stresses

Extremes in wind, temperature, and soil moisture are abiotic factors that can affect hardwood seedling growth. The diagnosis of abiotic damage relies on observing patterns of damage to the crop in the nursery or field, damage to individual seedlings, and weather records and cultural practices (Cram 2012). However, the occurrence of an abiotic stress may not always result in visible seedling symptoms, even when resulting in a reduction in seedling growth.

Drought Stress

Drought stress may or may not cause visible symptoms in the nursery, depending on the severity of the stress. Drought stress can occur in the summer when sufficient irrigation to maintain optimum growth is not provided. If the reduction in irrigation is minor and of short duration, seedlings may not suffer. If the irrigation reduction is sustained, however, at a minimum the growth rate will probably be reduced even if there are no visible seedling symptoms. A prolonged reduction in irrigation may result in symptoms where the top-most seedling leaves wilt, followed by tip burn on the edges, starting with the top-most leaves. Premature dropping of the leaves may occur in cases of more severe drought stress.

Heat Stress

Heat injury on southern hardwoods is not commonly reported. One of the primary reasons is that hardwoods are most often sown early in the spring, before high temperatures cause significant injury. If heat injury should occur, the injury would likely be similar to that occurring on conifers. The severity of the injury will depend upon the thickness of the bark at the ground line. Heat lesions generally occur on one side of the seedling stem at the ground line. The lesion may appear as a discoloration or an actual collapse of the stem tissue on one side. When the damage is a lesion resulting from collapsed tissue, it is common for the stem just above the lesion to swell slightly resulting from damage to the phloem tissue and the inability of carbohydrates to flow normally from the leaves to the roots.

Table 7.1*—Comparison of root pruning methods. (Modified from Landis, 2008)*

Term	Function	Cultural objectives	Implement	Timing
Undercutting	1. Cut roots in a horizontal plane. 2. Generally 15-18 cm.	1. Encourage root fibrosity. 2. Reduce shoot growth (make sure height target is achieved). 3. Control tap root growth. 4. Facilitate lifting.	1. Sharp, thin fixed blade or oscillating blade covering full bed width. 2. Frequent sharpening of the blade is important. 3. Tractor must be kept at a constant speed. 4. Keep blade absolutely horizontal.	One or two times during the growing season, or prior to lifting.
Wrenching	1. Induce moisture stress and loosen soil within root zone. 2. Tear or break fine feeder roots.	1. Reduce shoot growth 2. Improve soil physical properties: - Reduce compaction, - increase aeration, - improve drainage.	Sharp fixed blade at an angle (30°) covering full bed width.	Once to several times during the growing season, or prior to lifting.
Lateral root pruning	Cuts roots in vertical plane between rows of seedlings.	1. Encourage root fibrosity 2. Facilitate lifting.	Coulter blades spaced between seedling rows.	Once to several times during the growing season, or prior to lifting.

Freeze injury

Freeze injury occurs when seedlings have not been acclimated to cold temperatures. This can occur in hardwood nurseries when fall-sown seedlings begin to germinate and are subjected to freezing temperatures after germination (Cram 2012) or when spring-sown hardwoods are exposed to an early fall freeze before the seedlings are hardened off. Information regarding the freeze tolerance of hardwood seedlings is far from complete. It is known that conifer families differ in freeze tolerance. In the case of hardwoods, however, even the relative sensitivity to freeze damage among species is unknown. Also, even though freeze injury is not commonly reported on hardwoods, it should not be assumed hardwoods are more tolerant to freeze injury than pines. It may be just a lack of observation. Much of the research on freeze tolerance in hardwoods has been done in the northern region and relates specifically to seedling storage (Wilson and Jacobs 2006).

Reports of freeze injury to hardwoods is less common than to conifers (Lantz 1985, South 2006). The author has personally examined hundreds of reports of freeze injury on conifers in the Southern Region, but none on hardwood seedlings. There may be several reasons why freeze injury on hardwood seedlings is not frequently reported.

1. Nursery managers may believe that freeze-associated leaf damage is generally of little concern since the leaves are going to fall off anyway in late fall/early winter or will resprout.
2. Following an early winter freeze in the nursery, a nursery manager may incorrectly assume seedlings are not injured because at this time of year most hardwood leaves are already losing their color and vigor and are already falling. Attention may be focused on more visible damage to conifers.

***Figure 7.3**—A healthy conifer seedling stem (top) compared to a freeze-damaged stem (bottom). (Photo Tom Starkey 2013.)*

***Figure 7.2**—Freeze injury in the cambium area of conifer seedling. (Photo by Tom Starkey, 2012.)*

3. The thicker bark on some hardwoods may provide some protection from stem damage which is easier to observe than root damage.
4. Many times freeze injury is noted in conifers as burned needles or needle tips only after outplanting and warm weather begins. Postplanting foliar damage on hardwoods, however, may not be visible because they do not typically have leaves at outplanting. Freeze injury may, therefore, appear as a seedling that is just slow to break bud in the spring. The major impact of freeze injury for both conifers and hardwoods is damage to cambium tissue of the stem and roots, or both. Seedlings may even be killed in the nursery when freeze damage is severe. More commonly, however, freeze injury causes partial mortality of cambial tissue and results in poor outplanting survival and slow growth.

Assuming that identifying freeze injury in hardwoods is similar to that in pines, the identification of such injury is easily diagnosed following a freeze event in the nursery or the field. Temperatures in the mid- to low-20s ˚F have the greatest impact on conifers, and subfreezing temperatures that are preceded by a warm spell have the greatest impact on seedlings. To diagnose freeze injury, the nursery manager should wait about 2 weeks following a freeze event. Choose seedlings from the outside drills facing the predominant wind direction. On these seedlings scrape the bark off the stem or root to reveal a light brown to khaki-brown discoloration. Figures 7.2 and 7.3 show this discoloration in conifers. Sometimes this brown discoloration is only on one side of the stem or root. In this case, the seedling will live, but establishment will be slow until the seedling is able to outgrow the effect of the freeze. Similar stem discoloration has been reported for citrus (http://www.crec.ifas.ufl.edu/extension/trade_journals/2016/2016_December_freeze.pdf).

Seedling root systems never go dormant in the Southern Region, thus the root systems of conifers and probably hardwoods are more susceptible to freeze injury than the shoots. Applying irrigation (chapter 5) may help reduce freeze injury to the roots. Wet soils provide more insulation to the seedlings and conduct heat better than do dry soils. Moist, compact soils will store more heat during the day and thus be able to transfer heat to the seedling roots at night. (Poling 2007, Striegler 2007, Perry 1988, Powell and Himelrick 2000). When soils are dry, cold air can permeate the air spaces into the soils and reach temperatures below freezing. Many conifer nurseries leave irrigation pipes in the field during the winter to provide moisture if needed, particularly before a dry weather front. Ensuring that the seedbed is moist to wet prior to a dry front passing will provide some freeze protection for roots.

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