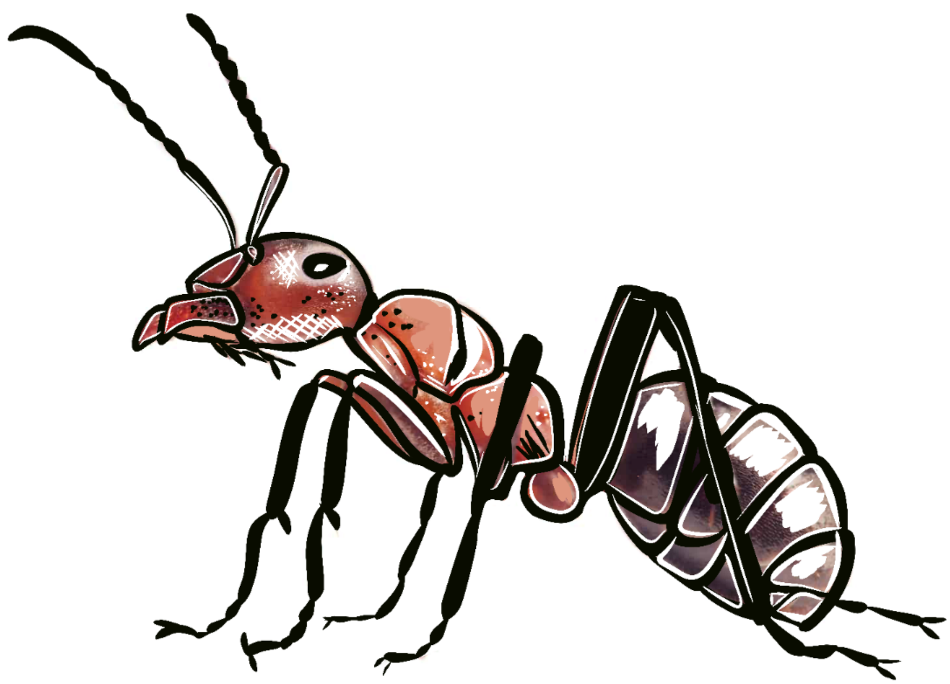
MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #100-113

Integrated Pest Management & The Diagnostic Process



Formica, Ant
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This Integrated Pest Management & The Diagnostic Process curriculum was developed by David Whiting, CSU Extension, retired and Carol O'Meara, CSU Extension, retired. Cover art by Melissa Schreiner. Used with permission.

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EXTENSION

CMG GardenNotes #100

Integrated Pest Management and the Diagnostic Process

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #101, *IPM and Plant Health Care*.
- #102, *Diagnosing Plant Disorders*.
- #112, *Systemic Plant Evaluation.*
- #113, *Diagnosing Root and Soil Disorders on Landscape Trees.*
- #145, *Plant Growth Factors: Hormones*.
- #512, *Herbaceous Plants, Right Plant, Right Place*.

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #2.903, *Nonchemical Disease Control*.
- #2.926, *Healthy Roots and Healthy Trees*.
- #2.932, *Environmental Disorders of Woody Plants*.
- #5.547, *Insect Control: Soaps and Detergents*.
- #7.402, Perennial Gardening.

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.
- #1461, *IPM & PHC: What Are They?*

Other

- *Homeowner's Guide to: Pesticide Use Around the Home and* Garden, https://extension.colostate.edu/docs/pubs/garden/xcm220.pdf.
- *Homeowner's Guide to: Alternative Pesticide Management for the Lawn and Garden*, https://extension.colostate.edu/docs/pubs/garden/xcm221.pdf.
- High Plains Integrated Pest Management. Colorado State University, University of Wyoming, University of Nebraska, North Dakota State University, Montana State University, South Dakota State University, https://wiki.bugwood.org/Main_Page.
- University of California Agriculture and Natural Resources Statewide Integrated Pest Management Program, https://ipm.ucanr.edu/.
- Colorado Center for Sustainable Pest Management. Colorado State University College of Agricultural Sciences, https://agsci.colostate.edu/agbio/ipm/.

- The American Phytopathological Society (APS), https://www.apsnet.org/Pages/default.aspx.
- *Abiotic Disorders of Landscape Plants: A Diagnostic Guide*. University of California Agriculture and Natural Resources Publication 3420, 2004. ISBN: 1-879906-58-9.
- *Aspen: A Guide to Common Problems in Colorado*. Colorado State University Extension Publication 559A, 1996.
- *Insects and Diseases of Woody Plants of the Central Rockies*. Whitney Cranshaw, David Leatherman. CSU Extension, 2004. ISBN: 978-1889143040.
- *Plant Health Care for Woody Ornamentals*. University of Illinois Cooperative Extension, 1997. ISBN: 1-883097-17-7.

Learning Objectives

At the end of this training, the student will be able to:

- Describe concepts of Integrated Pest Management, including the three basic elements of maintaining damaging insects/disease below thresholds, use of multiple, reinforcing tactics, and the conservation of environmental quality.
- Describe the concept of Plant Health Care (PHC) and how it relates to IPM.
- Distinguish between predisposing, inciting, and contributing factors affecting plant health.
- Outline the life cycle of trees and describe how trees need to change with stages in the life cycle.
- List steps in the diagnostic process.
- Using the diagnostic process, diagnose routine insect and disease problems of plants.

Review Questions

IPM, Plant Health Care, and Diagnosing Plant Disorder

1. Define IPM and PHC.
2. Describe concepts central to IPM.
3. Give examples of common IPM tools used in home gardening.
4. In pest management, what are *biocontrols*? What is the difference between conservation biocontrol and augmentation biocontrol?
5. What is the PIC cycle? What does it explain about tree care and pest problems?
6. In diagnosing contributing disorders, why is it important to also identify the predisposing and inciting factors to the extent possible?
7. Explain why it is important to define what is normal versus abnormal about a plant problem.
8. List the four steps in the diagnostic process.
9. Give examples of living (biotic) factors that cause plant problems. Give examples of non-living (abiotic) factors that cause plant problems.
10. Why is it important to correctly identify the plant being diagnosed?
11. Define *symptom* and *sign*. Give examples of each.
12. Define the following terms:
    - Chlorosis.
    - Blight.
    - Dieback.
    - Decline.
    - Leaf spot.
    - Leaf scorch.
    - Canker.
    - Gall.
    - Fruiting bodies.
    - Mycelium.
    - Gummosis.
13. List the five growth phases of landscape trees, giving growth objectives for each. What indicates that trees have changed their phase?
14. Why is it important to talk about tree care issues as they relate to growth phases?

Diagnosing Tree Disorders

15. Explain how knowing the context of the situation helps in diagnosing the disorder.
16. Explain how painting a mental picture of a plant problem helps in diagnosing a disorder.
17. Explain how repeating back the details in your own words helps in diagnosing a disorder.
18. Explain how to tactfully change directions when the evidence leads down another road.
19. Why is it important to discuss management options only after the problems have been diagnosed?
20. List the four steps in the diagnostic process.
21. List steps for systematically evaluating a tree.
22. In the landscape setting, what is the universal limiting factor for root growth?
23. Describe the typical rooting system of a tree. Describe location and function of the following root types:
    - Root plate or zone of rapid taper.
    - Transport roots.
    - Feeder roots.
    - Sinker roots.
    - Tap root.

10. What two factors play into the rooting depth and spread?
11. What is the typical depth and spread of tree roots? How does this change for compacted/clayey soils?
12. Explain how to calculate the Critical Rooting Radius *and Tree Protection Zone (Protected Root Zone).*
13. Describe how potential rooting spread impacts tree growth and vigor. What happens when a tree's root system cannot spread as needed?
14. Describe techniques to evaluate soil/root disorders and soil compaction.
15. Describe worthwhile techniques to reduce soil compaction around trees. Explain why questionable techniques to reduce soil compaction are out of favor.
16. What single factor accounts for the most deaths of landscape trees? What causes trunk-girding roots? How long after planting can trunk-girdling root develop? What can be done for a tree with trunk girdling roots?
17. Describe how a tree balances root growth with canopy growth.
18. List the PHC questions for using pesticides.

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CMG GardenNotes #101

IPM and Plant Health Care

Gardening and the Environment

Gardens and landscapes do not exist in a vacuum, but as part of a larger urban/suburban or rural ecosystem. Landscape maintenance and gardening practices may have positive or negative influences on the health of the neighborhood environment. For example, turf enhances the environment by:

- Converting carbon dioxide to oxygen.
- Increasing water infiltration into the soil.
- Reducing surface runoff and erosion.
- Reducing dust.
- Providing a micro-ecosystem that effectively breaks down pollutants.
- Moderating summer temperatures.
- Creating a pleasant "people" space.

On the other hand, lawn care practices negatively affect the environment when grass clippings are mowed or blown onto the street (water quality problem), when fertilizers are over-spread onto hard surfaces, and when the unwarranted use of pesticides occur. Maintaining turf requires energy for equipment and supplemental water use.

Gardeners and land managers must make decisions that consider as many of the possible effects of management as possible, weighing costs and benefits for both the user and the environment. *Integrated Pest Management* and the concept of *Plant Health Care* provide a user-friendly framework for these choices.

Integrated Pest Management, IPM

Integrated Pest Management, IPM, incorporates a variety of strategies for pest and disease management, including cultural, mechanical, biological, and chemical methods. It is "integrated" because the pest management techniques are compatible with one another and with the environment; having re-enforcing rather than competing effects. IPM objectives include minimizing both pest damage and health/environmental hazards while maintaining plant quality above a predetermined economic or aesthetic threshold.

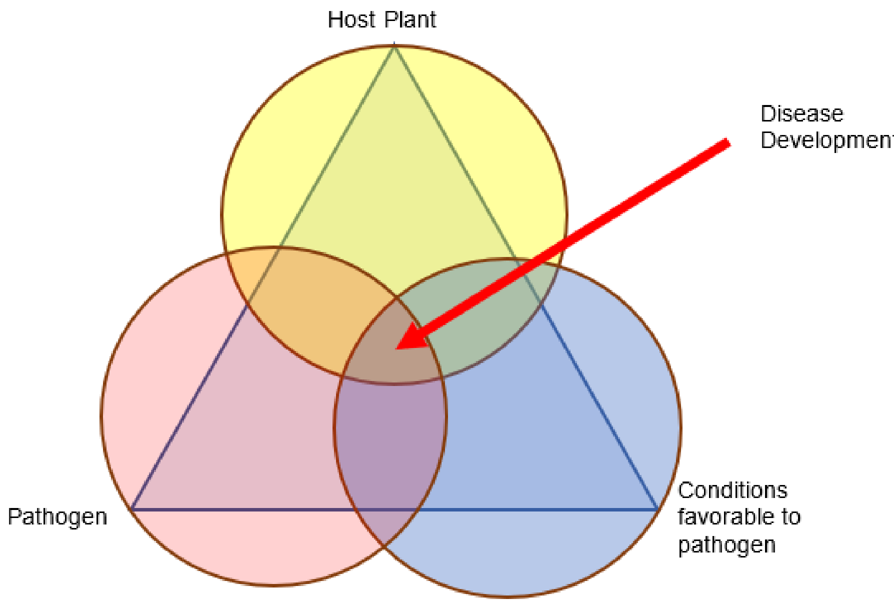
Because insect and disease problems and their consequences vary significantly from crop to crop, application of IPM principles is *situational*. The IPM techniques used in an alfalfa field (perennial crop), a wheat field (annual crop), and an apple orchard (perennial crop with minimal tolerance for pest damage) and the landscape (site with multiple plant species and high tolerance to pests) will be vastly different.

The use of IPM ensures a holistic approach, minimizing (or eliminating) the use of pesticides.

IPM Strategies

IPM requires careful observation of plants and landscapes to correctly diagnose plant pests, diseases, and disorders. In order for a plant problem to develop, three things are required: the pest or pathogen must be present, a suitable host plant must be present, and conditions favorable to pest/disease development must occur. When all three factors are present over a required period of time, a pest or disease problem develops. This concept is illustrated by a "disease triangle" (or "pest triangle," etc.). [**Figure 1**]

Figure 1. Disease Triangle



Successful application of IPM relies on interrupting the cycle of pests or diseases by eliminating one or more of the contributing factors from the disease triangle. For example, not planting (or removing) all susceptible host plants for a pest or disease would prevent that disease from developing (e.g. Mountain Pine Beetle is not a problem in landscapes without pine trees). Depending on the plant problem being managed, different "corners" of the triangle may be simpler or more difficult to eliminate.

A generalized IPM "to-do" list could look like this:

1. Identify the Plant
    - What is normal?
    - What is not?

2. Identify the Problem
    - Was it sudden or progressive?
    - What are the signs and symptoms?

3. Read/Refer
    - What diagnoses are possible?
    - What can be ruled out?
    - What tests or other methods could be used to confirm a diagnosis?

4. Evaluate if Management Is Needed
    - What is the threshold for treatment for this crop/plant?

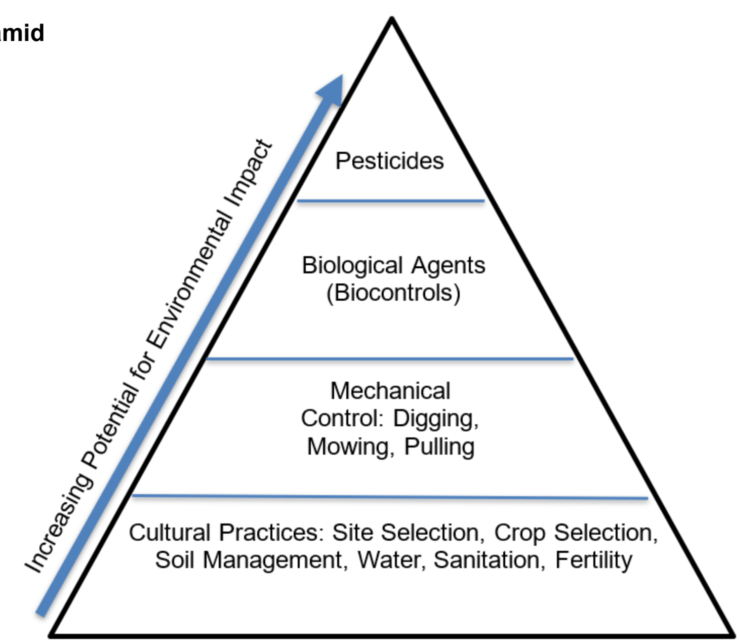
5. Determine the Treatment Options in **This Situation**.
    - On what should management focus (host, pest, conditions?)
    - What treatment options are available?
        - Cultural.
        - Mechanical.
        - Biological.
        - Chemical.

IPM Techniques

Integrated Pest Management control options (cultural, mechanical, biological, and chemical) are often organized on a “pyramid,” [**Figure 2**] showing various techniques from commonly used, “foundational” cultural controls at the bottom to chemical controls (pesticides) at the peak. The further up the pyramid you go, the higher the potential for environmental impact from the chosen method. Each management situation begins at the bottom and works up the pyramid to the level where a pest or disease is suppressed below the desired threshold.

Remember, each method applied will be “integrated” with the preceding control measure. One would not apply insecticides if releasing beneficial insects were part of the management strategy, for example, or use tillage to control weeds where cover-crops were being employed at the same time.

Figure 2. IPM Pyramid



Cultural Methods

Plant Selection: Right Plant, Right Place – Select plants that are adapted to the site conditions.

Soils Management – Many landscape plant problems relate to soil conditions.

- Manage soil compaction (low soil oxygen and poor drainage).
- Manage soil drainage.
- Improve soil tilth with applications of organic matter.
- Nutrient (fertilizer) management.

Water and Irrigation Management

- Water plants appropriately. The water requirement for plants to survive compared to the water needed for plant growth may be vastly different.
- Use plant tolerance to wet or dry conditions in water management.

Pest Exclusion

- Covers and barriers.
- Traps.

Physical Removal

- Hand picking insects.
- Pulling weeds.

Biological Methods

Biocontrols – use of predators, parasitoids, and disease organisms (usually invertebrate) of the pests of plants.

- **Preservation or Conservation Biocontrols** is taking steps to encourage naturally occurring predators and parasitoids through habitat improvement (often considered a cultural control).
- **Augmentation Biocontrol** is the purchase and release of predators and parasitoids, also known as “bugs for hire.”
- **Pesticides** are the use of organic or synthetic chemical products that are designed to kill pests. Pesticides have the greatest potential for environmental harm if misused. All pesticides must be applied in strict accordance with the product label.

Plant Health Care, PHC

The term ***Plant Health Care***, ***PHC***, was coined by the *International Society of Arboriculture* to provide a framework for IPM techniques as they apply to tree care and landscape maintenance.

Concepts of PHC include:

Healthy plants have fewer pests. Many insects and diseases only affect stressed plants. Minimizing stress can therefor prevent many common pests. For example, *Cytospora* canker fungus and many borers only attack trees stressed by factors such as soil compaction, drought, or root damage.

Healthy plants are more tolerant of pests. For example, aphids on shade trees generally do not warrant management efforts. Only those trees that are stressed by drought, non-established root systems, limited root spread, etc. are intolerant of aphid feeding.

Life cycle: Plant needs change with stages in their life cycle. A plant's needs for irrigation, fertilizer, pruning, etc., and its tolerance to pests change through the year and through the life of the plant.

PIC cycle: Plant problems are not created equal. Plant disorders can be "predisposing," "inciting," or "contributing" factors of decline.

The PIC Cycle

Plant pests and diseases vary in their impact on plant health. Some cause chronic or acute stress, weakening a plant's defenses. Others attack healthy plants; still more only develop on plants that are already in decline for other reasons. Understanding the biology of plant pests and diseases can help one to make good decisions about management.

Predisposing factors reduce a plant's tolerance to other stressors. These factors should be considered in plant selection – putting a plant in a stressful location will challenge the plant's survival from the very beginning. Examples of predisposing factors include:

- Planting trees in a site where root spread will be restricted due to soil compaction or hardscape features.
- Chronic drought stress.
- Planting trees susceptible to iron chlorosis in soils with high pH or heavily irrigated soils.
- Failure to structurally train young trees (predisposing trees to storm damage).
- Most leaf-chewing insects, such as caterpillars and sawfly larva.
- Most sap-sucking insects, such as aphids and leafhoppers.

Inciting factors include primary insect, disease, and abiotic disorders that attack healthy plants or cause acute stress. Examples include:

- A soil compaction "event," the most common stress factor leading to many insect and disease problems.
- Planting trees too deep (leads to trunk girdling roots).
- Acute drought.
- "Outbreak" populations of certain insects (e.g., Mountain Pine Beetle or Ips Beetles).
- Many invasive insects, like Emerald Ash Borer, Asian Longhorn Beetle, or Spongy Moth.
- Bark damage from lawn mowers.
- Bark cankers and frost cracks from rapid winter temperature changes coupled with winter drought.
- Phytophthora, Verticillium, Fusarium, and other fungi.

Contributing factors include secondary insects, diseases, and disorders that affect plants that are already stressed. They often are noticeable, lead to the plant's death, and frequently the target of management efforts that would be better directed toward predisposing or inciting factors. Examples include:

- Most bark beetles and borers (secondary to soil compaction, drought, and wind damage).
- Cytospora fungus (secondary to soil compaction, drought, and restricted rooting system).

- Trunk girdling roots caused by planting too deep.
- Iron Chlorosis resulting from chronic springtime overwatering.

Management of contributing factors typically ultimately fails unless the predisposing and inciting factors that stress the plant are addressed.

Life Cycle of a Plant

A key concept in PHC includes recognizing that plant care changes with various stages of growth. Failure to relate cultural practices to the life cycle often leads to reduced growth and confusion about appropriate cultural practices. **Tables 1** and **2** give an overview of the life cycle of trees.

Life Cycle of a Tree

1. Nursery production.
2. Establishment phase.
3. Growth phase.
4. Maturity.
5. Decline phase.

Life Cycle of a Vegetable (annuals)

1. Seed germination and emergence.
2. Seedling growth.
3. Growth phase.
4. Flowering and fruiting phase.

Table 1. Generalized Life Cycle of a Nursery-Grown Tree

Growth Phase	Growth Objectives	Change to Next Growth Phase
Nursery production	Top growth = selling price.	Planting.
Establishment phase	Root establishment.	When roots become established, length of annual twig growth significantly increases.
Growth phase	Period of canopy growth. Balance canopy growth with root growth limitations.	Growth slows as tree approaches mature size (for site).
Maturity	Canopy growth slows as tree matures. Balance canopy growth with root growth limitations.	Accumulation of stress and age. Minimizing stress on aging trees prolongs tree life.
Decline phase	Minimize stress levels.	Death.

Table 2 – next page.

Table 2. Influence of Life Cycle on Cultural Practices for Trees				
Growth Phase	**Irrigation Water Need**	**Fertilization**	**Pruning**	**Pest Tolerance**
Nursery production	Water = Growth.	Fertilizer pushes desirable top growth.	Structural training desirable.	LOW, could influence sales.
Establishment	CRITICAL. Trees are under water stress due to the reduced rooting system.	None to very little as high nitrogen forces canopy growth at the expense of root growth.	Heavy pruning slows root establishment.	LOW due to drought imposed by reduced root system.
Growth	Water = Growth. Good tolerance to short-term drought. However, short-term drought will slow growth.	If other growth factors are not limiting, fertilization supports growth.	Structural training sets the tree's structural integrity for life.	HIGH except in stress situations.
Maturity	Good tolerance to short-term drought. Severe drought leads to decline.	Need for fertilizer reduces. Over fertilization could force canopy growth that the roots cannot support in summer heat and wind.	Maturing trees that were structurally trained while young have minimal needs for pruning.	HIGH except in stress situations.
Decline	Intolerant of drought.	Evaluate stress factors as fertilization can accelerate stress in some situations.	Pruning limited to cleaning (removal of dead wood). Do not remove healthy wood on stressed trees.	LOW, pests could accelerate decline.

Authors: David Whiting, CSU Extension, retired. Revised June 2017 by Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension. Artwork by John Murgel. Used with permission.

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CMG GardenNotes #102

Diagnosing Plant Disorders

Outline:

Skills Essential to the Diagnostic Process

Judiciously examine the plant. Many gardeners have a difficult time describing their plants and plant problems. For example, the description "*leaves are yellow*" is so general that nothing can be diagnosed without more details. A typical home gardener may say they have "*black bugs*." What do they mean by "bug"? Are they saying they have a black insect? More details are needed to diagnose the problem.

Read. Part of the diagnostic process is to consult peer-reviewed references, comparing the symptoms and signs of plant problems with details in references. Do not simply work from memory.

Referring to multiple books or other references on the same topic gives a better understanding of a pest or disease's description and its management options. Read for the details.

Ask questions. Diagnosis requires extensive two-way conversations. Often the person trying to diagnose the problem has not been on site and must rely on the descriptions of someone else. In this situation, diagnosis can be difficult or impossible. Even with good samples or when visiting the site, information about the care of the plant, history of the site, and progression of symptoms is valuable for the diagnostic process.

Practice. The diagnostic process requires the integration of observation, gardening experience, and scientific information. While reference information is necessary for diagnosing plant diseases and pests, practical knowledge and horticulture experience are important tools.

Patience. Diagnosing plant disorders is a process and is usually not a simple answer to a question. It takes time and patience. Never jump at an answer just because it seems easy. Do not guess. Take the time to work the process, asking lots of questions.

In pest management, first diagnose the problem and then discuss management options. Because management options can be very pest specific, the correct diagnosis of the problem must be completed before management can be discussed.

Asking Questions and Gathering Information

Ask questions that create dialogue. For example, "*Tell me how you watered the plant.*" Avoid accusatory type questions (e.g., "*Did you overwater the plant?").*

Some disorders cannot be diagnosed. We can only complete a diagnosis when detailed information is available. Descriptions, like "yellow leaves" or "poor growth" are inadequate descriptions for a diagnosis. Obtain as much information as you can.

Diagnosis must be done in the context of the plant's environment. For example, is a tree in a routinely irrigated lawn or in a site with limited irrigation? Does the site have an open area for root spread or is the root system limited by poor soils or hardscape features?

For example, a client calls with concerns that a tree looks wilted. Should the tree be watered more? After asking questions, it is discovered that the tree is located in a construction site and had most of the root system cut. Understanding the context of the root damage is essential to addressing the watering issue.

Questions asked may not reflect the real issues. In the diagnostic process, Colorado Master Gardener volunteers must often help frame questions as well as provide answers. For example, in the previous situation with the tree in the construction site, an important question is the stability of the tree with respect to why most of the roots have been cut.

A useful tool in diagnosis is visualizing the plant. Create a mental picture of it and its surroundings. As you create the picture, ask questions about details. Verify the details. Explain to clients that you are trying to create a mental picture of their plant problem; this will encourage them to provide the needed information more patiently. When possible, ask the client to provide photographs.

When working with clients, repeat back their description in your own words. This helps clear up miscommunications about symptoms.

When working with clients, verbally explain how you rule out possible causes. This helps the client move on with you and may clarify miscommunication about symptoms.

Diagnosis is not possible when general symptoms are the only ones with which we have to work. Keep in mind that multiple problems can have similar symptoms.

Management should only be addressed AFTER the diagnosis is complete. Because disorders generally arise from a combination of factors, management may focus in more than one area, or where the client does not expect.

Steps in the Diagnostic Process

Step 1: Diagnosis – Identify the Plant

Hundreds of pests and diseases that attack plants can be found in any geographic region. Once the host plant has been correctly identified, the list of potential insects and diseases is substantially shortened. When working with abiotic disorders, plant identification will still be helpful but will not shorten the list of potential possibilities significantly.

Many gardeners are not familiar with plant materials and need help to correctly identify them. Identification is not practical over the phone. A branch sample with leaves attached should be brought to the Extension office or good photographs should be sent to the diagnostician. (It is really best to see a sample.) For ornamental grasses and flowering plants, samples with as many plant parts as possible (stems, roots, leaves, and especially flowers and/or fruits) are most helpful. If asking for photographs, remember to ask for both "wide shots" of the whole plant with its surroundings as well as close-ups of the symptoms and/or signs.

Step 2: Diagnosis – Identify the Problem(s)

Step 2a – LOOK. Define the Problem by Describing the Signs and Symptoms

Take a close look at the plant and surroundings. A detailed description of the problem is essential for diagnosis. In situations where the description is limited or symptoms are too general, diagnosis will be impossible. Systematically evaluating a plant will help organize questions.

- ***Symptoms*** are changes in the plant's growth or appearance in response to causal factors, for example, leaf cupping, wilting, or galls.

- ***Signs*** are the presence of the causal organism or direct evidence of the causal factors, for example, frass, mycelium, or insects.

Time development. Knowing the time frame for the development of signs and symptoms is a helpful tool. Did damage occur suddenly or over a period of time? Keep in mind that the gardener may not actually know as early development may not have been noticed. Symptoms that occur suddenly and do not progress, or are across several plant species, are typical of abiotic disorders. Symptoms that develop progressively, are not uniformly distributed on the plant, and affect only one or a few related plant species are typical of biotic factors (pests and diseases).

Keep in mind that **multiple problems have similar symptoms**. Let the symptoms lead you to the diagnosis rather than trying to make a diagnosis fit a group of symptoms.

Terminology used to describe common *symptoms* include:

- **Blight** – A rapid discoloration and death of twigs, foliage, or flowers.
- **Canker** – Dead area on bark or stem, often sunken, and discolored.
- **Chlorosis** – Yellowing.
- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch, or root starting at the tip.
- **Gall** or **gall-like** – Abnormal localized swelling or enlargement of plant part.
- **Gummosis** – Exudation of gum or sap.
- **Leaf distortion** – The leaf could be twisted, cupped, rolled, or otherwise deformed.
- **Leaf scorch** – Browning along the leaf margin and into the leaf from the margin.
- **Leaf spot** – A spot or lesion on the leaf.
- **Necrosis** – Dead tissue.

- **Wilt** – General drooping of the plant or plant part caused by loss of turgor pressure within the plant.
- **Witch's broom** – Dense twiggy growth originating at or near a single point of woody plants.

Terminology used to describe *signs* include:

- **Bacterial streaming** – A cloudy discharge from cut plant parts when submerged in (usually distilled) water.
- **Fruiting bodies** – Reproductive structures of fungi; could be in the form of mushrooms, pycnidia, rusts, or conks.
- **Hypha (pl Hyphae)** – A branching filament of fungal tissue; the basic fungal unit.
- **Mycelium (pl Mycelia)** – A mass of fungal threads (hyphae).
- **Rhizomorphs** – Root-like fungal threads found under the bark of stressed and dying trees caused by *Armillaria* fungi.
- **Slime flux** or **ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.

Examples of abiotic (non-living) signs include the following:

- Girdling roots (caused by planting too deep); leads to root starvation.
- Lack of a root flare (sign that the tree was planted too deep with a high potential to develop girdling roots).
- Bark damage on a trunk from lawn mowers and weed eaters.
- Standing water over rooting zone.
- Plugged drip irrigation system emitters.
- Record of springtime freezing temperatures or severe winter temperatures.
- Hardscape over tree rooting area.
- Soil tests indicate high soil salts.

Define What Is Normal Versus Abnormal

It is common for the home gardener to suddenly observe normal characteristics of a plant and mistakenly attribute it to an insect or disease. For example, on evergreens:

- Needle problems and dieback of the **new needles at the branch tip** are abnormal.
- **Yellowing and dropping of older needles from the inside of the tree** are normal in the fall. The number of years that needles are retained is a factor of plant genetics and stress.

Other examples of "normal" occurrences often mistaken for problems include:

- Fuzz on underside of leaves.
- Variegated leaves.
- Male pollen cones on pine or spruce.
- Inconspicuous fruit, such as juniper berries.
- Mushrooms.
- Bluegrass going to seed.
- Spores on the underside of fern fronds.
- Flowers and fruit on potatoes.
- Male squash blossoms not producing fruit.
- June drop of apples and other fruit.
- Aerial roots on tomatoes and corn.

- Seed stalk on rhubarb and onions.

While these examples may seem straightforward enough, remember that not all diagnosis of “normal” is so simple. For example, while yellowing and dropping needles from the interior of a conifer is normal in the fall, it can still be a sign of plant problems. Under stressful conditions or as a result of diseases like needle-casts or Cytospora canker, older needles may drop sooner than normal. Do not assume normality; careful, open-minded observation is key.

Step 2b – READ. Refer to Published Materials Describing Similar Signs and Symptoms

The reading will often send you back to the plant to look for more details.

Resources from other parts of the country or world should be used only with the recognition that they may not be completely relevant in Colorado. Try to find comprehensive resources that include regional occurrences for pests and disease or that are regionally organized.

References from Cooperative Extension, the USDA, and the American Phytopathological Society are often available in Extension offices.

Step 2c – COMPARE. Determine Probable Cause(s) Through Comparison and Elimination

When the description of the disorder matches the details in the reference materials, diagnosis may be complete. It requires careful reading of fine details. When things do not match up, back up. Is the plant correctly identified? Work through the process again paying attention to details missed. Some problems can only be confirmed in a diagnostic laboratory, so be sure to report to clients only what you know, not what you assume. For example, “Based on what you described and what I can see, these symptoms are consistent with Fire Blight. A laboratory test would be needed to confirm this diagnosis.”

Let the process guide you through the diagnosis rather than trying to match symptoms to fit a diagnosis.

Abiotic disorders are generally difficult to diagnose. A systematic evaluation of a plant will be helpful in diagnosing abiotic disorders. Abiotic disorders often predispose plants to insects and disease problems. In these cases, diagnosing the underlying abiotic stress is just as important as diagnosing the more obvious insect or disease issue.

Step 3: Management – Evaluate if Management Efforts Are Warranted

Step 3a – What Type of Damage/Stress Does This Disorder/Pest Cause?

The primary question here is to determine if the disorder/pest is only cosmetic, if it adds stress, or if it is potentially life-threatening to the plant. This may depend, in part, on the overall health of the plant before the problem starts.

Step 3b – Under What Situations Would Management Efforts Be Warranted?

Many insect and disease problems are only cosmetic on healthy, stress-free plants. However, stressed plants are much less resilient.

For example, aphids feeding on shade trees normally do not warrant management efforts unless they become a nuisance (like dripping honeydew on a car or patio table). However, under water stress, aphid feeding can create a potentially serious stress issue. In this situation, cultural (watering the tree), mechanical (hosing off the aphids with a strong jet of water), biological (adding beneficials to feed on the aphids) or insecticidal management efforts could be warranted to protect the tree.

As a rule of thumb, healthy deciduous trees can tolerate the loss of one-third of the total leafing surface before stress becomes a management issue. Tolerance is much less for trees with growth-limiting factors.

Evergreens are much less tolerant of defoliation because the needles last for multiple years. For example, a sawfly outbreak that removes all the new needles would have an influence over multiple years; this would bring a healthy tree to a threshold where management would be warranted.

Step 3c – Are Management Efforts Warranted for This Situation?

The bottom line in Step 3 is to determine if management efforts are ***warranted for this situation***. The answer needs to be focused on the ***specifics***; the individual plant, what the client will accept aesthetically or otherwise, and what treatment options are available.

Step 4 – Evaluate Effective Management Options for This Disorder/Disease/Pest

Management options may take many forms or directions. For pest and disease issues to persist, the pest or pathogen must be present along with susceptible host plants and conditions favorable for disease/pest development. Management could be directed at the pest, the host, or the conditions, or at a combination of two or all three. Management recommendations should be considered in the context of an Integrated Pest Management Plan, discussed in more detail in GardenNotes 101, *IPM and Plant Health Care*.

Ultimately, the client will make the decision of what control options to apply on their property. Strive to provide an accurate diagnosis and, whenever possible, suggest several science-backed solutions as options from which to choose.

Pesticide Use Questions

When pesticides are a management option, encourage clients to answer these important questions below to guide pesticide application. Remember that pesticide use must be in strict accordance with the label instructions, which represent a contract between the purchaser and the product manufacturer. Tell clients to read the label and follow the directions explicitly; ***the label is the law***.

- Which pesticides have the lowest **risks of exposure** to the user or others? (Refer to the pesticide label.)
- Which have the lowest ***health hazards***? (Refer to the pesticide label and signal words.)
- Which have minimal ***environmental risks*** for the site? (Refer to the pesticide label.)
- When are they applied to be effective? (Refer to the pesticide label and Extension Fact Sheets.)
- How are they applied and is specialized equipment needed? (Refer to the pesticide label.)

- What is the re-entry period and the application-to-harvest interval following application? (Refer to the pesticide label.)

Authors: David Whiting, CSU Extension, retired; Carol O'Meara, CSU Extension, retired. Revised June 2017 by Mary Small, CSU Extension, retired. Reviewed April 2023 by John Murgel, CSU Extension, and Matias Reynoso, CSU Agricultural Biology.

Reviewed April 2023

CMG GardenNotes #112

Systemic Plant Evaluation

Steps to Systematically Evaluate a Plant with Focus on Trees

It is important to systematically evaluate the entire plant as part of the diagnostic process. Refer to CMG GardenNotes #102 *Diagnosing Plant Disorders, Step 2 – Identify the Problem(s).*

1. **Macro-Look** – Look for things that stand out. These may be clues for other steps. For example, decline from the top down is typical of root problems and/or drought. Give extra attention to the soil and roots in step 3.

2. **Macro-Look at Surroundings** – Insects and diseases (biotic problems) are often *host specific.* If symptoms are found on a variety of plants, it may suggest abiotic disorders, which are **not** host specific. Abiotic problems (like soil compaction) may also affect surrounding plants. For example, how is the lawn under a struggling tree performing? It will share the same soil problems.

3. **Soil and Rooting Area** – Soil issues contribute to a large part of the problems in the landscape. While we cannot see a root system, other clues will help evaluate it. Look for the following:
   - How is the lawn under the tree performing? It may share the same soil growth-limiting factors.
   - Push a screwdriver into the soil. How easy or hard it is to push into a moist soil provides an estimation of soil compaction.
   - With a soil probe, take some cores from the rooting area of trees or shrubs. It may indicate issues with soil texture changes and rooting.
   - Surface roots of trees or shrubs indicate soil compaction and/or wet soils, as the roots develop closer to the surface where oxygen is available.
   - The lack of a root flare on a tree suggests that it was planted too deeply or that soil was added over the rooting area (smothering the fine feeder roots). Planting too deep causes trunk girdling roots.
   - Trunk-girdling (circling) roots are a common cause of death in landscape trees. Trees often show a gradual decline from trunk girdling roots twelve to twenty years after planting. The girdling root is usually below the soil surface.

- Decline of a tree or shrub from the top down or a uniform decline of the entire tree suggests root/soil problems. For additional details on the diagnosis of soil and rooting problems of trees, refer to CMG GardenNotes #113, *Diagnosing Root and Soil Disorders.*

4. **Trunk (if a tree or shrub)** – Look for the following:
   - Cankers.
   - "Lawn mower decline" (bark damage at ground level from lawn mowers and weed trimmers) is common in many landscapes. If the bark is removed down to the wood on more than 50% of the tree's circumference, the tree is considered to have no value.
   - Look for evidence of decay in large size pruning cuts. A drum-like hollow sound when the trunk is tapped with a wood mallet is a symptom of extensive internal decay.
   - Ridges and valleys along the trunk are symptoms of internal problems and decay.
   - Borer exit holes may indicate stress issues.

5. **Major Branches** (scaffold branches or secondary trunks) – Look for the following:
   - Cankers.
   - Large pruning cuts and evidence of storm damage (suggests the possibility of internal decay).
   - Borer exit holes could indicate stress issues.

6. **Minor Branches and Limbs** – An important part of the evaluation is to get an assessment of the plants' growth and vigor by comparing the annual growth increments of the twigs. [**Figure 1**] Starting at the branch tip, follow the twig back to the first ***annual growth ring*** *(terminal bud scar).* This is where the growth ended the previous year. The annual growth ring looks like a small ring or crown going completely around the twig. On some trees, a slight change in bark color helps identify where the annual growth rings are located. [**Figure 1**]

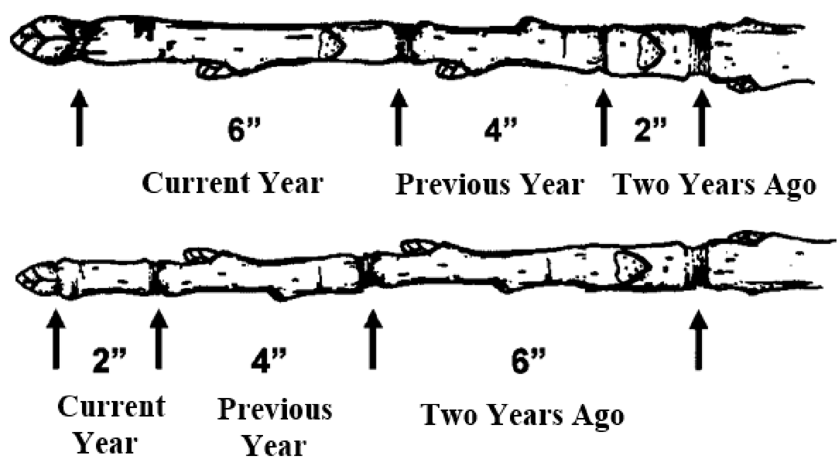

Figure 1. Comparison of Annual Growth

- Twig on top shows a decrease in stress levels as growth increases from two inches to four inches to six inches in current year.
- Twig on bottom shows an increase in stress levels as growth decreases from six inches to four inches to two inches in current year.

During your evaluation, look at several branches around the tree. Going back three to five years, determine what is typical for each year, not what is longest or shortest. Is the annual growth what would be expected for that species of tree? For example, a young honeylocust tree in an open lawn could readily put on eighteen to over twenty-four inches per year. The same tree located where buildings and hardscape features limit root spread may put on only six to twelve inches per year. This reduced growth is in response to the restrictions in rooting. Another important comparison is the change from year to year. For example, if the length of annual growth is shortening each year, it indicates that the stress levels are increasing. On newly planted trees, twig growth will be minimal until the root system is established. A significant increase in annual twig growth indicates that the root system has established.

On mature trees, growth will naturally be reduced and must be evaluated by looking at the growth near the top rather than the bottom of the tree.

Evaluating annual growth helps interpret the effects of other problems (like soil/root issues) observed in previous steps.

Other things to look for include scale and other twig insects, borer exit holes (which may indicate stress issues), cankers, and galls.

7. **Foliage** – Look for the following:
   - Leaf color and size.
   - Leaf spots and other foliage diseases – Typically more serious on the lower inner foliage of any plant where humidity is higher.
   - Leaf chewing insects, sucking insects, mites, and galls.
   - Leaf scorch and dieback from the top down are general symptoms of root problems and/or drought.
   - Leaf scorch on a specific side (suggests abiotic disorders originating on that side).
   - Early fall color (a general symptom of stress).

Authors: David Whiting, CSU Extension, retired; and Carol O'Meara, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised June 2017, by Mary Small, CSU Extension, retired. Reviewed September 2022 by Mary Ortiz Castro, CSU Extension.

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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 CMG GardenNotes #112 *Systemic Plant Evaluation*, *step 3 - Soil and Rooting Area*.

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 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 throughout the canopy or stress from the top down suggests related root, soil, and water 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

Root Plate – Zone of Rapid Taper

The *root plate* or *zone* of *rapid taper* consists of 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 transporting 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 ½ feet).

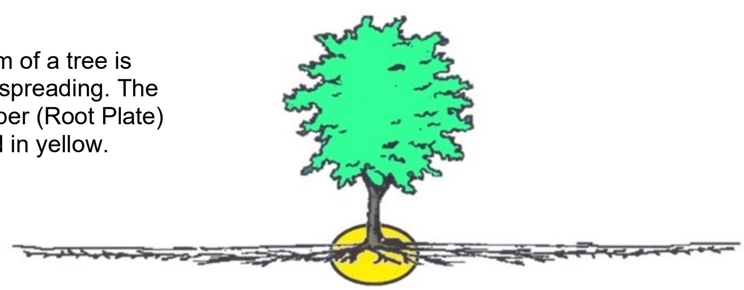
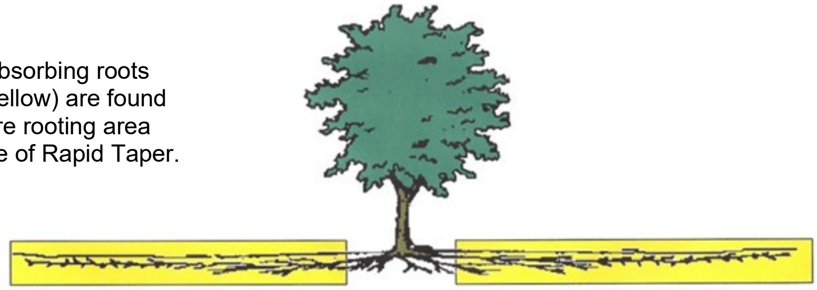


Figure 1.
The rooting system of a tree is shallow and wide spreading. The Zone of Rapid Taper (Root Plate) area is highlighted in yellow.

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 (highlighted in yellow) 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, others heavily concentrated. In a hole dug in the rooting area, transport roots are readily observed sticking out the side. [**Figure 3**]

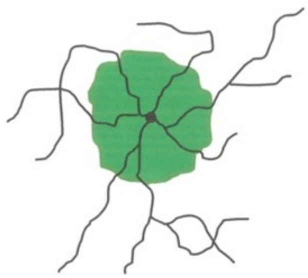


Figure 3.
Transport roots are long and meandering. They are NOT uniformly distributed around the trunk.

Absorbing Roots

Absorbing (feeder) roots serves 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**]

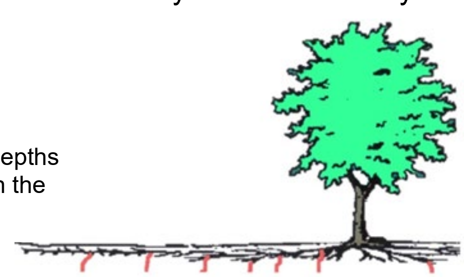
Absorbing roots have a short life, being replaced in four to five flushes of growth through Colorado's growing season. A short-term drought stress (defined as ten days) can shut down growth for one to five weeks. Long-term drought stress (defined as twenty-two days) can shut down growth for one to two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

Sinker Roots

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

Sinker roots can extract water from deeper soil depths when the surface soil is dry. This ability 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 become aware of the tap root when 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 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**]

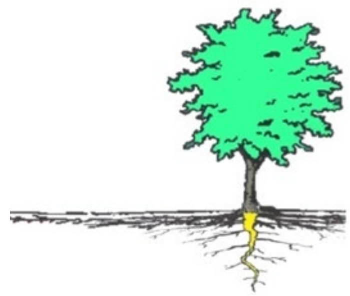


Figure 5.
The tap root develops from the seed radicle. In the seedling stage, the tree develops the root plate system due to low soil oxygen. Tap roots are rare in landscape trees.

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 are a factor related to 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** shows a 'rule of thumb' on root spread. Roots will be sparser 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
- 90-95% in top 36 inches.
- 50% in top 12 inches (absorbing roots).
- Spread 2-3 times tree height and/or canopy spread.
- Modified to by actual soil conditions.

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

Tree Protection Zone/Protected Root Zone

The *Tree Protection Zone*, *TPZ* (Protected Root Zone, PRZ) defines the rooting area with direct influence on tree health and vigor. Not every root is essential for tree health. 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 is the rooting area defined by the outer reach of the branches. The drip line 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 significantly underestimates the critical rooting area for most landscape trees. [**Figure 6**]

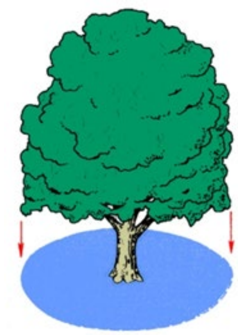


Figure 6. The drip line is a poor choice for estimating a tree protection zone.

Trunk Diameter Method

The trunk diameter is probably the better method for use on landscape trees. The 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 ½ feet). For trees with a broad canopy in an open lawn, it is approximately 40% larger in area than the dripline method. [**Figure 7**]

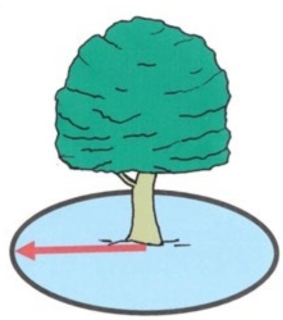


Figure 7. The Tree Protection Zone defined by the trunk formula method is a good estimate of the rooting area with direct influence in tree health and vigor. It is approximately 40% larger than the area defined by the drip line.

Trunk Diameter Method by Circumference

TPZ radius = 1 feet per 2 inches of trunk circumference

1. Measure the tree's circumference at DBH (4 ½ feet) in inches.
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:

$[\text{TPZ radius}]^2 \times \pi$
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 one foot or less, requiring an 18-foot or greater radius root spread. Anything less will reduce tree size, growth rates, vigor, and longevity.

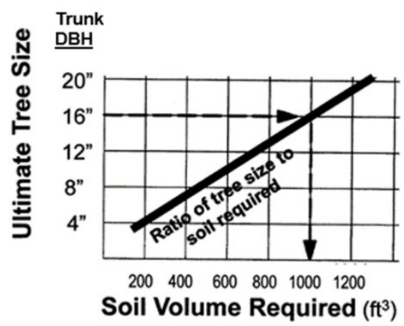
Tree roots can generally cross under a sidewalk to open lawn areas beyond. The ability of roots to cross under a street depends on the road base properties. A good road base does not typically support root growth due to compaction and low soil oxygen levels.

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 trees 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, *IPM and Plant Health Care*, for a discussion on Predisposing, Inciting, and Contributing factors, known as 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 GN #213, *Managing Soil Tilth: Texture, Structure, and Pore Space*, and GN #215, *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.

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

Soil compaction is 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 easily 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 is best if the soil was watered the day before performing this test.

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

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.

Practices Worth Considering

- **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**]
- **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 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.

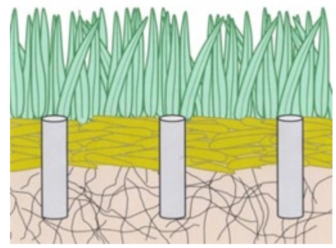


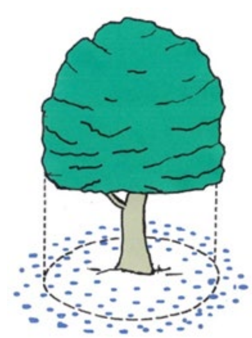
Figure 10. Core aeration helps reduce soil compaction around trees. To make a difference, plugs need to be at two-inch intervals.

- **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 three to four inches. Less does not give 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.

Practices of Questionable Value

- **Vertical mulching with an auger** – The TPZ is drilled with two-inch holes, typically at twelve-to-twenty-four-inch intervals. The hole may be filled with coarse sand or organic matter. Research has found that this practice 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. Research has found 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**]

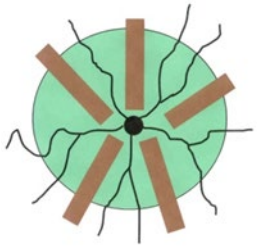


Figure 12.
Trenches dug between primary root paths does not result in significant improvements in tree vigor.

- **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 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 a 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. 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

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.

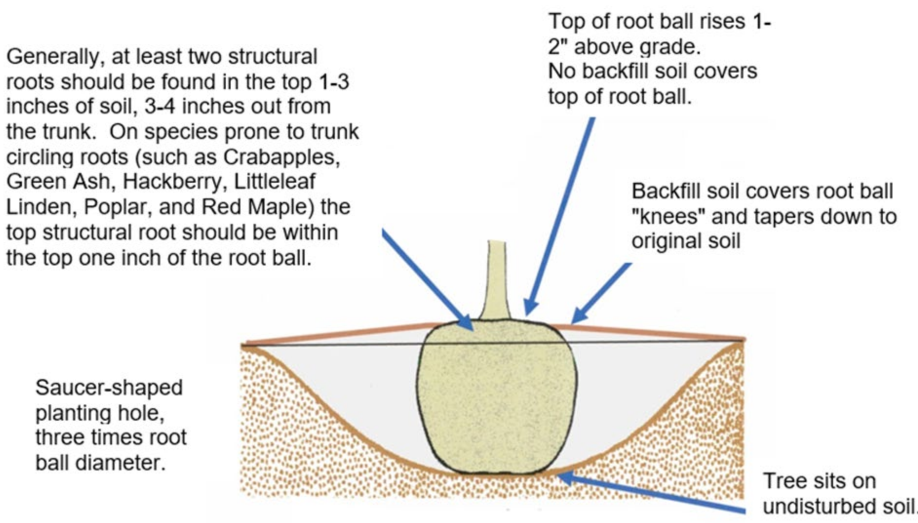
Two considerations are important in evaluating the planting depth of trees: the depth of tree in the root ball, and the depth of root ball in the planting hole. [**Figure 14**]

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

- Generally, at least two structural roots should be within the top one to three inches of the soil surface, measured three to four 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 one to two inches above grade (depending on root ball size). When the root ball settles, it will be at ground level.

Figure 14. Summary: Planting Hole Specifications



Recently Planted Tree Planted Too Deep

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 and watch 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 will 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 are 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 15**]

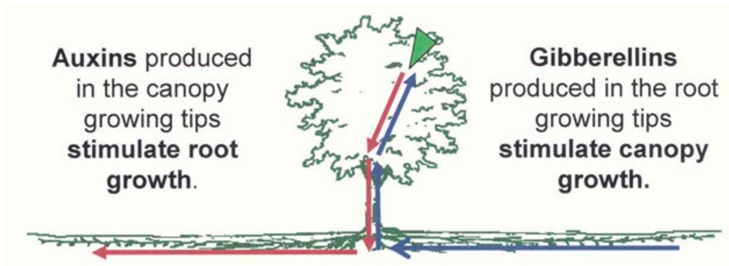


Figure 15. Trees balance shoot and root growth based on the concentration of auxins and gibberellins.

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.

Authors: David Whiting, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised June 2017 by Mary Small, CSU Extension, retired. Reviewed September 2022 by Mary Ortiz Castro, CSU Extension.

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