Root Management Challenges on Urban Sites: Human Intervention in Root Development

By Angela Hewitt and Gary W. Watson

Learning Objectives
- Explain how human activities affect tree root systems.
- Discuss the impacts of soil compaction, and root severance on root health.
- Describe common root defects that can arise from field- and container-grown trees.
- Provide examples of root–infrastructure conflicts and common mitigation strategies.

CEUs for this article apply to Certified Arborist, Utility Specialist, Municipal Specialist, Tree Worker/Climber, Aerial Lift Specialist, and the BCMA management category.

Conflict between human activity and tree roots is constant in the built environment. Soils are excavated, compacted, covered, and depleted of organic matter. Tree roots are damaged as a result. Infrastructure elements present barriers to root growth and root damage often occurs during infrastructure construction and repair. Knowledge of how human activities affect tree root systems is the best way to prevent root damage.

Soil and Root Disturbance

Soil Compaction

Compaction is a common and serious problem in urban soils. Soil bulk densities similar to concrete (2.2 g/cc) have been reported. Lack of a 'cushioning' litter layer and reduction of organic matter in the soil itself are contributing factors. Compaction affects root development through changes in soil strength, porosity, water content, hydraulic conductivity, and gaseous diffusion rate, but it is difficult to single out the effects of each of the interrelated factors.

Severe compaction can occur with just a few passes of heavy equipment when the soil is moist, and can take decades to reverse naturally. Bulk densities that inhibit root growth vary with soil texture. Root-limiting bulk densities are higher in coarse textured soils than in fine textured soils. Compaction can restrict root growth through increased soil strength (penetration resistance) and low soil oxygen content. Some species, such as silver maple (*Acer saccharinum*), are more tolerant of urban conditions because their roots can grow at low levels of soil aeration and take advantage of reduced soil penetration resistance when compacted soils are wet.

Remediation of compaction can be difficult when tree roots are present. Use of air excavation tools to cultivate compacted soils without damaging tree roots was recently introduced, but few research studies evaluating its effectiveness have been published. Mulching can increase organic matter over time and speed up natural reversal of compaction. Equipment designed to reduce compaction through injection of compressed air has not proven to be very effective. A mulch or gravel layer over the soil surface is more effective at preventing vehicular compaction than plywood. Preventing compaction is preferred.

Fill Soil

Though practical experience indicates that adding fill soil over root systems can result in decline and death of trees, controlled research experiments have failed repeatedly to produce the same results. Soil texture and structure, as well as the depth of the fill layer, all factor in. A thin layer of clay may be more damaging than a deeper layer of sandy or loamy soil. Compaction will decrease the permeability of any soil type. Heavy equipment used to add the fill soil can compact existing soils, causing direct injury to roots. The fill may intercept rainwater and prevent it from reaching the roots. Adding fill over the root system is an indication that other grading changes are taking place on the site. If drainage patterns are changed as a result, this may be more damaging to roots than the fill.

Aeration systems constructed between the original soil and the fill layer are unproven through research but have been considered successful in practice. Since the consequences of adding fill over a root system can be catastrophic, and aeration systems are unproven, avoid adding soil of any type or amount over root systems. If retaining walls are used at the perimeter of the root zone, be sure that drainage is not altered, causing water to accumulate in the root zone.

Root Severance

Direct damage to tree roots in developed landscapes is common. As more effective soil-moving equipment is developed, roots are more easily damaged. The growing need to repair aging infrastructure and the increased use of underground wires increase the potential for root damage.

Fortunately, roots are generally good compartmentalizers, and injury does not often lead to extensive decay. Research is inconsistent on whether size of root and distance from the trunk affect discoloration and decay. Injury early in the growing season may be compartmentalized better than injuries sustained in winter.

Root severance as a result of construction activity has the potential to reduce the stability of trees. The limited research available on the stability of trees after roots are severed indicates that cutting roots at a distance closer than three times the trunk diameter reduces stability. These results are from small trees of a few species, and so caution should be exercised in applying these findings to large trees in urban areas until more research is available.

Severing root flare roots just a few feet from the trunk can cause stress. There may be as few as four or five roots forming the root flare. If just one of them is cut, up to 25 percent of the root system may be lost. A trench that severs all roots close to the trunk on one side can cut off nearly half of the root system.

Avoiding severing roots is the preferred approach. Directional boring equipment can be used to avoid severing roots during utility installation. Air excavation and ground-penetrating radar technology can be used to locate roots prior to excavation.

If roots are severed, the situation is similar to that of a transplanted tree and it will take many years for the roots to regenerate, but the tree may recover if proper care is provided. If roots are cut and there is a permanent loss of root space (lowered grade or soil covered with solid pavement), the tree will not be able to regenerate the root system. It will be subject to permanent and potentially severe stress that can lead to decline.

Alteration of Natural Root Structure

"Survival of the fittest" is a basic law of nature, and a good root system contributes to survival in highly competitive natural forests. Landscape trees are subject to human intervention that does not exist in nature. The root structure of nursery-produced trees may be quite different than the root structure of naturally regenerated trees. Roots are severed multiple times by the transplanting process. Because growing conditions are excellent and competition is minimized in nurseries, strong root systems are less of a factor in survival.

Field-grown Nursery Stock

When young seedlings are transplanted and root pruned in the early stages of field production, rapidly growing adventitious roots are produced at the cut end of the primary root. Most of the natural lateral roots above the regenerated roots that would have formed a natural root flare are often lost as well. The vigorously growing adventitious roots have the potential to develop into an adventitious root flare (Figure 1) deeper in the soil than the natural root flare would have developed. The depth of the adventitious root flare is determined by the length of the primary root (root shank) after pruning. Even if the tree is planted at the original depth and the graft union is visible above ground, the adventitious root flare can be

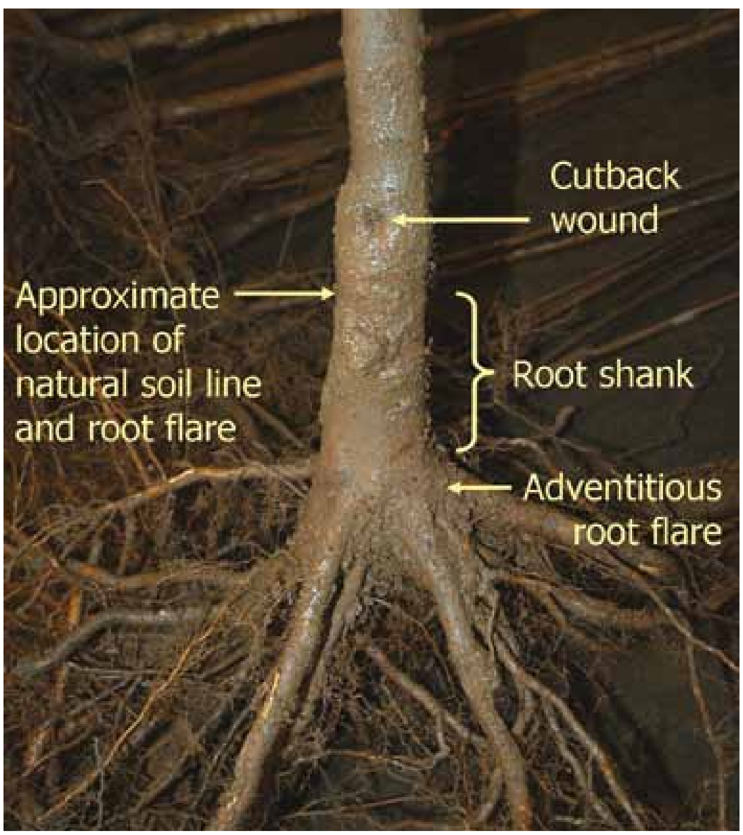

Figure 1. Root pruning as a seedling results in an adventitious root flare on field-grown trees. The location of the pruning determines the length of the root shank and depth of the adventitious root flare.

12 inches (30 cm) or more below the soil surface if the root shank is long. Planting too deep each time the tree is replanted can increase the depth of the adventitious root flare.

Although trees can grow well with deep roots in nursery high-quality soil, they may struggle when planted on difficult urban sites with heavy soils and poor drainage. Root crown excavation is the only option available to treat an established tree with deep roots. Removing the soil from around the base of the tree provides better aeration to the soil and roots. Typically, soil is removed with air excavation tools just wide enough to expose the root flare and create a slope that will keep the soil from falling back into the excavation area. (Figure 2) The depression left by the excavation may need to be filled with another well-aerated material, such as pea gravel, to avoid creating a hazard.

Overall, prevention is the best approach. Select trees with several major lateral roots just below the soil surface of the root ball soil. Reject root balls with deep roots because the root ball is effectively undersized, with roots only in the lower portion (Figure 3).

Defects Caused by Containers

Many root problems in the landscape can be traced back to nursery containers. Because the natural spread of the roots is restricted by the container, lateral roots reaching the sides are redirected by the container. No container design completely eliminates defects. Root defects caused by container walls persist after repotting or transplanting unless pruned away; therefore, multiple layers of defects may be hidden from view below the surface of the substrate. Root defects may not result in a difference in tree growth during nursery production, or in the initial years after planting in the landscape, and so the problem can go undetected until it is too late to correct. Roots redirected by the container wall, especially descending roots, reduce the development of normal radially directed roots and can result in serious instability in the landscape.

Slicing the root ball exterior vertically reduces circling roots, but not descending roots or any interior defects. Root ball shaving (Figure 4), also called box cutting, is the removal of the roots growing on the outer surface of the root ball. If the root ball is shaved every time the tree is moved to a larger size container, root defects can be eliminated, allowing development of a normal root system after planting, with many radially oriented roots.

Girdling Roots

Transplanting of field-grown nursery stock has been identified as one cause of girdling roots—a different cause than circling roots on container stock. When radially-oriented lateral roots are severed by transplanting, existing lateral roots can begin to grow more rapidly and become a part of the permanent structural root system. If oriented perpendicular to the other major roots and near the base of the trunk, the lateral roots can become girdling roots as both the roots and the trunk continue to increase in diameter (Figure 5). These girdling roots restrict the flow in the vascular system and can cause stress, decline, and possibly the death of the tree. Additional evidence that girdling roots may result from


Figure 2. Root crown excavations are used to expose buried root flares.

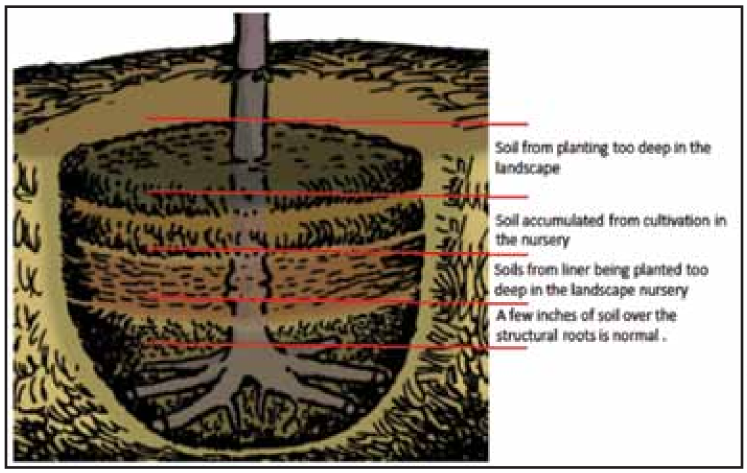

Figure 3. From seed to the landscape, many factors can contribute to deep root systems.


Figure 4. Shaving off the outer inch (2.5 cm) of the container root ball is the best way to prevent root defects.

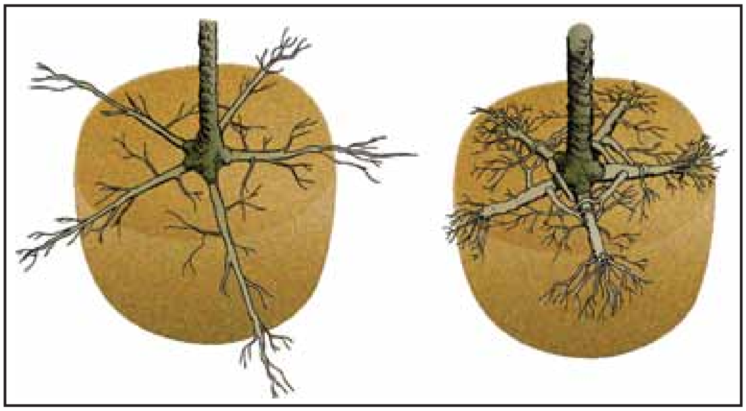

Figure 5. When spreading lateral roots are severed during transplanting, growth of existing branch roots is stimulated and are positioned to become girdling roots as the roots and the trunk enlarge.

transplanting is provided by the low incidence of girdling roots in nature.

Girdling roots can cause severe constriction of the trunk and stress, if not removed. There is also a chance that removing the root could cause additional stress, but it is often worth the risk. Remove girdling roots when the tree is dormant, if possible, to minimize stress. If the girdling roots are numerous, remove them gradually over several seasons. Because the girdling roots may regenerate from the wound in some trees, a follow-up inspection two to three years later is advised.

Root–Infrastructure Conflicts

When root space is limited by structures and hardscape, there is always potential for roots to conflict with infrastructure. Roots are often associated with pavement lifting, clogged sewer pipes, and foundation subsidence.

Pavements

When pavements are laid on a compacted soil base, roots often grow in the space between the pavement and the compacted soil. Moisture is adequate for root growth because the pavement prevents evaporation, and moisture condenses beneath the pavement as it cools. As roots increase in diameter they can eventually lift and crack the pavement. Potential for conflicts between trees and pavements are high when one or more of the following factors are present: tree species that are large at maturity or fast growing, shallow rooting habits, trees planted in restricted soil volumes, limited or no base materials, less than 6–10 feet (2–3 m) between the trees and pavement, or trees more than 15 years old.

Pavement cracks near roots are usually assumed to be caused by the roots, but recent research has shown that sidewalk damage is also related to soil type and age of pavement. Roots are more likely to be found under a crack, but even with no roots present, 61 percent of all pavement expansion joints crack.

Barriers constructed from plastic, metal screening, and geotextile impregnated with herbicide are sometimes installed to force roots to grow deeper under pavements. Root barriers do reduce the number of roots and force them deeper for a limited distance, usually about five feet (1.5 m). There is no evidence that root barriers cause tree instability. Research indicates that slightly more force is required to pull over trees within root barriers. The increased stability is attributed to deeper roots. The situation may be different if roots are not able to grow under the barrier.

Other installations have proven to be effective in preventing roots from growing immediately beneath pavements to cause cracking and lifting. Extruded polystyrene foam, four inches (10 cm) thick, installed directly under poured concrete, forced roots to grow under the foam. The expanding roots crushed the foam instead of damaging the pavement. When pavements were laid on a base of coarse gravel or brick rubble [six inches (15 cm) or greater], the roots tended to grow in the soil below the rubble.

Sewer Pipes

Tree root intrusion into sewer systems can be an expensive problem. Tree roots do not often cause pipe damage, but do take advantage of breaks and loose joints and proliferate rapidly once inside the pipe's moist, nutrient-rich environment (Figure 6).

Modern plastic pipe construction can reduce root intrusion, but pipe joints are designed to keep liquids in, not to keep roots out. The distance between the trees and the pipes is important to minimize conflicts. Tree roots are less likely to grow into sewer pipes if planted 20 feet (6.1 m) or more from existing pipes.

Foundations

Tree roots have been associated with foundation subsidence. Roots in the vicinity of shallow foundations built on soils with a high shrink-swell capacity can contribute to soil moisture depletion during drought, causing the soil to shrink and the building foundation to settle and crack.

Figure 6. Although tree roots commonly grow into sewer pipes through breaks and loose joints, they are rarely the cause of damage to pipes.

Preventing tree roots from contributing to subsidence is based on the relationship between the tree and the structure. For example, the British National Home Building Council recommends that on a highly shrinkable soil, if a high-water demand tree is located a distance equal to its height away from the foundation, then the foundation should be five feet (1.5 m) deep. At half of that distance, a foundation depth of eight feet (2.4 m) is recommended.

Human intervention in root development in the built environment is unavoidable. Management strategies must focus on avoiding problems, whenever possible, and being able to respond when problems do arise. With the intense competition for space in urban landscapes it will always be a challenge to maintain root systems that can support vigorous, healthy trees.

About the Authors

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Photos courtesy of the authors unless noted otherwise.

1. Which material is more effective in preventing vehicular soil compaction during construction?
   a. grass
   b. mulch
   c. plywood
   d. clay

2. In Britain, on a highly shrinkable soil, if a high-water-demanding tree is located a distance equal to its height away from the foundation, how deep should the foundation be?
   a. 5 feet (1.5 m)
   b. 2 feet (0.6 m)
   c. 10 feet (3 m)
   d. 8 feet (2.4 m)

3. Roots may be better compartmentalizers during which season?
   a. late summer
   b. spring
   c. mid-summer
   d. any time of year

4. What distance are roots forced deeper by root barriers before returning to the surface?
   a. 3 feet (0.9 m)
   b. 5 feet (1.5 m)
   c. 7 feet (2.1 m)
   d. 2 feet (0.6 m)

5. Over a long period of time, what can be used to speed up natural reversal of compaction?
   a. stone–soil mix
   b. water
   c. gravel
   d. mulch

6. Root defects associated with containers can be managed by
   a. planting the root ball higher in the planting hole
   b. shaving the root ball
   c. burying the root ball deeper at planting
   d. not increasing pot size regularly during growth

7. If one of the flare roots on a tree is severed, up to what percent of the root system could be lost?
   a. 25 percent
   b. 40 percent
   c. 35 percent
   d. 30 percent

8. What equipment or techniques can be used to minimize root severance during construction?
   a. trencher
   b. directional boring
   c. excavator
   d. pile driving

9. How can the addition of fill soil affect soil properties?
   a. changing original soil structure
   b. decreasing permeability of soil
   c. changing original soil texture
   d. all of the above

10. What root defect is associated with container grown trees?
    a. kinked
    b. circling
    c. descending
    d. all of the above

11. At what distance may tree stability be compromised when roots are severed?
    a. closer than four times trunk diameter
    b. closer than five times trunk diameter
    c. closer than three times trunk diameter
    d. closer than six times trunk diameter

12. Soil compaction can affect rooting through changes in which of the following?
    a. porosity
    b. soil strength
    c. gas diffusion rate
    d. all of the above

13. Of the species listed below, which is tolerant of urban soil conditions?
    a. red pine (*Pinus resinosa*)
    b. silver maple (*Acer saccharinum*)
    c. white pine (*Pinus strobus*)
    d. paper birch (*Betula papyrifera*)

14. An established tree with deep roots can be effectively treated by
    a. adding mulch to the existing soil surface
    b. starting a watering regimen
    c. fertilization
    d. root crown excavation

15. When selecting a tree to plant, where should the roots be located in the root ball?
    a. just below the soil surface
    b. more than five inches (12.7 cm) deep in the root ball
    c. exposed above the soil surface
    d. at the soil surface

16. The depth of the adventitious root flare is determined by
    a. the length of the primary root (root shank) after pruning
    b. soil fertility and moisture
    c. the number of natural lateral roots above it
    d. planting depth

17. In what way can girdling roots cause tree stress?
    a. restricting carbon allocation
    b. restricting transpiration
    c. restricting photosynthesis
    d. restricting vascular system flow

18. At what density can the compaction in an urban soil be similar to the density of concrete?
    a. 8.0 g/cc
    b. 5.5 g/cc
    c. 0.5 g/cc
    d. 2.2 g/cc

19. Tree roots are less likely to grow into sewer pipes if planted how far from existing pipes?
    a. 25 feet (7.6 m)
    b. 8 feet (2.4 m)
    c. 20 feet (6.1 m)
    d. 11 feet (3.4 m)

20. When is the best time of year to remediate girdling roots?
    a. summer
    b. winter
    c. spring
    d. none of the above