Growing Good Roots in the Nursery©

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I have been interested in roots during much of my professional career. Observing roots in natural settings, in water, in air, over granite rocks, provides a glimpse of how adaptable they are. In the nursery, we initiate them, prune them, and manage them in order to provide the best possible chance for them to grow and survive after they are sold. Sometimes nursery-grown root systems are inappropriately structured to enable the plants to provide the long term environmental and aesthetic benefits for which they were produced. This paper presents some reasons why growers should pay close attention to roots, some illustrations of good and bad roots, and repeats the cry for all nurseries to grow and sell the best possible root systems. Didn't Charles Darwin say "the root is the heart of the tree"?

Roots are opportunistic. When provided with water, air, a nutrient supply to keep the tree alive and no physical, biological, or environmental constraints, they survive and grow anywhere (Coder, 1998; Perry, 1982). That ability gets roots into trouble when they damage pavement, invade sewer pipes, and absorb water from some clay soils near building foundations (Watson and Himelick, 2013). We have all seen how easily roots explore the area beyond the drain holes of nursery containers. Yet that same ability allows trees to exist in many unique locations. Mangrove, bald cypress, and willow may come to mind in wet locations. Desert vegetation is an opposite contrast. In Ontario, not far from our meetings here in Niagara Falls, researchers have documented stunted, deformed examples of *Thuja occidentalis* that have been clinging to limestone cliff faces for nearly 2000 years (Kelly and Larson, 2013; Kelly et al., 1994).

Roots are not entirely geotrophic. As the radical emerges from the seed, the tap root responds to gravity. However, roots soon begin to grow laterally and even up. This down, up, sideways, any-which-way root growth pattern is clearly evident in many container-grown plants.

Much to our benefit, roots grow more roots as a result of natural or manipulated factors. Root pruning enables roots to form near the pruned point. Both mechanical and air pruning are common nursery practices. The number of new roots formed depends on the species as well as physiologic and environmental conditions (Watson and Himelick, 2013).

Growing plants in containers may result in circling roots (Appleton, 1998). Circling roots often have little adverse effect in the nursery. However, the circling begins the potential for circling roots to become girdling roots that may and often do affect tree longevity in the landscape (Watson and Himelick, 2013). When the physical constraint of the container is removed, subsequent root growth does not continue to circle (Fig. 1). This growth pattern allows plants with severely circling and constricted roots to establish and grow for some time in the nursery or landscape. However, the initial imprint of circling and girdling roots soon begin to restrict the flow of absorbed water and nutrients through the xylem as well as the downward movement of metabolites in the phloem. Early signs of root problems are reduced shoot elongation and abnormal leaf color during the growing season.

During my career, I have seen many bad roots, their configuration the result of poor nursery practice. Nurseries do not purposely grow or sell bad roots. Bad roots result from a number of causes like improper field and container planting practices, poorly designed containers and not up-sizing into a larger container. I think the up-sizing issue followed by container configuration are the greatest reasons for bad roots of container-grown plants.

We have all heard home gardeners say they "kill plants." My observation is that some of their failed plants are not the homeowner's fault but the result of a bad root system from the nursery. Since it has happened in my home garden I am sure it has happened for others.

Fig. 1. A circling root system does not continue to circle after nursery field planting. However, this tree will die soon because of the severe root constriction.

For forest tree seedling growers, economy of scale often requires very small containers in the initial stages of production, some as small as 40 cm^3 (2.5 in^2) (Landis et al., 1990). "The major constraint on container volume is economical, not biological, because (A) larger containers take up more growing space, (B) seedlings grown in large containers require longer growing periods for the seedling root system to occupy the container completely, and (C) large containers are bulkier to handle during shipping and outplanting." (Landis et al., 1990).

Tree failures as a result of bad roots usually occur some years after planting (Fig. 2). That fact has deflected the blame away from bad roots to less than ideal urban soil and environmental conditions or inadequate maintenance. However, landscape architects, urban foresters, and municipal managers are becoming more aware that some tree failures are the result of bad roots originating from poor nursery practices. As these professionals come to your nursery to talk about roots, tell them about your production practices that ensure good roots. Show them examples (Fig. 3). Better yet, don't wait for them to come to you. Communicate to them. Sell your roots. One example is J. Frank Schmidt & Son Co. nursery in Boring, Oregon. Their colourful promotional material illustrates the containers they use to produce fibrous root systems with no circling.

James Urban, a well-known American landscape architect, is a passionate advocate of how to get trees to grow well in cities (Urban, 2008). He may have come to your nursery with his spade to check on root orientation and upper root depth. "Root safe containers" and certified growers are ways to ensure trees have quality root systems (J. Urban, pers. comm.). Since trees planted in cities originate in nurseries, better nursery trees will help to ensure better city trees.

Fig. 2. This pine, like others in the nursery field, was planted as a liner without checking the roots. Several years after planting the trees broke at the base because the circling roots severely constricted the stems.

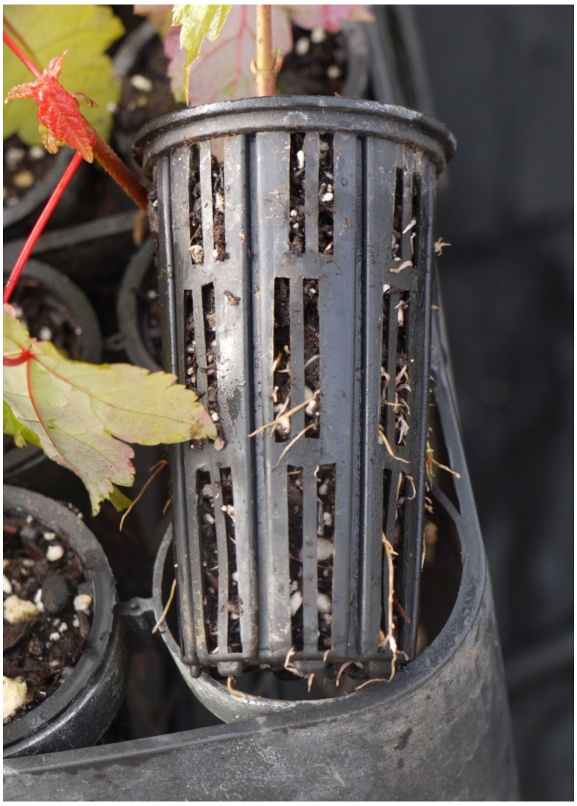

Fig. 3. Propagation containers like this enable air root pruning and help to prevent circling and future constriction. It also enables visual inspection of developing roots.

Several conferences focusing on urban tree-root issues (Neeley and Watson, 1998; Watson and Neeley, 1994; Watson et al., 2009), have brought together "research scientists, growers, and landscape professionals (from) around the world working in earnest for better nursery production, site preparation, soil management, planting and arboricultural care" (Watson et al., 2009). Since very few nursery growers attend such conferences, root researchers such as Dr. Ed Gilman of the University of Florida, Gainesville, Florida; Dr. Gary Watson of the Morton Arboretum, Lisle, Illinois; and many others have written in trade publications and spoken at nursery meetings about the causes and implications of bad roots and ways to grow good roots. Some nursery growers have been innovative in their approach to producing better good roots and are happy to share their findings (A. Verbinnen, K. Warren and J. Winkelmolen, pers. commun.).

A constricted container root system leaves an imprint when the container is removed. The negative implications of failing to alter or manipulate the imprint include the lack of newly formed lateral roots from the imprint area and new roots that are too deep below the surface. Deep roots often have an adverse effect on stability, establishment and survival of landscape plantings (Gilman, 2012). An important production strategy is not to allow root abnormalities to occur. When they do occur, some sort of correction, such as shaving, is needed.

Beginning root "training" early is key. It starts at propagation, particularly when producing seedlings in containers. Tap-root manipulation by mechanical or air pruning to encourage laterals, container material and configuration to eliminate circling and encourage laterals, up-sizing before a root imprint forms and root ball shaving are "training" techniques. Gilman et al. (2009) have shown that shaving the outer edge of the root ball eliminates surface circling and helps to encourage horizontal root orientation when up-sizing and out-planting. Cull anything with a bad root. One nursery is so selective it culls as many as two thirds of its seedlings (K. Warren, pers. commun.).

Nurseries that bring in potted liners from other growers may be at risk of potting-up bad roots. Some of the plants that have failed in my landscape, and I'm sure others, have had bad roots initiated by the propagation grower and perpetuated by the subsequent grower (Fig. 4). Learn about the good root techniques of supplies and do random destructive root sampling. Even good roots without structural defects may benefit from manipulation prior to potting.

Fig. 4. This small tree grew more slowly each year after planting. Its demise was not the homeowner's fault. It was the fault of a bad root system from the nursery.

Many types of containers on the market encourage good roots (Appleton, 1998). Some are formed with many openings in the side wall and bottom or made of fabric to encourage air pruning, some are ridged to eliminate root circling, some are made of biodegradable material such as coir (coconut fiber) to allow root penetration and direct planting, while others are very deep in an attempt to accommodate tap rooted species. Each container type has production implications such as purchase price, irrigation frequency, stability, strength, longevity of use, and rooting-out.

The advantage of natural fiber and biodegradability may result in a false sense of the container's air pruning ability. Some coir (coconut fiber) containers have thicker bottoms than sides. This manufacturing flaw often leads to root circling at the bottom rather than root penetration and air pruning (Fig. 5).

Fig. 5. The thick base of this small, porous-walled coir (coconut fiber) container restricted root penetration and prevented air root pruning.

Tap rooted species such as *Carya* seeded in containers are a particular challenge. The lack of naturally formed laterals and the limited number of laterals formed from mechanical and air pruning quickly result in poor root structure (Fig. 6). Some growers have tried very deep, narrow pots in an attempt to provide more space for laterals along the tap root. However, such deep pots make future nursery and landscape planting awkward.

Auxin-type growth regulator applications to roots have been used in an attempt to increase root number (Lumis, 1982; Prager and Lumis, 1983). However, there has been too little positive benefit for their adoption and use in the nursery or in landscape planting (Watson and Himelick 2013).

Achieving good roots in the nursery is a challenge, especially for tap rooted species and for plants grown in containers. Understand the importance of good root architecture and achieve it. Your customers deserve and should demand good roots. Provide them with roots without defects to ensure long term survival and establishment in the landscape (Fig. 7). Begin early in the life of the plant and continue through different stages of production. Prevent and avoid constricted imprints that will jeopardize the plant's future. Discard plants with poor root structure. Grow the best roots possible.

Fig. 6. Getting a good initial root system in the first season on tap rooted species such as *Carya* can be a challenge. Note the lack of laterals.

Fig. 7. Good root structure like on this one-year-old red oak seedling should be the goal of every nursery and a requirement of every purchaser. The radical was pinched right after germination then the seedling was planted in a wide, non-restrictive container that enabled air pruning of the elongating tap root.

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