MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #113

Diagnosing Root and Soil Disorders

On Landscape Trees

Symptoms of root and soil disorders on landscape trees are often non-specific, making diagnosis difficult. This CMG GardenNotes expands on ***Step 3, Evaluate Roots and Soil***, in the ***Systematic Evaluation of Trees***, (CMG GardenNotes #112).

Root Function and Symptoms of Root/Soil Disorders

Roots account for approximately 1/3 of the total biomass of a tree. The functions of tree roots include the following:

- Water and nutrient uptake
- Anchoring the plant
- Production of gibberellins, a hormone that promotes canopy growth
- Storage of photosynthates (along with the woody tissues)

Symptoms of root/soil disorders are non-specific in nature, including the following:

- Reduction in photosynthesis
- Reduction in root growth
- Reduction in canopy growth
- Reduction in winter survival
- Reduced tolerance to other stress factors (insects, diseases, drought, etc.)
- Poor anchoring of the plant resulting in tree failure

Root, soil and water issues contribute to a large portion of landscape plant problems, for example:

- Soil compaction and/or drought are the *inciting* factor for many *contributing* insects (borers) and diseases (Cytospora and other cankers).
- Soil compaction and/or hardscape features often limit root spread, which is expressed as reduced growth and leaf scorch.
- Soil compaction reduces a trees' tolerance to common stress factors, including drought, heat and wind, aphids, mites, and other insects.
- Overwatering and drainage problems (soil compaction) are often expressed as iron chlorosis, root rots, leaf scorch and limited growth.
- Trunk girdling roots, caused by planting too deep, is the most common cause of tree decline and death in the landscape.

Diagnosing Root and Soil Disorders

Uniform stress through canopy or stress from the top down suggests root, soil, and water related problems. Diagnosis cannot be from these symptoms alone, but requires a more complete evaluation of the tree, its rooting system and growth. The following is a systematic approach to diagnosing root and soil disorders, based on common problems.

1. Define the Root System

Types of Roots

Root Plate – Zone of Rapid Taper

The *root plate* or *zone of rapid taper* is the primary structural roots extending outward from the trunk. Roots branch readily, tapering in diameter. It is a continuation of the pipeline carrying water and nutrients from the absorbing and transport roots into the tree trunk. [Figure 1]

The root plate is the tree's primary support in winds up to 40 mph. Avoid disturbing the soil and roots in the root plate area. Construction and hardscape features should not encroach into the root plate! When the tree fails by tipping over, often exposing the root plate, it is failure at the edge of the root plate.

As a rule of thumb, the radius of the root plate is three to six times the trunk DBH (diameter at breast height, 4.5 feet).

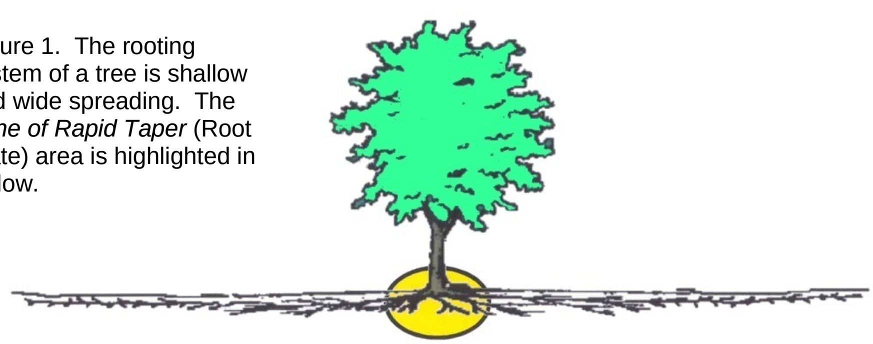


Figure 1. The rooting system of a tree is shallow and wide spreading. The *Zone of Rapid Taper* (Root Plate) area is highlighted in yellow.

Transport Roots

Transport roots serve as a continuation of the pipeline carrying water and nutrients from the absorbing (feeder) roots to the root plate root and trunk. These are the major spreading roots of the tree and follow soil oxygen gradients across the rooting area. In compacted areas (with lower soil oxygen), they will come to the surface. In soils with good structure (higher oxygen), they will be deeper. They also provide additional support to the tree in winds above 40 mph. [Figure 2]

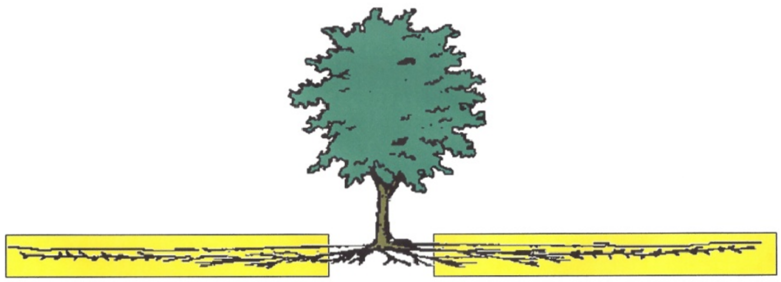
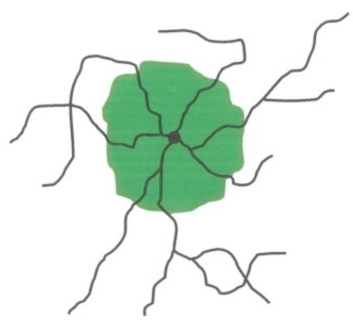


Figure 2. Transport and absorbing roots are found through the entire rooting area beyond the *Zone of Rapid Taper*

Transport roots are typically thumb-size in diameter, long, meandering, and with limited branching. Transport roots do not uniformly spread around the tree. Some areas may be void of roots, other heavily concentrated. In a hole dug in the rooting area, transport roots are readily observed sticking out the side [Figure 3].

Figure 3. Transport root are long and meandering. They are NOT uniformly distributed around the trunk.



Absorbing Roots

Absorbing (feeder) roots serve the function of water and nutrient uptake. These tiny roots are found near the soil surface throughout the entire transport rooting area. As a rule of thumb, they are found in the top 12 inches on soils with good tilth, and in the top four inches or less in compacted, clayey soils. [Figure 2]

Absorbing roots have a short life, being replaced in four to five flushes of growth through Colorado's growing season. A short-term drought stress (defined as 10 days) can shut down growth for 1-5 weeks. Long-term drought stress (defined as 22 days), can shut down growth for 1-2 years! Refer to CMG GardenNotes #635, *Care of Newly Planted Trees*.

Sinker Roots

Sinker roots follow natural openings into deeper soil as soil oxygen levels allow. It is unknown to what extent trees actually have sinker roots in the compacted soils of a landscape setting.

Sinker roots have the ability to extract water from deeper soil depths when the surface soil is dry. This helps explain how trees have good short-term drought resistance. It also helps explain the severe drought stress observed on trees when there are dry seasons with dry subsoil. Sinker roots also provide additional support in strong winds. [Figure 4]

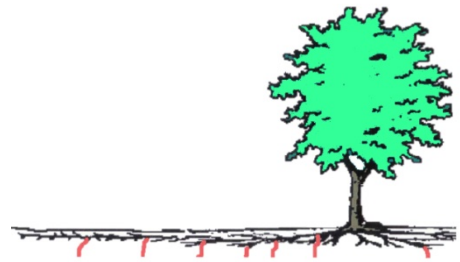


Figure 4. Sinker roots follow cracks in the soil to deeper depths as oxygen levels allow. They extract water when the *absorbing roots* near the surface have dry soil.

Tap Root

The tap root develops from the seed radicle, being the primary root emerging from the germinating seed. Gardeners are very much aware of the tap root as they try to pull seeding maples or elms as weeds in the garden.

However, beyond the seedling stage, the tap root is nonexistent on most trees. As the root system develops beyond the seedling stage, the roots grow into the root plate system due to low soil oxygen. Studies found less than 2% of landscape trees actually have a tap root. In nursery production, the tap root is cut while tiny, forcing a more branching root system that is tolerant of transplanting. [Figure 5]

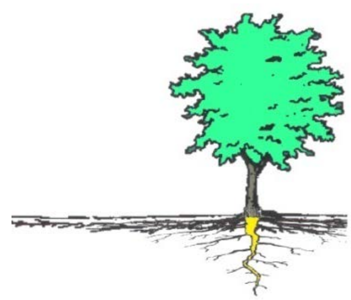


Figure 5. The tap root develops from the seed radicle. In the seedling stage, the tree develops the root plate system due to low soil oxygen. Tap roots are rare in landscape trees.

Depth and Spread

The typical tree rooting system is shallow and wide spreading because roots only grow with adequate levels of soil oxygen. Rooting depth and spread is a factor of 1) the tree's genetic tolerance to soil oxygen levels and 2) soil texture and structure (actual soil oxygen levels).

It is difficult to estimate the actual depth and spread of a tree's root system. Table 1 gives a rule of thumb on root spread. Roots will be more sparse and spreading in dry soils, and more concentrated in moist soils. [Table 1]

Table 1. Estimated Depth and Spread of a Tree's Root System

With good soil tilth

- o 90-95% in top 36 inches
- o 50% in top 12 inches (absorbing roots)
- o Spread 2-3 times tree height and/or canopy spread
- o Modified to by actual soil conditions

With compacted/clayey soils

- o 90-95% in top 12 inches or less
- o 50% in top 4 inches or less (absorbing roots)
- o Spread five or more times tree height and/or canopy spread

Tree Protection Zone / Protected Root Zone

Obviously, not every root is essential for tree health. The *Tree Protection Zone, TPZ* (Protected Root Zone, PRZ) defines the rooting area with direct influence on tree health and vigor. The TPZ is the area of focus in tree care activities and evaluating root/soil related disorders.

To protect trees in a construction area, there should be NO grading, trenching, parking, or stock piling of materials in the TPZ. Several methods have been used to estimate the TPZ.

Dripline Method

The drip line (outer reach of branches) is often used in construction activities and by some city ordinances to define the TPZ. It may be suitable for a young tree with a broad canopy in an open lawn area. But it critically underestimates the critical rooting area for most landscape trees. [Figure 6]

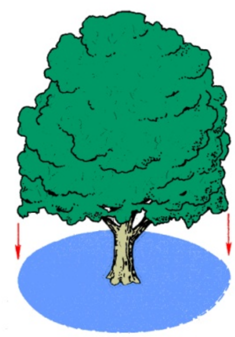
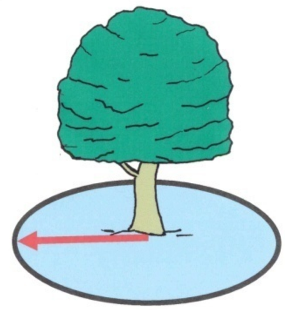


Figure 6. The dip line is the rooting area defined by the outer reach of the branches. It is a poor method for estimating a tree protection zone.

Trunk Diameter Method

The trunk diameter is probably the better method forl use on landscape trees. Size of the TPZ is based on the diameter of the trunk, increasing as the tree ages. It may be calculated by measuring the trunk circumference or diameter at DBH (diameter at breast height, 4.5 feet). For trees with a broad canopy in an open lawn, it is approximately 40% larger in area than the dripline method. [Figure 7]

Figure 7. The Tree Protection Zone defined by the trunk formula method is a good estimate of the rooting area with direct influence in tree health and vigor. It is approximately 40% larger than the area defined by the drip line.



Trunk Diameter Method by Circumference

TPZ radius = 1 feet per 2 inches of trunk circumference

1. Measure the tree's circumference at DBH (4.5 feet) in <u>inches</u>.
2. Divide the number of inches by 2.
3. This is the radius, <u>in feet</u>, of the TPZ.

For example
1. Circumference = 24 inches
2. 24 / 2 = 12
3. TPZ radius = 12 feet

Area of the TPZ

The area of the TPZ can be calculated by the formula:
[TPZ radius]^2 × π

For example - 12 foot radius:
12 feet × 12 feet × 3.14 = 452 square feet

2. Evaluate Root Spread Potential

The potential for the roots to spread is a primary consideration in evaluating a tree's root system. The mature size, growth rate and longevity of a tree are directly related to the available rooting space. Many trees in the landscape are predisposed at planting to a short life and limited growth potential due to poor soil conditions and limited rooting space. [Figure 8]

Figure 8 shows the relationship between root space and ultimate tree size. For example, a tree with a 16 inch diameter requires 1000 cubic feet of soil. In a compacted clayey soil, rooting depth may be restricted to 1 foot <u>or less</u>, requiring an 18-foot or greater radius root spread. Anything less will reduce tree size, growth rates, vigor and longevity.

Tree roots can generally cross under a sidewalk to open lawn areas beyond. The ability of roots to cross under a street depends on the road base properties. A good road base does not typically support root growth due to compaction and low soil oxygen levels.

The rooting area does not need to be rounded, but can be about any shape. Trees can share rooting space.

When roots fill the available 'root vault' area and cannot spread beyond, 1) root growth slows, 2) canopy growth slows, and 3) trees reach an early maturity and go into decline. Routine replacement may be necessary.

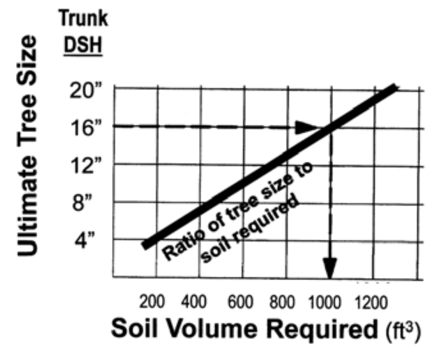


Figure 8. Tree size, growth rate, and longevity are directly related to the size of the available rooting area.

For tree in Colorado's clayey soils, effective rooting depth is probably less than one foot deep.

3. Evaluating Soil Compaction

Surface roots of trees are an indication of low soil oxygen caused by soil compaction and/or overly wet soil. Soil compaction is often expressed as low vigor and dieback symptoms. Soil compaction is the most common *inciting* factor leading to *contributing* factors in the decline process. (Refer to CMG GardenNotes #101, *Plant Health Care,* for a discussion of the PIC Cycle.)

Soil compaction is a reduction in large pore space, reducing soil oxygen levels and decreasing soil drainage. As a result, rooting depth is reduced. For additional details, refer to CMG GardenNotes #213, *Managing Soil Tilth*, and #214, *Soil Compaction*.
Primary causes of soil compaction include construction activities, foot traffic, and the impact of rain on bare soil. Soils are extremely prone to compaction when wet as the water serves as a lubricant allowing soil particles to slide closer together.

Evaluating Soil Compaction

Soil compaction is somewhat difficult to evaluate. Evaluation tools include the following:

- **Look at the lawn -** It shares the same soil conditions as the tree and may be easier to evaluate. Is the lawn thick or thin?

- **Screwdriver test** – How easy can a screwdriver be pushed into the soil? For this test, the soil needs to have been watered the day before.

- **Soil probe** – With a soil probe, evaluate soil type, texture interfaces, and rooting. It's best if the soil was watered the day before performing this test.

- **Penetrometer** – This instrument measures the amount of pressure it takes to push the probe into the soil. The colored dial sections indicate when root growth may be slowed or inhibited. The soil must be watered the day before performing this test.

Figure 9. Soil penetrometer measures the pressure it takes to push the probe into the soil. It is a great tool to evaluate soil compaction.

- **Shovel** – Sometimes the only way to evaluate the soil is with a shovel and some hard work.

Methods to Deal with Compaction Around Trees

Standard methods of dealing with compaction in a garden setting (adding organic matter, cultivating the soil only when dry, and avoiding excessive tilling) do not apply to tree situations, as we do not cultivate the rooting zone.

<u>Practices Worth Considering</u>

- **Aeration, with plugs at two-inch intervals** – Lawn or soil aeration is helpful for tree root oxygen levels if enough passes are made over the area to have plugs at two-inch intervals.

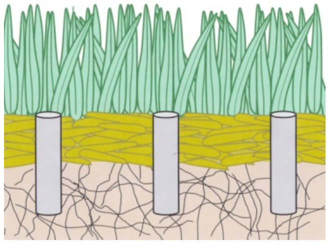


Figure 10. Core aeration helps reduce soil compaction around trees. To make a difference, plugs needs to be at two-inch intervals.

- **Managing traffic flow** – Established walks help minimize the compaction to other areas. The first time a cultivated soil is stepped on, it can return to 75% maximum compaction. The fourth time a newly cultivated soil is stepped on it could return to 90% maximum compaction. Foot traffic on a compacted soil causes little additional compaction. Soils are much more prone to compaction when wet, as the soil water acts as a lubricant allowing the soil particles to slide closer together.

- **Organic mulch** – A wood/bark chip mulch prevents soil compaction from foot traffic if maintained at adequate depths. When using medium sized chips, the ideal depth is 3-4 inches. Less does not give the protection from compaction; more reduces soil oxygen levels.

- **Soil renovation with an air spade** – This method is used by arborists on high value trees (due to the expense). Steps include the following:

   1. Sod in the TPZ is removed with a sod cutter
   2. Organic matter is spread and mixed into the soil with an air spade. The air spade is a high pressure stream of air that cultivates the soil without cutting the roots.
   3. The area is covered with organic wood/bark chip mulch.

<u>Practices of Questionable Value</u>

- **Vertical mulching with an augur** – The TPZ is drilled with 2” holes, typically at 12-24 inch intervals. Hole may be filled with coarse sand or organic matter. Long-term research finds that is does not aerate enough soil area for a significant increase in tree vigor. [Figure 11]

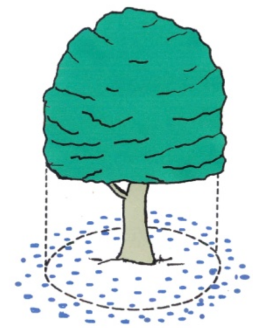
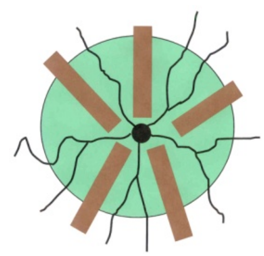


Figure 11. Vertical mulching with hole drilled throughout the tree protection zone.

- **Trenching** – Trenches (dug between primary rooting paths) are backfilled with improved soil. Long-term research finds that while it improves root growth in the backfilled trenches, it does not support a long-term significant increase in overall tree vigor. [Figure 12]

Figure 12. Trenches dug between primary root paths does not result in significant improvements in tree vigor.



- **Punching holes with a pipe, pick, or bar** – This practice compacts the soil around the punch site and does not increase soil oxygen levels. It does not aerate enough soil area for a significant increase in tree vigor. To be effective, the soil cores must be removed.

- **Fracturing** – The soil is subjected to a high-pressure release of air or water, fracturing the soil profile. It has limited effectiveness in sandy soils. It may actually increase the compaction around the fracture lines in clay soils.

  In summary, there is NO quick, easy fix for compacted soils in tree rooting areas.

4. Evaluate Planting Depth

Trunk girdling roots are the most common cause of tree decline and death of landscape trees. Trunk girdling roots are caused by planting the tree too deep. It may show up some twelve to twenty plus years after planting, causing decline and death of trees after they have significant growth. Thus in evaluating the rooting system of a tree, it makes sense to evaluate the tree planting depth. [Figure 13]

Figure 13. Trunk Girdling Roots

Circling/girdling roots may also develop as trees are planted up from pot size to pot size in nursery production. They may be hidden inside the root ball.

For additional information on tree planting, refer to CMG GardenNotes #633, *The Science of Planting Trees.*

Recently Planted Trees

Two considerations are important in evaluating the planting depth of trees: 1) the depth of tree in the root ball, and 2) the depth of root ball in the planting hole. [Figure 14]

Depth of tree in the root ball – Industry standards include the following:

- Generally, at least two structural roots should be within the top 1-3 inches of the soil surface, measured 3-4 inches from the trunk.
- On species prone to girdling roots (crabapples, green ash, hackberry, littleleaf linden, red maple, poplars, and possibly others), the top structural root should be within the top one inch of the soil surface.

Depth of root ball in planting hole – To deal with the texture interface between the root ball soil and the back fill soil, the root ball must come to the surface with NO backfill soil over the root ball. The top of the root ball on newly planted trees should rise 1-2 inches above grade (depending on root ball size). When the root ball settles, it will be at ground level.

On recently planted trees, the height of the root ball should be slightly above grade or at grade level after the root ball settles. The root ball soil should be visible on the surface with the site soil to the sides. With a small trowel, evaluate the planting depth of the root ball in the planting hole. With a small trowel or screwdriver, evaluate the planting depth of the tree in the root ball.

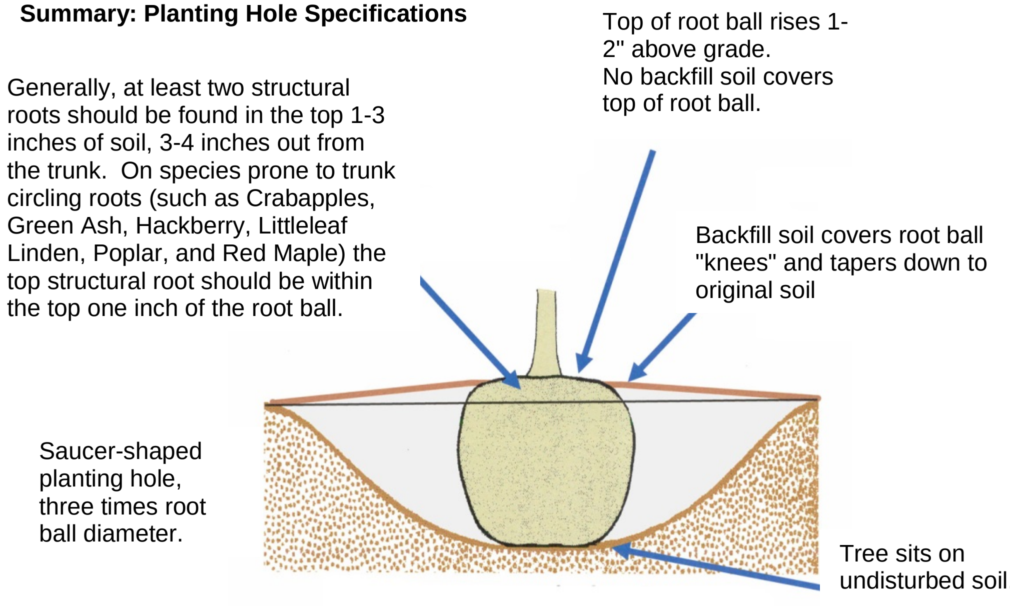


Figure 14.
Summary: Planting Hole Specifications

<u>**Recently planted tree, planted too deep**</u>

- If the tree is stressed with poor vigor, replace the tree.
- If the tree is currently in good health:
    - Live with possible consequences of slower growth and trunk girdling roots. Check for circling/girdling roots.
    - Replant the tree – 1) Dig around the tree exposing the root ball. 2) Wrap the root ball in burlap and twine to hold it together. 3) Lift the root ball from the hole. 4) Replant at correct depth. This would be difficult to do!

Established Trees Planted Too Deep

The lack of a visible root flare is an indication of planting too deep (or that soil has been added over the root system). If the root flare is not visible, check for trunk circling/girdling roots. Circling/girdling roots may be several inches below ground.

Circling roots not embedded into the trunk should be cut and removed. For girdling roots putting pressure on the trunk, cut and remove the root without causing injury to the trunk. The tree will likely recover without any long-term effects.

When girdling roots embedded into the trunk, cut the root without causing injury to the trunk, if possible. However, do not remove the girdling root section if it is embedded into the trunk, as this opens the trunk to decay and the trunk will be structurally weak. The tree may or may not survive; only time will tell.

5. Evaluate Root/Shoot Hormone Balance

Auxins (plant hormones) produced in the twig's terminal buds stimulate root growth. Gibberellins (plant hormones) produced in the root tip stimulate canopy growth. The tree balances root growth versus canopy growth by these hormones. [Figure 14]

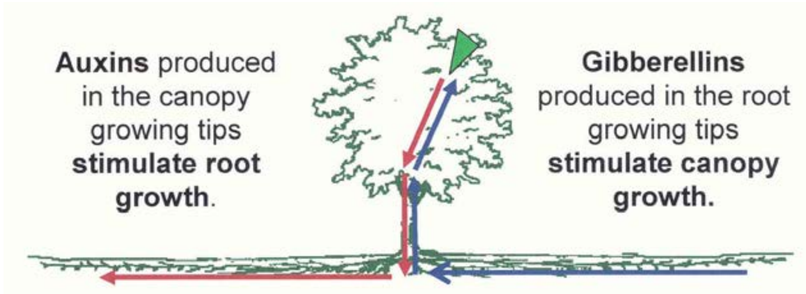


Figure 14. Trees balance shoot and root growth based on the concentration of auxins and gibberellins.

Soil factors that limit root growth will influence canopy growth.

Storm damage or excessive pruning may reduce auxins, slowing root growth. Following storm damage, trees often develop a large amount of water sprout growth due to a low auxin/high gibberellin ratio (coupled with unobserved, limited root growth). This is followed by a decline in the canopy caused by the reduced root growth.

Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University. Artwork by David Whiting; used by permission. Revised by Mary Small, CSU Extension

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