Chapter 22
Tree Protection During Construction and Landscaping Activities

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In this chapter you will learn about the impact of construction activity on the long-term health of trees. We will discuss the obvious physical damage that may occur to the above ground portions of the tree. More importantly we will discuss what is going on in the below-ground portions of the tree after soil cuts, soil fills, soil compaction and chemical changes. The concepts of a critical rooting zone, salvageable tree inventories, and how to properly set up and maintain a tree protection zone will also be discussed.

Proper planning and clear communication is key to a successful tree save. All parties need to be involved. The property owner's wishes need to be known yet the contractors also need reasonable access routes and work areas. Not every tree can or should be saved. Construction impacted trees often take years to decline and can be much more costly to remove from an established landscape.

Figure 1. Healthy Tree

Tree Biology and Function

Trees are dynamic organisms providing beauty and function to our home and commercial landscapes, cities and parks. In order to better protect these valuable resources, it's important to have a basic knowledge of how a tree grows and functions. It is also vital to understand how construction activity close to a tree can disrupt tree functions and ultimately impact survivability.

Trees grow by producing new cells in a very limited number of places. These places of cell division are called meristems. Meristems are zones of intense metabolic activity where new cells form and expand.

Trees grow in two ways: upward and outward. To help explain the way a tree grows, let's think for a moment about a fence or a sign that has been nailed to a tree. The fence remains in contact with the ground even though the tree has grown taller. A closer look at the fence and you see the tree trunk is expanding over the wire and nails as the tree girth expands. Lets consider why this happens.

Trees grow taller as a result of meristems located at their branch tips. These meristems are called apical meristems. Roots also expand through the soil from apical meristems at their tips. All buds that you see on a tree contain apical meristems. The apical meristems are adding cells at the tips of the roots and shoots in areas of rapid cell elongation and continues moving outward as it produces new cells.

Tree branch and trunk diameter growth occurs from another meristem called the vascular cambium. The vascular cambium contains xylem and phloem which are the vascular transport systems for food and water. The vascular cambium is located just under the bark of the tree and forms a continuous ring around the circumference of the trunk or branch. Lets consider the cambium layer as a ring structure with new xylem cells being created on the inner most part of the ring and new phloem cells being produced on the outside of the ring adding to the diameter of the tree.

Each year cells in this layer divide and grow. As the cambium divides, wood and bark cells form. Phloem cells push outward to form the bark which eventually splits and falls off and is replaced.

The inward growth of the cambium forms the main part of the trunk and is called xylem. The xylem contains small tubes which transport water and minerals from the root to the trunk, branches and

Figure 2. Root Plate of a toppled tree.

leaves. Leaves need this water to help them make food from sunlight.

The phloem cells make up of tiny tubes that transport the sugar, amino acids, protein and other building blocks produced predominately in the leaves to the rest of the tree.

It is important to note that the cambium layer which contains both the xylem and phloem, the food and water transport systems, is located on the outer circumference of the trunk and is only protected by a thin bark layer. If the cambium layer is damaged, food and water transport will be affected. If a significant amount of the cambium layer is damaged the tree will die. This often happens during construction when heavy equipment backs into a tree wounding the trunk. Great care must also be taken when installing new trees not to damage the trunk.

Let's take a closer look at the three main components of a tree – the roots, trunk and crown and how they grow.

Roots

Tree roots grow from apical meristem at the tips of the root structure and are protected by a root cap as they push through the soil. The root cap sloughs off its oldest tissues to provide lubrication as the root pushes through the soil. As the apical meristem grows, it develops new cells through cell division. A zone of cell elongation directly behind the meristem is where new cells are enlarging and differentiating into specialized root tissue. Just behind the root cap numerous root hairs form and extend into the soil, increasing the surface area of the root for absorption of water and nutrients.

The rate of root growth is quite variable throughout a growing season. Roots usually begin growing before the top, although root growth is cyclic and responds to environmental changes, such as soil depth, water supply, aeration, mineral supply, and temperature.

A tree's root system is made up of large, permanent roots (which mainly provide anchorage and transport), and many small, temporary feeder roots and root hairs. It is these small parts of the root system through which most water and nutrient absorption occurs. Many of these small roots function for one or two years then die or become part of the large root system.

Many older books depict trees with root systems as deep and spreading downward as the canopy is tall and wide. This is a common misconception. While some roots may penetrate deeply in the soil to anchor the tree, most roots occur in the top twelve inches of the soil where they can readily absorb water, nutrients and oxygen.

A tree root system extends outward in an irregular pattern, two to three times further than the canopy. However, on a dry weight basis, the "root to shoot" ratio is around 20% root to 80% shoot, making the shoot four to five times heavier than the roots.

Roots of most species of trees are assisted by beneficial soil fungi to form root-fungus structures called mycorrhizae. The tree supplies carbohydrates and other growth requirements to the fungus, and the fungus increases water and mineral uptake (particularly phosphorus) of the host tree by increasing the total absorptive area of the root system. There are more than 2500 different fungi which form mycorrhizal relationships with trees; often there are several different fungi associated with an individual tree. The presence of this association is necessary for establishment and growth of many trees. Its absence has often reduced the success of new tree plantings, especially on old field sites. Nurseries are careful to maintain the mycorrhizae populations in the nursery beds.

Trunk

Growth in diameter of trees is due to the cell divisions in the cambium, a thin cylinder of meristematic tissue found just under the bark. New cells are formed on both sides of the cambium each year. The formation of these cells help to create the visible growth rings in a cross-section of the tree trunk. The annual rings found in tree trunks are a result of variations in growth rate and in the type of wood produced early and late in the growing season. Within each ring, the lighter wood is spring-wood, formed early in the season with larger, thin-walled cells; the darker, thick-walled cells of the summer-wood are formed later in the year. When counting the rings to determine the age of a tree, both of these bands are included in one year. The environmental conditions of an individual tree, most notably the amount of moisture and light available, are recorded each year in its rings. The width of these rings may be used as a measure of the health and vigor of the tree.

A cross-section of the stem of a tree reveals differences in its basic structure. Heartwood is found at the center of the tree. It is composed of old xylem tissue that is no longer living, but still retains structural strength and infection resisting ability. Sapwood is the living xylem inside the cambial layer that is actively involved in fluid transport. Researchers have found that the number of annual rings still living at any time is highly variable, ranging from one to 20 rings, depending on the species.

Crown

Like roots, trunks and branches grow in length from apical meristems found in buds. Buds may grow into shoots, leaves, and/or flowers. Buds containing all of the above are referred to as mixed, while those containing one or the other are referred to as either leaf buds or shoot buds. The terminal bud, located at the apex of the main stem, forms the trunk of the tree over time. Lateral buds, formed at the leaf axils and nodes along the trunk, grow into branches and/or flowers.

Within the bud, two growth habits are possible: fixed growth and free growth.

Fixed growth occurs in species like pines, hickory, and oaks, where the buds contain a preformed shoot. All of the components of next year's shoot are contained in the bud formed this year; the number of leaves and nodes is predetermined by this year's environmental conditions. The length between leaves and nodes is influenced by the environmental conditions the tree encounters next year.

Free growth, in species such as cottonwood, willow, and silver maple, occurs when buds contain not only shoots with some preformed leaves, but are also capable of forming additional leaves. These species can continue to grow as long as environmental conditions are favorable. They may produce a series of buds at the tip of the same elongating shoot in waves or flushes. Some fixed growers, under favorable growing conditions, are also capable of a second flush of growth in one season.

Construction Damage and How it Affects Trees

Trees can be damaged or killed by a wide variety of construction activities. Obvious injuries such as broken branches or torn bark deplete the tree's resources and provide entry points for insects, or for diseases such as oak wilt.

Figure 3.
Damaged Trunk

The worst damage, however, often remains hidden underground. Roots are one of the most vital parts of a tree. They are responsible for nutrient and water uptake, energy storage and anchoring the plant. It is critical that you protect roots that lie in the path of construction.

Soil compaction is the leading killer of urban trees. Tree roots need loose soil to grow, obtain oxygen, and absorb water and nutrients. Stockpiled building materials, heavy machinery, and excessive foot traffic all damage soil structure. Lacking good soil aeration, roots suffocate and tree health declines.

Preparing Trees for Construction Activities

Healthy trees are generally more tolerant of construction activity than unhealthy trees. Here are some suggestions that may improve survivability. However, tree health should be considered several months or years prior to anticipated disturbances. Water trees as needed to prevent drought stress. Fertilize according to a soil test and the needs of the tree species. Prune dead wood and any limbs that will be in the way of construction activity. Root prune at the edge of the protected zone to minimize tearing by construction equipment.

Try to plan for construction during the dormant season. Tree recovery times depend greatly on the season of construction activity.

Season of Construction Average Recovery Times:

- Fall - 2 years
- Winter - 1 year
- Spring - 3 to 4 years
- Summer - 3 years

Coder 2006

Pre-Construction Assessment

Landscape professionals, arborists, and property owners should meet on-site with the building contractor at the inception of the project to set clear and reasonable goals for tree protection. Buildings, walkways and utilities should be sighted, not only for their greatest aesthetic appeal, but also to minimize damage to the existing trees. The building contractor will need to identify the primary access routes, work areas, material storage areas, parking and paint/concrete washout areas. Other major considerations are soil grading activities that occur in a critical rooting zone which may change drainage patterns. Clear communication among all parties involved is key to a successful tree save.

Tree Inventory

Not every tree can or should be saved. If a tree protection zone can not be maintained for a particular tree, then it may be more economically feasible to remove the tree. A certified landscape professional or arborist should evaluate the areas to be protected for weak trees and undesirable plant species. Some tree species are more tolerant of construction activity than others. **Table 1** on the following page lists several native tree species and their sensitivity to root disturbances.

Table 1. Tree Characteristics

Species	Root Severance	Soil Compaction & Flooding	Soil pH Preference	Mature Tree Height (feet)	Mature Crown Spread (feet)	Hazard Tree Rating*	Damage-Causing Roots	Landscape Value**
White pine	Tolerant	Sensitive	4.5-6.5	80-100	50-80	Medium	.	High
Eastern redcedar	Tolerant	Sensitive	4.7-7.8	40-50	10-20	Low	.	Low
Green ash	Tolerant	Tolerant	6.0-7.5	30-60	30-50	Medium	.	Low
River birch	Tolerant	Tolerant	4.0-6.5	40-70	30-50	Low	.	High
Boxelder	Tolerant	Tolerant	6.5-7.5	40-60	35-50	High	Yes	Low
Catalpa	Intermediate	Tolerant	6.1-8.0	50-80	30-50	Medium	.	Medium
Black cherry	Intermediate	Sensitive	6.0-7.5	50-70	40-50	Low	.	Low
Eastern cottonwood	Tolerant	Tolerant	5.5-8.0	80-100	80-100	High	Yes	Low
American elm	Tolerant	Intermediate	5.5-8.0	70-100	70-150	Medium	Yes	Low
Hackberry	Tolerant	Intermediate	6.6-8.0	30-130	50+	Low	.	High
Hawthorn	Intermediate	Intermediate	6.0-7.5	20-40	20-30	Low	.	High
Bitternut hickory	Intermediate	Intermediate	6.0-6.5	40-75	30+	(Medium)	.	Medium
Honeylocust	Tolerant	Intermediate	6.0-8.0	50-75	50-75	Medium	Yes	Medium
Ironwood	Sensitive	Sensitive	6.1-8.0	25-50	20-30	(Low)	.	High
Basswood	(Intermediate)	Sensitive	5.5-7.3	70-100	50-75	(High)	.	Medium
Black locust	Tolerant	Sensitive	4.6-8.2	30-60	20-50	(Medium)	.	Low
Red maple	Tolerant	Tolerant	4.5-7.5	50-70	40-60	Medium	Yes	High
Silver maple	Tolerant	Tolerant	5.5-6.5	60-90	75-100	High	Yes	Low
Sugar maple	(Intermediate)	Sensitive	5.5-7.3	60-80	60-80	Medium	Yes	High
Black oak	Sensitive	Sensitive	6.0-6.5	50-80	50-70	(Medium)	.	High
Bur oak	(Tolerant)	Intermediate	4.0-8.0	70-80	40-80	Low	.	High
Northern pin oak	Sensitive	Sensitive	5.5-7.5	50-75	30-50	(Medium)	.	Medium
Red oak	Tolerant	Sensitive	4.5-7.0	60-80	40-50	(Medium)	.	High
White oak	Sensitive	Sensitive	6.5-7.5	60-100	50-90	Low	.	High
Wild plum	Tolerant	Sensitive	6.5-6.6	20-25	15-25	Low	.	Medium
Serviceberry	Intermediate	>Sensitive	6.1-8.5	6-35	6-15	>(Low)	.	>High
Black walnut	>Sensitive	Intermediate	6.6-8.0	70-100	60-100+	Medium	.	Medium
Black willow	Tolerant	Tolerant	6.5-8.0	30-60	20-40	High	Yes	>Low

***Hazard Tree Rating** refers to the relative potential for a tree to become hazardous. For a tree to be considered hazardous, a potential "target" (e.g., a house, a sidewalk, or other trees) must be present. A high hazard tree rating does not imply that the tree will always fail.

****Landscape Value** refers to the relative value of each species based on hardiness, form, color, growth habits, flowering and fruiting characteristics, structural strength, longevity, insect and disease resistance, maintenance requirements, and general desirability.

Johnson 1999

Tree Save Check List:

- Is the tree species desirable?
- Is the tree healthy?
- Does the tree have any visible damage that will make it undesirable or structurally weak?
- Can a tree protection zone be reasonably maintained during the entire construction process?

If the answer to any of these questions is "no", then consider removing the tree prior to construction.

Figure 4. Bradford Pear tree.

Bradford Pear trees like the one pictured in Figure 4 above are no longer considered a desirable tree species. They are genetically predisposed to splitting due to narrow branch crotch angles.

Preparing for Construction

Create a desirable tree save list that is agreed on by all parties. Call your County Arborist or Extension Agent and ask about any local tree and landscape ordinances. Unauthorized tree removals may result in excessive fines. Look closely at the site grading plan for encroachment into tree protection areas and major changes in drainage that may affect the protected tree species. If a dry tree habitat begins receiving and holding more moisture due to grade changes, the long term health of the existing tree species needs to be considered.

Before construction or site work begins, tree protection zones must be established. A tree protection zone is a designated area around the trees to be saved in which no construction activity or traffic is allowed. Remember soil compaction begins with the first pass of a vehicle.

To set up a tree protection zone:

1. Measure the diameter of the tree trunk in inches at 4.5 feet from the ground. This is called the diameter breast height or DBH.

2. Multiply this value by 2.5. This result is the diameter of the root protection zone in feet. This is also considered the critical rooting distance.

Figure 5. Tree Protection Zone

For example if an oak has a DBH of 20 inches the tree protection zone is 50 feet in diameter (20 x 2.5). Another way to think about it is to protect an area extending 25 feet in all directions from the trunk.

Once the size of the area is determined, consider fencing materials. Orange tree save fencing pictured in Figure 5 or black silt fencing are commonly used. These materials are easy to install but they often get knocked down or removed when it is inconvenient to go around the tree save area. In some cases more permanent materials, such as chain link fencing, (Figure 6) may be required. Whatever fencing material is used, it must be maintained throughout the construction process.

Figure 6. Chain-link Tree Protection Zone

Tree protection zones are extremely important because they prevent harm from construction activities like soil cuts, soil fills, soil compaction, and the effects of chemicals from washing of equipment and disposal of wash waters.

Most construction jobs start with rough grading of the property and removal of undesired vegetation. Keep in mind that trees grow in communities and often share rooting areas and wind loads, so grading and tree thinning may make the remaining trees prone to breakage from wind.

The removal of soil is called a soil cut. The addition of soil is called a soil fill. The effects of soil cuts and soil fills are greatly influenced by soil texture.

Soil Fills

Simply adding one inch of clay soil over the root system will affect the health of a tree while three inches of clay will cause massive root damage. Likewise, sandy-textured soils used as fill initiate root damage at a depth of 8 inches, massive root damage at 24 inches. Soil texture influences soil porosity and structure. The finer the soil texture, the smaller the pore size. As pore size decreases, drainage and oxygen levels become more of a problem.

Tree wells often provide a false sense of protection. They are used to protect the original soil grade around a tree, but they are only as effective as the amount of critical rooting distance they leave undisturbed. Far too often, tree wells are undersized and roots are damaged from too much soil fill and lower oxygen levels. See Figure 7 below.

Figure 7. Undersized Tree Well

Soil Cuts

Soil texture also needs to be considered when determining how much soil can be removed from the rooting area of a tree. Significant root damage is initiated when 2 inches or more of clay soil, or 10 inches or more of sandy soil are removed. This is because roots generally grow deeper in sandy soils, so less roots will be disturbed by surface soil removals than in clay soils. However, care should be taken when determining soil cut depths on soils with a high water table as roots will be located closer to the surface.

On steep slopes, some grading projects require that a retaining wall be installed to stabilize the soil. Retaining walls require a 2:1 slope (one foot of rise for every two feet of distance) be cut into the hill to be able to properly install the wall and for its structural integrity. This has the potential to disturb many more tree roots than is necessary for the project. Spence Rosenfeld, Owner of Arborguard Tree Specialists in Atlanta uses a less invasive process called “soil nailing”. He uses soil anchors and gunnite (a product often used to stabilize soil for in ground pool construction) to stabilize slopes. The result is less impact on the surrounding trees.

Figure 8. Trees disturbed by road and sidewalk construction

Trenching, Roads, and Walkways

Another construction process that can damage root systems is trenching and soil cuts for utilities, roads and walkways. How many times have you seen a sidewalk being installed right under a mature oak? This construction activity has a negative impact on the tree when 20 to 30% of the critical rooting zone is damaged. Trenching may not disturb as much surface soil as cuts and fills, but it can have a major impact on a tree's root system. Trenching severs the root system, killing roots from the severed point outward. When many of the large anchor type roots are severed, the tree may become unsafe and prone to falling. Are there better options? Absolutely. Equipment is now available that can tunnel the utility lines under trees without cutting roots. You probably have noticed construction crews tunneling utilities under roads with this type of equipment.

Another method is called bridging, or creating a raised walkway over the rooting zone. Bridging the root zone is the least invasive method of creating roads and walkways, but can be more expensive. With bridging, the only points of root disturbance are where the support pilings are anchored into the soil.

If the root zone must be encroached upon by a soil cut or trench, root pruning of the desired trees is recommended. Root pruning is done by making a clean, vertical cut of the root system at the perimeter of the construction zone 3-6 months in advance of soil disturbance. This allows the tree time to produce more feeder roots inside of the root pruning line and reduces tree stress from the construction activity. Root pruning also helps minimize tearing of roots because it makes clean vertical cuts.

Construction Wash Out Areas

Almost all construction sites need an area to wash equipment and tools. Painters need to wash their brushes and the chutes of concrete delivery trucks are often washed on site. Trees can be negatively affected by wash water, so and a designated wash out area should be planned to minimize the effects of the process.

Signage is as important as proper initial communications. Signs clearly designating washout areas and tree protection areas are visual reminders to all involved parties that a successful tree save depends on everyone's cooperation.

Soil Compaction

Soil compaction is the silent killer of trees. It seems innocent enough, you park your truck in the shade to keep cool. However by the time you have driven over the same spot three times, the soil may reach 90% compaction.

Figure 9. Construction equipment contributing to tree decline by soil compaction.

Soil compaction is affected by soil texture, soil moisture, and the weight and amount of ground contact of the vehicle. Which vehicle do you think causes the greater amount of soil compaction, a military tank or a passenger car? Believe it or not the tank has half of the effect of a passenger car with an average of 15

PSI (pounds of pressure per square inch) and a passenger car averages 30 PSI. The weight of the military tank is distributed over a larger area by the use of tracks instead of wheels.

Table 2 shows that trees growing in a clay soil are already at a disadvantage due to less porosity. Root growth becomes limited as air filled pores percentages fall below 15%.

Soil Texture	Root-limiting % Pores normally filled with air
Sand	24%
Fine sand	21%
Sandy loam	19%
Fine sandy loam	15%
Loam	14%
Silt loam	17%
Clay loam	11%
Clay	13%

Table 2 Root growth becomes limited in fine textured soils as air filled pores drop below 15% Coder 1996

Two of the primary influences on soil compaction are soil texture and soil structure. Soil texture refers to the percentage of sand, silt and clay particles in a soil sample. Soil structure is how the soil particles and pores are arranged to create larger units of soil and thus the interconnectedness of the pore channels. Soil structure can be destroyed by tillage/movement, vibration, and/or surface pressure. Soil disturbance under wet conditions exasperates the structure collapse. Soils with a poor structure have poor drainage and poor air exchange which can cause tree decline.

Spreading the Load

If traffic across a protected root zone is unavoidable, consider using one of the following bridging methods in the traffic area:
1. A logging mat such as the one pictured in Figure 10
2. Plywood panels (3/4 inch or thicker)
3. A geotextile fabric and six inches or more of wood chips.

Avoid working in the area if the soil is wet. All materials need to be removed once construction activity has ended.

Figure 10. Logging Mat Photo courtesy of Carolinamat.com

Recognizing Damage

Obvious symptoms of construction damage may take years to appear. Tree decline from soil compaction, for instance, may take three to seven years to appear. Because of this delay, landowners often attribute tree losses to other causes. Carefully monitor affected plants and keep written records to help you recognize the less visible signs of tree stress. Remember, the most serious damage remains hidden in the root system.

Wilted or scorched leaves and drooping branches usually are the first signs of construction damage. In deciduous plants, these symptoms may be followed by early fall coloring and premature leaf drop. Damaged conifers will drop excessive amounts of inner needles. In subsequent years, yellowed or dwarfed leaves, sparse leaf cover, or dead branches may appear.

Other indicators of construction damage include flowering out of season, excessive water sprout formation on the trunk, abnormal winter dieback, or abnormally large amounts of seed. Flower and seed production and water sprout formation are defense mechanisms for ensuring species survival and commonly indicate that the plant is experiencing extreme stress.

In addition to observing a tree's appearance, monitor its annual growth. A damaged plant will grow more slowly and will be less resistant to insects, diseases, and weather-related stresses. Examine the annual shoot and branch growth. Healthy trees generally will grow two to six inches at the ends of branches each year. Photographs and records of the tree prior to construction can help identify growth problems.

A key component in assessing developmental impacts on trees is systematic evaluation of damage. Many types of damage occur repeatedly over a site and can differ from location to location. This constant and repetitive damage often results from tree-illiterate activities. Using a systematic assessment, patterned damage can be prevented or minimized. Some types of damage (one-time, one-spot, chance occurrences) can also be assessed, but they are difficult to prevent. By attempting to categorize damage, patterns can be recognized and steps taken to minimize tree injury and site degradation. Decisions must be made early in the planning process to maintain tree quality of life and minimize injury.

As developmental activities occur on a site, continually monitor tree quality and site resources. Expected tree reactions to construction damage vary from: immediate death; single-year decline and death; multiple-year decline and death; or decline with major living mass loss. The latter two are the most common expectations among residual trees, and the most difficult to prove a cause-and-effect relationship with construction activities.

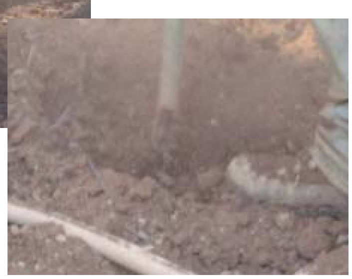

Figure 11.
Vertical Mulching

Post-Construction Tree Care

Once construction has ended, remove any excessive mulch (wood chips) that was used for protection leaving only a 3-5 inch layer of mulch for weed control. Prune out any damaged limbs. Inspect for any cut and fill changes or areas of excessive traffic that may have become compacted. Water and fertilize as needed.

A quick way to check for grade changes is to look for the buttress flare at the base of the trunk of mature trees. If too much fill has been added the flare will not be visible. Not all tree species create buttress flares so fill soil levels may also be measured by digging small sample holes down to the original grade.

If too much fill has been used some major decisions need to made quickly.

- Is the grade change necessary for the construction process?
- Do you really need or want to save this tree?
- Has the tree already begun to exhibit symptoms of decline? If so, you may be wasting your time trying to excavate the soil.

If you discover areas that have become compacted, are their remedies? This is an area of tree care that needs to have more research. One procedure that is attracting some attention is soil fracturing with compressed air and/or vertical mulching (drilling 2 inch holes 12 inches deep on a set grid pattern under the drip-line and backfilling with more organic soil mixes). Unfortunately many studies done on this subject indicate no statistical improvement in tree growth. The take home message here is use tree protection zones to minimize unwanted soil compaction if you want to give your trees the best chance of survival during construction and landscaping activities.

Study Questions

1. At what soil depth are most tree roots found?
2. What is the typical spread of a tree's root system in comparison to the crown?
3. What is the function of mycorrhizae?
4. What is the single largest killer of urban trees?
5. Name several symptoms of tree decline from construction damage.
6. What is the key principal in a tree save program?
7. Name two of the four items on a tree save check list.
8. How do you calculate the critical rooting distance?
9. What should you consider in choosing tree save fencing?
10. How many inches of clay soil can be used for fill over the root system of a tree before massive root damage occurs?

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