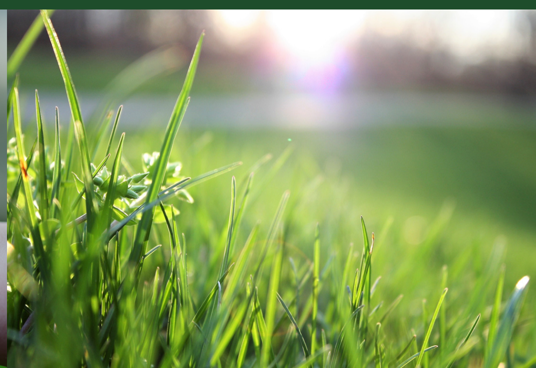
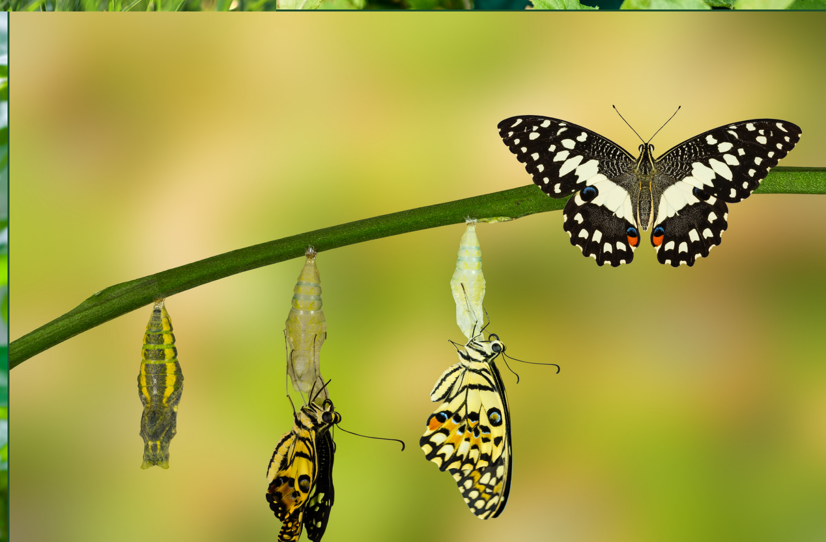
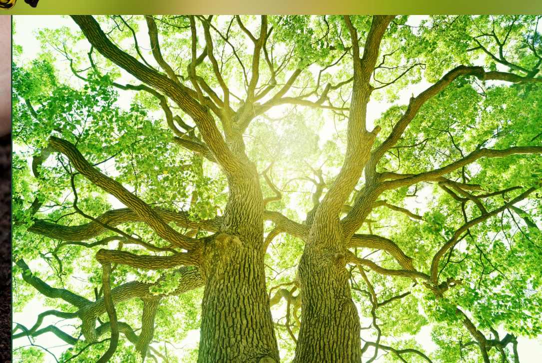
2023 Garden Notes

FOR COLORADO MASTER GARDENER AND COLORADO GARDENER CERTIFICATE TRAINING

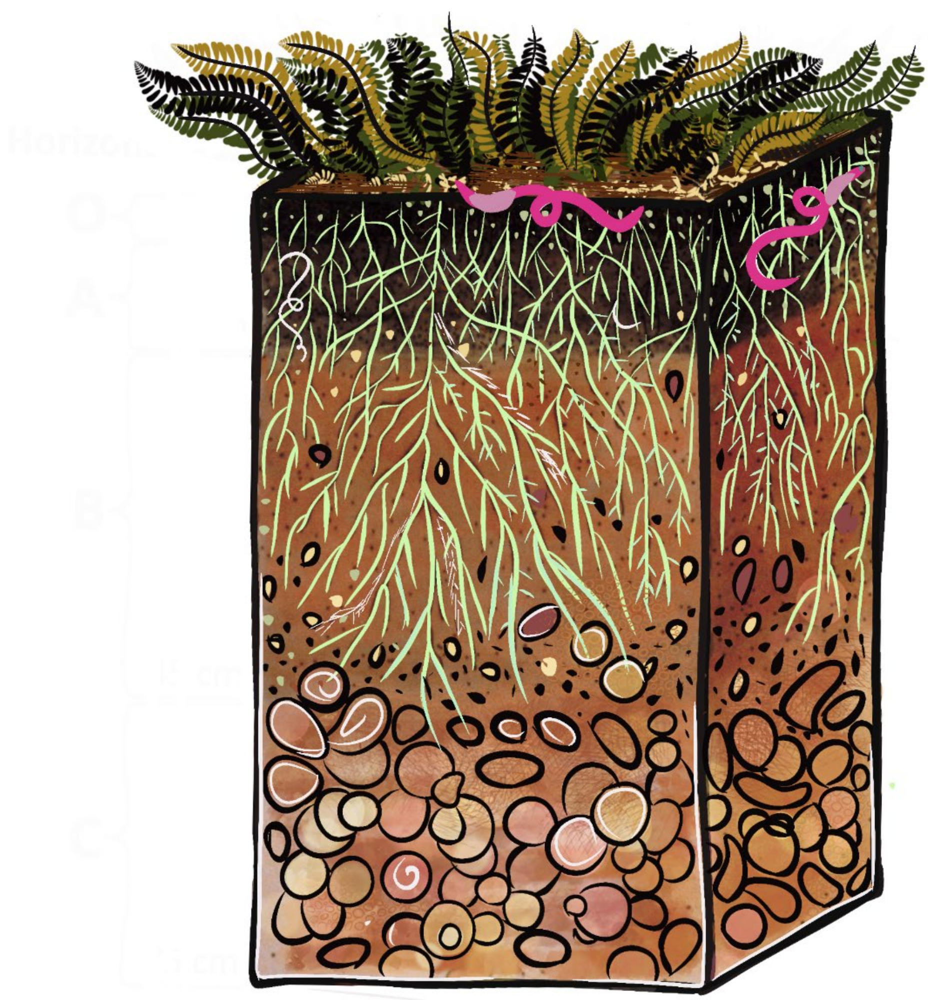



COLORADO STATE UNIVERSITY EXTENSION

CMG GardenNotes #210-251

Soils, Fertilizers, and Soil Amendments



Soil Horizons with Worms
Artwork by Melissa Schreiner © 2023

This Soils, Fertilizers, and Soil Amendments curriculum was developed by David Whiting, CSU Extension, retired; Carl Wilson, CSU Extension, retired; Catherine Moravec, former CSU Extension employee; and Jean Reeder, PhD, USDA-ARS, retired. Cover art by Melissa Schreiner. Used with permission.

- Colorado Master Gardener GardenNotes are available online at https://cmg.extension.colostate.edu/.
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Updated 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #210

Soils, Fertilizers, and Soil Amendments

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #211, *Introduction to Soils.*
- #212, *The Living Soil.*
- #213, *Managing Soil Tilth: Texture, Structure, and Pore Space.*
- #214, *Estimating Soil Texture: Sandy, Loamy, or Clayey.*
- #215, *Soil Compaction.*
- #218, *Earthworms.*
- #219, *Soil Drainage.*
- #221, *Soil Tests.*
- #222, *Soil pH.*
- #223, *Iron Chlorosis of Woody Plants.*
- #224, *Saline Soils.*
- #231, *Plant Nutrition.*
- #232, *Understanding Fertilizers.*
- #233, *Calculating Fertilizer Application Rates.*
- #234, *Organic Fertilizers.*
- #241, *Soil Amendments.*
- #242, *Using Manure in the Home Garden.*
- #243, *Using Compost in the Home Garden.*
- #244, *Cover Crops and Green Manure Crops.*
- #245, *Mulching.*
- #246, *Making Compost.*
- #251, *Asking Effective Questions About Soils.*

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #0.501, *Soil Testing*.
- #0.503, *Managing Saline Soils.*
- #0.504, *Managing Sodic Soils*.
- #0.520, *Selecting an Analytical Laboratory.*
- #0.521, *Diagnosing Saline and Sodic Soil Problems.*

- **Recommendations for plants that tolerate high alkaline/high pH soils:**
    - #7.220, *Colorado Gardening: Challenge to Newcomers*.
    - #7.421, *Native Trees for Colorado Landscapes*.
    - #7.422, *Native Shrubs for Colorado Landscapes*.
    - #7.214, *Mulches for Home Grounds.*

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.

Learning Objectives

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

- Describe characteristics of a typical landscape soil and how it differs from native or agricultural soils.
- Describe how soil organisms directly and indirectly benefit the soil and plant growth.
- Describe management practices effective in nurturing soil organisms.
- Describe the relationship between soil texture, structure, pore space, and tilth.
- Describe effective management practices for sandy soils, clayey soils, and decomposed granite rocky soils.
- Describe effective management practices to prevent and reduce soil compaction.
- Describe considerations in selecting soil amendments.
- Describe considerations in selecting mulch.
- Describe considerations in selecting appropriate fertilizers.

Review Questions

Introduction To Soils

1. Explain how soils may vary horizontally and vertically. Describe characteristics of the A, B, and C soil horizons.
2. Describe how landscape soils differ from agricultural and native soils.
3. Describe the typical percentage of air, water, organic matter, and mineral solids for a native soil. How does this change for a compacted landscape soil?

The Living Soil

4. Describe how organisms directly benefit the soil and plant growth.
5. Describe how organisms indirectly benefit the soil and plant growth.
6. Should gardeners inoculate their soil with rhizobia, mycorrhizae, and decomposers?
7. What makes up the soil organic matter? Define humus.
8. How does a gardener enhance the living soil? How can a gardener damage soil life?

Managing Soil Tilth

9. Define the terms soil texture, soil structure, and soil profile. Explain how they are interrelated.
10. Describe characteristics of the following soil types:
    - Coarse-textured, sandy soil.
    - Fine-textured, clayey soil.
    - Gravelly and decomposed granite soils.
11. Explain what is significant about large pore spaces and small pore spaces.
12. Describe how water moves through small pore spaces and large pore spaces.

13. In relation to root growth, air infiltration, and water movement, what happens when the soil has a texture interface?
14. Explain management of fine-textured clayey soils, coarse-textured sandy soils, gravelly and decomposed granite soils.

Soil Compaction

15. Describe soil compaction in terms of pore space, water movement, and air infiltration.
16. List techniques to prevent soil compaction. List techniques to mitigate soil compaction.

Soil Drainage Problems

17. Describe drainage problems as related to pore space, surface runoff, and leaching.
18. Why is it important to identify the causes of a drainage problem before attempting corrections?
19. List common causes of surface drainage problems with possible corrective actions. List common causes of sub-surface drainage problems with possible corrective actions.

Soil Tests

20. List situations when a soil test would be helpful. List examples of plant growth problems for which a soil test would not be helpful. Which nutrient is typically not accurately measured on a single soil test?
21. Describe the steps to a soil test.
22. Where does one find a list of soil testing laboratories?

pH and Iron Chlorosis

23. What does soil pH measure? What is an acceptable range for most plants? What are the implications for gardening in Colorado?
24. Describe the function of the free lime vinegar test. Can the pH of an alkaline soil be effectively lowered?
25. Describe the symptoms of iron chlorosis. What other situations can be confused with iron chlorosis? How can you tell them apart?
26. List primary factors that contribute to iron chlorosis.
27. What simple method identifies soils prone to iron chlorosis problems?
28. Describe the limitations and application criteria for the following iron treatments:
    - Soil applications of sulfur.
    - Soil applications of iron sulfate plus sulfur.
    - Soil applications of iron chelates.
    - Foliar sprays.
    - Trunk injections.

Saline Soils

29. Describe plant problems associated with excess soil salt levels.
30. List sources/causes of high soil salts.
31. Describe the leaching process for salty soils. What about situations when excess salts cannot be leached out?
32. Describe other management strategies for salty soils.

Plant Nutrition

33. Define plant nutrient and fertilizer.
34. Will the addition of nitrogen fertilizer help plant growth when soil compaction is the limiting factor? Explain.
35. What are the typical symptoms of nitrogen deficiency? What are the problems associated with excessive nitrogen fertilization?

36. In Colorado soils, under what situations will phosphorus levels likely be adequate and likely be deficient? How does one determine the need for phosphate fertilizer?
37. In Colorado soils, under what situations will potassium levels likely be adequate and likely be deficient? How does one determine the need for potash fertilizers?

Fertilizers

38. Define the following terms: organic fertilizer, certified organic fertilizer, and soil amendment.
39. What does grade or analysis indicate about a fertilizer? What is the fertilizer ratio?
40. What is a fertilizer formulation? What is a complete fertilizer? When applying a complete fertilizer, what is the application rate always based on?
41. What is the routine application rate for nitrogen fertilizer? How does it change based on soil organic matter? What is the routine application rate when using these fertilizers?
    - Ammonium sulfate, 21-0-0.
    - Ammonium nitrate, 34-0-0.
    - Urea, 45-0-0.
42. Address your answers relative to phosphorus water pollution. What happens to phosphate fertilizers applied 1) to a lawn or garden area, and 2) over-spread onto the street, sidewalk, or driveway? What is the major source of phosphate water pollution from the landscape setting?

Soil Amendments

43. Explain the differences between soil amendments, mulch, and compost.
44. Explain how organic soil amendments improve a clayey soil and a sandy soil.
45. Describe considerations in selecting a soil amendment as it relates to the following:
    - Desired results.
    - Potential for routine application.
    - Longevity.
    - Salt.
46. What is the routine application rate for soil amendments? What is a precaution about adding additional amounts?
47. Explain the use and limitations of using manure as it relates to:
    - *E. coli.*
    - Nitrogen release rates.
    - Salt.
    - Weed seeds.
48. What are cover crops and green manure crops? List benefits of cover-cropping and green manuring.

CMG GardenNotes #211

Introduction to Soils

Outline:

Soil Attributes

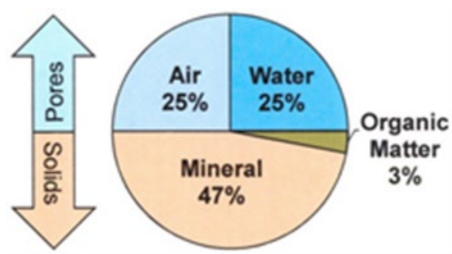
What is soil? Gardeners know that soil is more than simply broken up rocks. Rather than being an inert unchanging material, soil is a dynamic living substance in which complex chemical and biological reactions are constantly occurring.

According to the Soil Science Society of America, soil is defined as, "…the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants..." Unconsolidated materials are loose materials composed of multiple units (e.g., sand, gravel, etcetera.) unlike hard, massive materials like rock. Effective gardeners manage soils to produce healthy and resilient plants.

Soil contains a variety of substances. In a well-managed western soil, usually around 50% of the soil's volume is composed of solid particles, while the other 50% is empty space. Soil scientists refer to these empty spaces as "pores." [**Figure 1**]

Most of the solid particles are derived from mineral sources such as decomposed rocks or sediments. 1 - 5% of the soil's volume is organic matter - plant, animal, and microbial residues in various stages of decomposition. [**Figure 1**]

Figure 1.
A well-managed Western soil has 25% air, 25% water, 1-5% organic matter and 45-49% mineral solids.



The empty space between the solid particles can be occupied by water, air, or a combination of both. In a well-managed soil, about 25% of the soil's volume is air, while the remaining 25% is occupied by water. This combination of components provides a healthy environment for roots to grow.

Soil Forming Factors

Soils vary across the landscape. A Colorado gardener may have noticed substantial differences between the soil in his or her yard compared to their neighbor's soil. In Colorado, there are many diverse types of soils ranging from heavy clays to sands or decomposed granite.

The factors that cause variation in soils in different locations are referred to as soil forming factors. Soil scientists recognize five soil-forming factors, including:

- Parent material.
- Climate (precipitation, temperature, wind).
- Topography.
- Biological organisms.
- Time.

These factors differ in subtle and complex ways over the surface of the earth to create an infinite array of soils.

The term **parent material** refers to the starting material for a soil. It consists of specific minerals (or organic materials) from which a soil is formed. The mineralogy of the parent material has a significant effect on the mineralogy and properties of the soil.

Climatic factors influence soil formation in several ways. First, precipitation and temperature cause weathering of rocks. In dry climates like Colorado (unlike warm, moist climates), wind is often more important than water in weathering rocks and transporting parent materials. Second, climatic factors often transport parent materials over long distances. Sometimes the parent material for a soil is *residual*, meaning it disintegrated in place to form soil. In other cases, the parent material is *transported* by water (rivers and streams), wind, gravity, or glaciers. As with weathering, wind is the primary means of transport in Colorado. Once the parent materials land on a stable surface, the process of soil formation can begin. The presence or absence of biological organisms can determine how long it takes to create different soil horizons (see below). The characteristics of the resulting soil will depend on the interaction of the remaining four soil forming factors on the parent material. Together, these factors act over thousands of years to form soil.

Soil Variation

Soils are three-dimensional entities. Soil not only varies across the landscape, but also varies vertically with depth. Gardeners will notice changes in soil color, physical properties, and chemical properties as they dig deeper. Over time, the soil-forming factors change the undifferentiated parent material into a vertically differentiated soil. Soil scientists recognize **horizons**, or horizontal layers within a soil. Horizons are identified by letter codes. They may blend gradually or have abrupt borders between layers. [**Figure 2**]

A Horizon (also referred to as "topsoil")

The A horizon is usually the surface horizon. This is an area of high biological activity with the greatest organic matter content. It is also a zone of leaching. As precipitation enters the A horizon, it dissolves soluble soil organic compounds and minerals. These dissolved compounds are then moved downward through the soil profile. Most plant roots are found in the A horizon.

B Horizon (also referred to as "subsoil")

The B horizon lies underneath the A horizon. This layer usually contains less organic matter than the surface layer, but accumulates the dissolved materials leached from the A horizon (clays, iron oxides, aluminum, and dissolved organic compounds). For this reason, the B horizon typically contains more clay than the surface layer. The accumulated products in the B horizon increase over time as the soil forms.

C Horizon

The C horizon contains unconsolidated material that has been minimally affected by the soil forming factors. It lies beneath the B horizon and may or may not be the same as the parent material from which the soil formed.

Figure 2. Soil Profile

A Horizon
- High biological activity.
- Greatest organic matter.
- Leaching zone.
- Largest concentration of roots.

B Horizon
- Lower biological activity.
- Accumulated dissolved materials.
- More clay than A Horizon.

C Horizon
- Unconsolidated material.
- Not impacted by soil-forming factors.
- May or may not be the parent material form which the soil is formed.

Landscape Soils

Landscape soils differ significantly from agricultural or native soils. **Landscape soils** are soils that are found in a typical neighborhood community around homes, parks, schools, offices, parking lots, and buildings. Soil scientists often refer to landscape soils as "urban" soils.

During the construction process, soils in communities are often graded by moving large volumes of soil. This process often removes the A horizon, taking with it most of the organic matter. Furthermore, when construction workers drive large pieces of equipment over soil it becomes compacted. Thousands of years of soil development can be destroyed in minutes with a bulldozer and other soil moving equipment in a construction site.

Sometimes construction debris, such as wood, trash, drywall, bricks, asphalt, or concrete, is buried in the soil during construction. Other possible landscape soil changes include increased variability, increased surface crusting, increased pH, decreased drainage, decreased soil microbial activity, and increased soil temperature. All these factors can cause problems when managing soils around buildings.

Native, undisturbed soils typically have well defined A, B, and C horizons. In compacted landscape soils, the horizons are scrambled and not defined, organic content is low, and air and water movement are reduced.

In comparison, the compacted unamended landscape soil typically has 10% air, 20% water, 1% organic matter and 69% mineral solids. The most significant aspect of the compacted landscape soil is the reduction in air. Low soil oxygen is the most common limiting factor of plant (root) growth. [**Figure 3**]

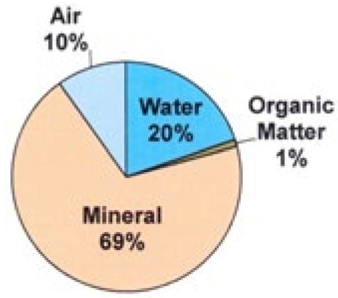


Figure 3.
A typical compacted, unamended landscape soil has 10% air, 20% water, 1% organic matter, and 69% mineral solids.

Soil conditions contribute to many plant problems. What can the gardener do?

1. Understand soils as a living ecosystem. Nurture soil organisms by providing their food source (organic matter) and improving aeration and drainage (oxygen and water). For additional information, refer to CMG GardenNotes #212, *The Living Soil*.

2. Understand the soil physical properties of texture, structure, and pore space as they relate to soil tilth. Compaction is a reduction in total pore space, but more importantly, compaction is a major reduction in large pore space where the air is located. Gardeners will be more successful in soil management by understanding what properties can be changed and what properties cannot be changed. For additional information, refer to CMG GardenNotes #213, *Managing Soil Tilth*: *Texture, Structure, and Pore Space*.

In summary, soils are important to gardeners because it strongly influences plant growth. In Colorado, soils vary horizontally across the landscape and vertically with depth. In addition, landscape soils may vary considerably from agricultural and native soils. Landscapers and gardeners must take these changes into account when developing a soil management plan.

Authors: Catherine Moravec, former CSU Extension Employee; David Whiting, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Dan Goldhamer, CSU Extension. Reviewed August 2022 by Dan Goldhamer, CSU Extension, and Cassey Anderson, CSU Extension.

CMG GardenNotes #212

The Living Soil

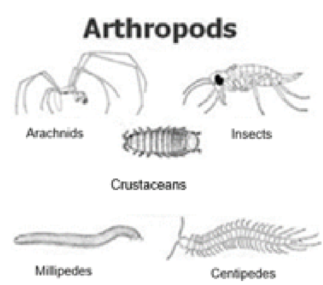
Soil Organisms Improve Garden Tilth

Rather than being an inert material, soil contains a dynamic living ecosystem. The 1-5% **organic matter found in soils includes living organisms**. Soil is thought to have the most biodiverse ecosystems, with only about 1% of the organisms being identified. Although most soil organisms are invisible to the naked eye, they help gardeners in multiple ways. One major benefit to gardeners is their ability of soil organisms to improve soil tilth. Soil **tilth** is the suitability of a soil to support plant growth, especially as it relates to ease of tillage, fitness for a seedbed, impedance to seedling emergence and root penetration. Soil organisms also play a significant role in making nutrients available to plants. The community of soil organisms is varied, versatile, and adaptable to changing conditions and food supplies.

Types of Soil Organisms

Soil contains an enormous number of living organisms. One cup of undisturbed native soil may contain:

Organism	Number
Bacteria	200 billion
Protozoa	20 million
Fungi	100,000 meters
Nematodes	100,000
Arthropods	50,000



Insects by Bob Hammon

Other organisms that can be found in the soil include earthworms and algae. Soil organisms are naturally active during certain times of the year. Most are active when the soil is warm and moist, like during late spring and early summer. If the soil dries out during the summer months, soil organism activity naturally declines. During fall, if there is rain or snow that moistens the soil while it is still warm, soil organisms may resume partial activity. As the soil cools in the fall, many soil organisms go dormant. Gardeners should note that fertilizers that require processing by soil organisms will be more available to plants when the soil is warm and moist and less available when the soil is cool or dry.

Despite their small size, soil organism activities have a large influence on plant growth. Soil organisms can be grouped into three categories:

1. Organisms that are **beneficial** to plants - directly or indirectly.
2. **Neutral** organisms - those whose activities have no effect on plants.
3. Organisms that are **harmful** to plants. Harmful organisms are often described as **pathogens**, such as the soil fungi that cause wilt diseases, or **plant pests**, such as white grubs that feed on plant roots.

Directly Beneficial Soil Organisms

Some soil organisms have a close, mutually beneficial (**symbiotic**) relationship with plants. Two examples include rhizobia and mycorrhizae. **Rhizobia** are bacteria that form symbiotic associations with legumes such as beans and peas. The bacteria form nodules on the roots of the host plant in which they fix nitrogen gas from the air. Rhizobia supply the plant with nitrogen and in turn the plant supplies the bacteria with essential minerals and sugars. It may be helpful to add Rhizobia in the first planting of beans and peas in a soil area. Afterwards they will be present.

Mycorrhizae are formed by symbiotic relationships of specific fungi with plant roots. Found in most soils, mycorrhizal fungi are very host specific (i.e., each plant species has specific species of mycorrhizal fungi associated with it).

The Latin word *mycor* means fungus and *rhiza* means root. The terms “mycorrhiza” (singular) or “mycorrhizae” (plural) refer to the tissue that forms when fungi and roots develop a mutually beneficial relationship. Enlarging the surface-absorbing area of the roots by 100 to 1,000 times, mycorrhizae create filaments or threads that act like an extension of the root system. This makes the roots of the plant much more effective in the uptake of water and nutrients such as phosphorus and zinc. In exchange, the fungus receives essential sugars and compounds from the roots to fuel its own growth. Some types of mycorrhizae can be seen on roots, while most are invisible to the naked eye.

Mycorrhizae improve plant health. They enhance the plant’s ability to tolerate environmental stress (like drought and dry winter weather) and reduce transplant shock. Plants with mycorrhizae may need less fertilizer and may have fewer soil borne diseases.

A by-product of mycorrhizal activity is the production of **glomalin**, a primary compound that improves soil tilth. In simple terms, glomalin glues the tiny clay particles together into larger aggregates, thereby increasing the amount of large pore space, which in turn creates an ideal environment for roots. For additional details, refer to the U.S. Department of Agriculture web site at https://agresearchmag.ars.usda.gov/2002/sep/soil.

Mycorrhizal cocktails are sometimes incorporated in planting or post-planting care of trees and landscape plants. However, results have been mixed from studies that *add* mycorrhizae to the soils to benefit plants (as opposed to naturally occurring mycorrhizae). Over time, additional research will help clarify what procedures result in improved plant health and vigor.

Indirectly Beneficial Soil Organisms

In addition to directly beneficial organisms such as rhizobia and mycorrhizae, there is a large portion of soil organisms whose activities indirectly help plants. Soil organisms collectively decompose organic matter, resulting in two principal benefits.

First, as soil organisms decompose organic matter, they transform nutrients into mineral forms that plants can use; thus, this process is called **mineralization**. Without soil microorganisms, insects, and worms feeding on organic matter, the nutrients in organic matter would remain bound in complex organic molecules that plants cannot utilize.

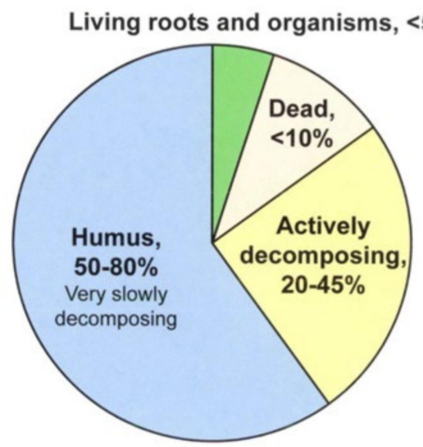
Second, as soil organisms break down organic matter, their activities help improve soil structure. Improved soil structure provides a better environment for roots, with less soil compaction and better water and air movement. Many gardeners know that organic matter improves soil, but it is important to note that its beneficial properties are only released *after* being processed by soil organisms.

Soils naturally contain these decomposers. Adding decomposers to the soil or compost pile is not necessary. Rather, the gardener should nurture them with food (organic matter) and good aeration and drainage (air and water).

Soil Organic Matter

Soil organic matter is composed of a wide variety of organic substances. Derived from plants, animals, and soil organisms, the soil organic matter "pool" can be divided into four categories. [**Figure 1**]

Figure 1. Make-Up of Soil Organic Material



First are the living organisms and roots, making up less than 5% of the total pool.

Second are the residues from dead plants, animals and soil organisms that have not yet begun to decompose (<10%).

Third is the portion undergoing rapid decomposition (20-45%).

Humus is the fourth. It is the stabilized organic matter remaining after further decomposition by soil microorganisms (50-80%).

The stabilized organic matter, or humus, is the pool of soil organic matter that has the longest lasting benefits for gardeners. After rapid decomposition occurs, a mix of stable, complex organic compounds remains, which decomposes slowly over time (about 3% per year). Humus is a mix of tiny solid particles and soluble compounds. While it is too chemically complex to be used by most organisms, it has great benefits for soil properties and thus plants. Humus contains a potpourri of sugars, gums, resins, proteins, fats, waxes, and lignin. This mixture plays a significant role in improving the physical and chemical properties of soil.

Humus improves the physical and chemical attributes of soil in several ways, including the following:

- Humus improves soil structure by binding or "gluing" small mineral particles together into larger aggregates creating large soil pores for improved air and water infiltration and movement.

- Humus improves water retention and releases it to plants.
- Humus slowly releases nitrogen, phosphorus, and sulfur over time, which plants then use for growth and development.
- Because of its positive surface charge, humus improves soil fertility by retaining nutrients.
- Humus buffers the soil pH, so it remains stable for plant roots.
- Humus can chelate or bind metals in soil, preventing metal toxicities.

As a point of clarification, garden stores sometime carry soil amendments labeled as “humus.” These are generally compost and do not meet the soil scientist definition of humus as given here.

Soil Inoculation

Gardeners can purchase products at garden centers that are intended to introduce soil organisms to an existing soil. Adding decomposing bacteria from a purchased product is not necessary because decomposing soil organisms are already present in the soil. Even if their populations are low due to unfavorable conditions, as soon as organic matter and water become available, their populations rapidly increase. Thus, soil biologists encourage gardeners to nurture existing communities rather than introducing external organisms through purchased products.

In addition, inoculating with rhizobia is generally not needed, unless a vegetable gardener is planting a leguminous crop for the first time. In this case, the gardener should purchase the appropriate inoculant (bacteria) for the leguminous vegetable being planted. Inoculation in future years is not needed, because rhizobia produce survival structures to over-winter.

Mycorrhizal products are not recommended by CSU Extension for general use. While there is ongoing research into mycorrhizal amendments for very specific objectives (e.g. native soil restoration, or nursery production of native plants), studies show mycorrhizal inoculation is unnecessary and ineffective in most landscapes.

Soil Food Web

Within the soil, organisms’ function within an ecological food web (the smaller becoming the food for the larger) cycling nutrients through the soil biomass. This soil food web is the basis of healthy, living soil. Significant soil organisms involved in the soil food web include bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.

Bacteria – are simple, single-celled microorganisms. Bacteria inhabit a wide variety of habitats, including soil. In fact, a teaspoon of productive soil can contain from one hundred million to one billion bacteria. Soil-inhabiting bacteria can be grouped as decomposers, mutualists, pathogens, or chemoautotrophs. Bacteria that improve soil quality feed on soil organisms, decompose organic matter, help keep nutrients in the root zone, enhance soil structure, compete with disease-causing organisms, and filter and degrade pollutants in soil.

Fungi – are a diverse group of multi-cellular organisms. The most known fungi are mushrooms, molds, and yeast, but there are many others that go unnoticed, particularly those living in soil. Fungi grow as long strands called hyphae (up to several yards long), pushing their way between soil particles, rocks, and roots. Fungi can be grouped as decomposers, mutualists, or pathogens. Fungi that improve soil quality decompose complex carbon compounds; improve accumulation of organic matter; retain nutrients in soil; bind soil particles into aggregates; compete with plant pathogens; and decompose certain types of pollution.

Protozoa – are microscopic, single-celled microbes that primarily eat bacteria. The bacteria contain more nitrogen than the protozoa can utilize, and some ammonium (NH4) is beneficially released to plants. Protozoa also prevent some pathogens from establishing on plants and function as a food source for nematodes in the soil food web.

Nematodes – are small, unsegmented round worms. Nematodes live in water films in the large pore spaces in soil. Most species are beneficial, feeding on bacteria, fungi, and other nematodes, but some cause harm by feeding on plant roots. Nematodes distribute bacteria and fungi through the soil as they move about. Predatory nematodes can consume root-feeding nematodes or prevent their access to roots.

Arthropods – in the soil are small animals such as insects, spiders, and mites. They range in size from microscopic to several inches in length. Most live near the soil surface or in the upper three inches. Arthropods improve soil quality by creating structure through burrowing; depositing fecal pellets; controlling disease-causing organisms; stimulating microbial activity; enhancing decomposition via shredding organic matter and mixing soil; and regulating healthy soil food web populations.

Soil arthropods can be *shredders* (millipedes, sowbugs, etc.), *predators* (spiders, scorpions, pseudoscorpions, centipedes, and predatory mites, ants, and beetles), *herbivores* (symphylans, root-maggots, etc.), or *fungal-feeders* (springtails and turtle mites). Most soil-dwelling arthropods eat fungi, worms, or other arthropods.

Earthworms – come in three types, two of which live in Colorado soils. Earthworms digest micro-organisms and organic matter. Refer to CMG GardenNotes #218, *Earthworms* for more information.

Ways to Encourage Beneficial Soil Organisms

Creating a favorable environment for soil organisms improves plant growth and reduces garden maintenance. Encouraging their efforts is central to building healthy fertile soil supportive to optimum plant growth. Suggestions for aiding soil organisms include:

- **Add organic matter to the soil.** Soil organisms require a food source from soil amendments (compost, crop residues) and/or mulch.
- **Use organic mulch.** It stabilizes soil moisture and temperature and adds organic matter. Mulches may help prevent soil compaction and protect soil oxygen levels needed by soil organisms and roots. **NOTE:** The term ***mulch*** refers to material placed on the soil surface. A mulch controls weeds, conserves water, moderates soil temperature and has a direct impact on soil microorganism activity. ***Soil amendment*** refers to materials mixed into the soil.
- **Water effectively.** Soil organisms require an environment that is damp, like a wrung-out sponge, but not soggy, between 50°F to 90°F. Soil organism activity may be reduced due to dry soil conditions that are common in the fall and winter. Avoid over-irrigation because water-logged soils will be harmful to beneficial soil organisms.
- **Avoid unnecessary rototilling**, as it will destroy the mycorrhizae and soil structure. Instead of tilling, mulch for weed control.
- **Avoid unwarranted pesticide applications.** Some fungicides, insecticides and herbicides are harmful to various types of soil organisms.
- **Avoid plastic sheets under rock mulch.** This practice discourages microorganism activity by reducing water and air movement and preventing the incorporation of organic matter.

Authors: Catherine Moravec, former CSU Extension employee; David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Susan Carter, CSU Extension. Reviewed October 2022 by Sarah Schweig, CSU Extension.

Reviewed October 2022

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #213

Managing Soil Tilth:
Texture, Structure, and Pore Space

Soil Tilth

The term soil ***tilth*** refers to the soil's general suitability to support plant growth, or more specifically to support root growth. Tilth is technically defined as the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration.

A soil with good tilth has large pore spaces for adequate air infiltration and water movement. (Roots only grow where the soil tilth allows for adequate levels of soil oxygen.) It also holds a reasonable supply of water and nutrients.

Soil tilth is a function of soil texture, structure, fertility, and the interplay with organic content and the living soil organisms that help the soil ecosystem.

Gardening in Colorado can be a challenge due to poor soil tilth. Sandy soils hold little water and nutrients. Along Colorado's Front Range, many soils are clayey and compact readily. These soils may have poor drainage, which may lead to salt problems. Due to low soil oxygen levels, root systems are typically shallow, reducing the crop's tolerance to drought and hot windy weather.

Special attention to soil management is the primary key to gardening success. While gardeners often focus their attention on insect and disease problems, a large number of plant problems begin with soil conditions that reduce the plant's vigor.

Gardeners often address the soil's nutrient content by applying fertilizers. However, fertilization is only one of the keys to a productive garden.

Managing Soil Tilth

Gardening on Coarse-Textured, Sandy Soils

The major limitation of sandy soil is its low capacity to hold water and nutrients. Plants growing on sandy soils do not use more water; they just need to be irrigated more frequently but with smaller quantities. Heavy irrigation wastes water because it readily leaches below the root zone. Water-soluble nutrients, such as nitrogen, also leach below the rooting zone with excessive irrigation or rain.

The best management practice for sandy soils is routine applications of organic matter. Organic matter holds ten times or more water and nutrients than sand. Sandy soils with high organic matter content (4-5%) make an ideal gardening soil.

Gardening on Fine-Textured, Clayey Soils

The limitations of clayey soils arise from a lack of large pores, thus restricting both water and air movement. Soils easily waterlog when water cannot move down through the soil profile. During irrigation or rain events, the limited large pore space in fine-textured soils quickly fills with water, reducing the roots' oxygen supply.

The best management practice for clayey soils is routine applications of organic matter and attention to fostering the activity of soil microorganisms and earthworms. As soil microorganisms decompose the organic matter, the tiny soil particles bind together into larger clumps or *aggregates*, increasing large pore space. This improvement takes place over a period of years. A single large application of organic matter does not do the trick.

A gardener may start seeing improvement in soil conditions in a couple of years as the organic content reaches 2-3%. As the organic content increases, earthworms and soil microorganisms become more active; this over time improves soil tilth. The ideal soil for most gardens has 4-5% organic matter. However, some native and xeric plants do not like this high organic content, having evolved for poor soils.

Take extra care to minimize soil compaction in soils. Soil compaction reduces the large pore space, restricting air and water movement through the soil, thus limiting root growth. <u>Soil compaction is the primary factor limiting plant growth in landscape soils.</u> Soils become compacted during home construction and need to have organic material added over several years to develop its tilth.

Gardening on Gravelly and Decomposed Granite Soils

Soils in Colorado foothills and mountains change with topography and precipitation. Soils may be well developed with organic matter on north and east facing slopes and in valley floors, but on dryer south and west facing slopes soils are often shallow and extremely low in organic matter.

Gardening in the gravelly and decomposed granite soils, common to many foothills and mountain areas, may be extremely challenging. Large rocks, erratic depths for bedrock, little organic matter, pockets of clayey soil and rapid drainage with poor water holding capacity characterize these coarse textured soils. They erode readily once disturbed.

If the soil has been disturbed with the surface layer removed, decomposed granite soils will benefit from organic matter. Add up to 25% by volume. For example, if tilling to a depth of eight inches, add two inches of compost or other organic materials. If only tillable to a depth of four inches, add one inch of compost. Use well decomposed materials. In some situations, mixing in the organic matter may be very labor intensive or impossible.

When Soil Amendment Is Not Practical Or Possible

In real world settings, the ideal approach of improving soils by adding soil amendments may not be practical or possible. For example:

- In existing landscapes, it is easy to add amendments to annual flower beds and vegetable gardens, but amendments cannot be worked into the soil in the rooting zone of trees, shrubs, perennials, and lawn.
- In working with new landscapes, the new homeowner may not have the financial resources to purchase the amendments desired.
- The gardener may not have the physical ability for this intense labor.
- On slopes, removing the plant cover predisposes the soil to erosion.
- On rocky soils, it may be physically impractical or impossible to work in amendments.

Where amending is not practical or possible, gardeners need to consider alternatives. Primarily, understand that without soil improvement the gardener may need to accept less than optimum plant growth and increased maintenance.

When amending is not practical or possible, consider the following options:

- Focus on selecting plants more tolerant of the soil conditions. This includes tolerance to low soil oxygen and reduced root spread (compaction issues), poor drainage (tolerance to wet soils), drought (tolerance to dry soils), and low fertility (fertilizer need). These are characteristics of some rock garden or alpine garden plants. However, be careful about assuming that these characteristics apply to native plants as it may or may not be the case.
- Space plants further apart to reduce competition for limited soil resources.
- Small transplants may adapt to poor soils better than either larger transplants or trying to grow plants from seed.
- Raised-bed gardening and container gardening may be a practical option when soils are poor.
- Pay attention to minimizing additional soil compaction with the use of organic mulches and management of foot traffic flow.
- Organic mulch (wood/bark chips) helps improve soil tilth over a period of time as the mulch decomposes and is worked into the soil, by soil organisms. To allow this process to occur, do not put a weed fabric under the mulch and add material periodically.
- Established lawns, which have been in place for more than twenty years, come to equilibrium between root dieback and soil organic content.

Soil Practices To Avoid

The following is a summary of common practices that should be avoided in Western soils to maximize soil tilth and plant growth potential.

- **Avoid working the soil when wet**. Water lubricates soil particles, making the soil easier to compact.
- **Avoid excessive fertilization**. This has the potential for surface and ground water pollution and adds salts to the soil that can become toxic to plants. Heavy fertilization will not compensate for poor soil preparation. Many gardeners have over applied phosphate and potash.
- **Avoid adding too much organic matter**. This leads to salt build-up, large release of nitrogen, the build-up of excessive phosphorus, and an imbalance in potassium, calcium, magnesium, and iron.

- **Avoid adding lime or wood ashes**. Being calcium sources, they are used to raise the soil pH. Most Colorado soils have a neutral to high pH. Lime or wood ashes would only be used on soils with a soil pH below 5.5.
- **Avoid adding gypsum (a calcium source)**. Gypsum is used to reclaim sodic soils by displacing the sodium with calcium.
- **Avoid creating texture interfaces**. For example, when making a raised bed, adding a different soil in the box creates an interface at the change line. Use similar soils and mix the soils.
- **Avoid trying to make dramatic changes in soil pH**. If the soil is high in *free lime* (calcium carbonate), lowering the pH is not effective.

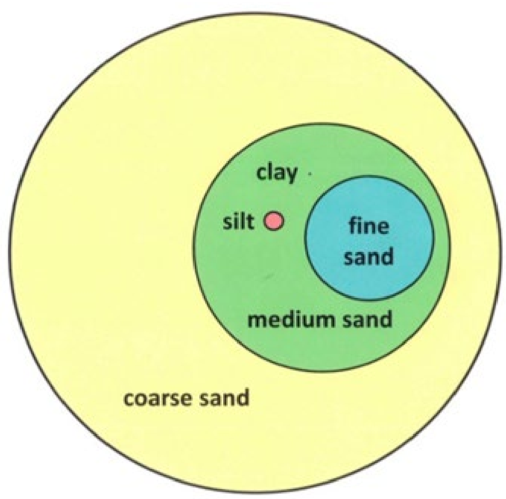
Texture

Texture refers to the size of the particles that make up the soil. The terms sand, silt, and clay refer to relative sizes of the individual soil particles. [**Table 1, Figure 1,** and **2**]

Table 1. The Size of Sand, Silt, and Clay

Name	Particle Diameter
Clay	below 0.002 mm
Silt	0.002 to 0.05 mm
Very fine sand	0.05 to 0.10 mm
Fine sand	0.10 to 0.25 mm
Medium sand	0.25 to 0.5 mm
Coarse sand	0.5 to 1.0 mm
Very coarse sand	1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 mm (~2 inches)

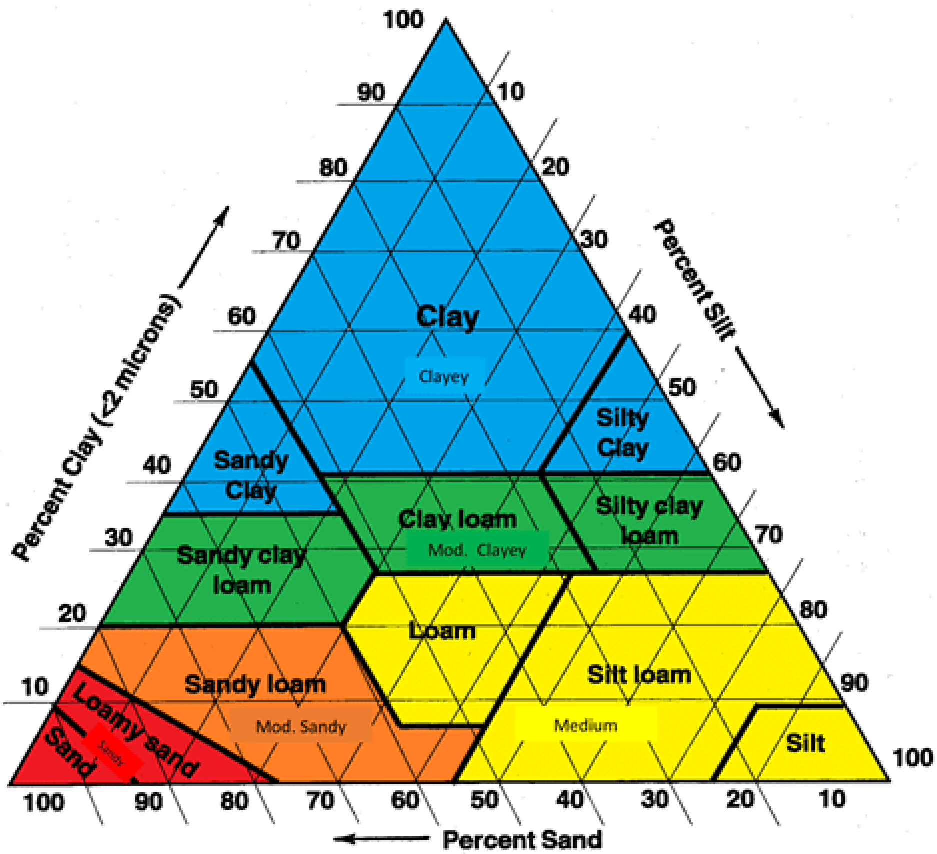
Figure 1.
Comparative size of clay to coarse sand. Clay is less than 0.002 mm (0.00008 inch) with coarse sand up to 1.0 mm (0.04 inch).



Based on the ***Soil Textural Class Triangle,*** [**Figure 2**]**,** the percentage of sand, silt and clay determine the texture class. (For example, a soil with 30% clay, 10% silt, and 60% sand is called a sandy clay loam. A soil with 20% clay, 40% silt and 40% sand is a loam.)
A ***fine-textured*** or ***clayey soil*** is one dominated by tiny clay particles. A ***coarse- textured*** or ***sandy soil*** is one comprised primarily of medium to large size sand particles. The term ***loamy soil*** refers to a soil with a combination of sand, silt, and clay sized particles.

Some types of clayey soils expand and contract with changes in soil moisture. These ***expansive*** soils create special issues around construction and landscaping. For homes on expansive clays, limit landscaping along the foundation to non-irrigated mulch areas and xeric plants that require little supplemental irrigation. Avoid planting trees next to the foundation and direct drainage from the roof away from the foundation.

Figure 2. Soil Texture Triangle. Source: USDA.



Clay
Clay particles are flat, plate-like, negatively charged particles. They are so tiny in size that it takes 12,000 clay particles in a line to make one inch. Clay feels sticky to the touch. <u>Soils with as little as 20% clay size particles behave like a sticky clayey soil</u>. Soils with high clay content have good water and nutrient holding capacity, but the lack of large pore space restricts water and air movement. Clayey soils are also prone to compaction issues. Clay particles are the source of most of the chemical properties of soil and retain many of the plant nutrients such as calcium, magnesium, potassium, trace elements, and some of the phosphorus. As organic matter breaks down, clay reacts with it to stabilize the humus in the soil. A soil without clay particles can be infertile.

Silt
Silt has a smooth or floury texture. Silt settles out in slow moving water and is common on the bottom of an irrigation ditch or lakeshore. Silt adds little to the characteristics of a soil. Its water holding capacity is similar to clay.

Sand
Sand, being the largest sized particles, feels gritty. There is a major difference in soil characteristics between fine sands and medium to coarse sands. Fine sands add little to the

soil characteristics and do not significantly increase large pore space. An example of fine sand is the bagged sand sold for children's sandboxes.

True sandy soil requires greater than 50% medium to coarse sized sand. Sandy soils have good drainage and aeration, but low water and nutrient holding capacity.

Gravel and Rock

Some Colorado soils are dominated by gravel and rock, making them difficult for the gardener to work. Gravel and rock do not provide nutrients or water holding capacity. They often drain readily with low nutrient holding capacity.

Texture effects how water and nutrients move through a soil profile as shown in **Table 2**.

Table 2. Comparison of Fine-Textured (Clayey) Soil and Coarse-Textured (Sandy) Soil

	Clayey	Sandy
Water Holding Capacity	High	Low
Nutrient Holding Capacity	High	Low
Compaction Potential	High	Lower
Crusts	Yes	No/Sometimes
Drainage	Slow	Fast
Salinity Build-Up	Yes	Seldom
Warming in Spring	Slow	Fast

Structure

Structure refers to how the various particles of sand, silt and clay fit together, creating ***pore spaces*** of assorted sizes. Sand, silt, and clay particles are "glued" together by chemical and biological processes creating ***aggregates*** (clusters of particles). Mycorrhizae, earthworms, soil microorganisms and plant roots are responsible for creating aggregates. [**Figures 3** and **4**]

Figure 3.
The size of pore spaces between soil particles plays a key role in plant growth. Pore spaces are a function of soil texture and structure.

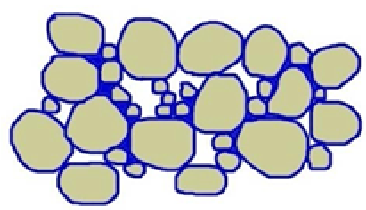
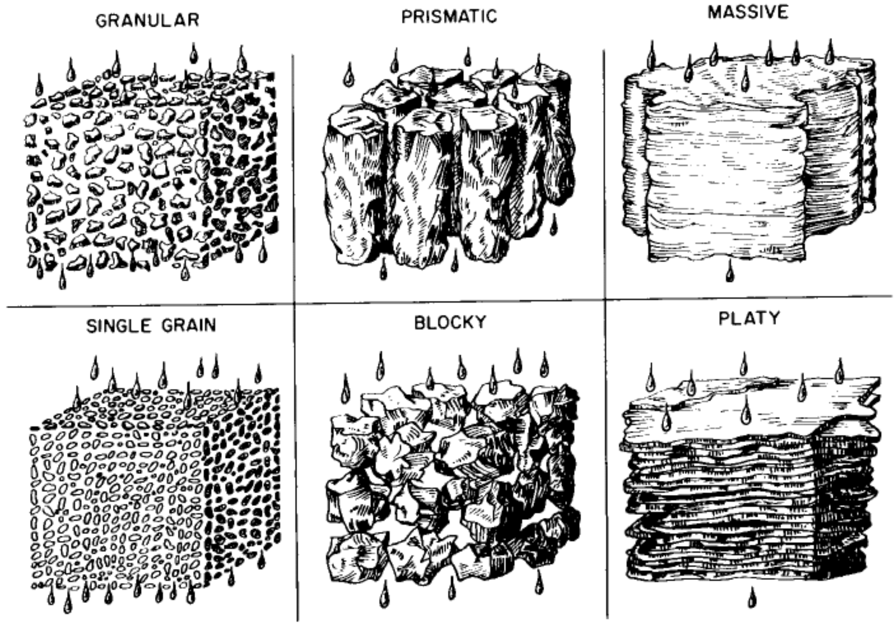


Figure 4 on next page.

Figure 4. Examples of soil structure types. Line drawing by USDA.



Undisturbed native soils often have a granular structure in the upper layer (with rapid drainage) and block structure (with rapid to moderate drainage) in the lower layers. A platy structure (with slow to no drainage) is common in soils high in clay.

Compacted, unamended landscape soils typically have a massive structure with no defined layers, little organic matter, low total pore space, and most significantly low large pore space.

The term ***peds*** describes the soil's individual aggregates or clods. Soils that create strong peds tolerate working and still maintain good structure. In some soils, the peds are extremely strong, making cultivation difficult except when the soil moisture is precisely right. Soils with soft peds may be easy to cultivate but may readily pulverize destroying the soil's natural structure.

Primary factors influencing structure include the following:

- Texture.
- Activity of soil mycorrhizae, earthworms, and other soil organisms.
- Organic matter content.
- Soil moisture (year-round).
- The freeze/thaw cycle.
- Cultivation – Tilling a soil has a direct impact on structure by breaking apart aggregates and collapsing pore spaces. Avoid tilling except to mix in organic matter, control weeds (limited use), or to prepare a seedbed.
- Soil compaction.

To maintain good structure avoid over-working the soil. Acceptable ped size depends on the gardening activity. For planting vegetable or flower seeds, large peds interfere with seeding. In contrast, when planting trees peds up to the size of a fist are acceptable and pulverizing the soil would be undesirable.

Pore Space

Pore space is a function of soil texture, structure, and the activity of beneficial soil organisms. Water coats the solid particles and fills the smaller pore spaces. Air fills the larger pore spaces. [**Figure 5**]

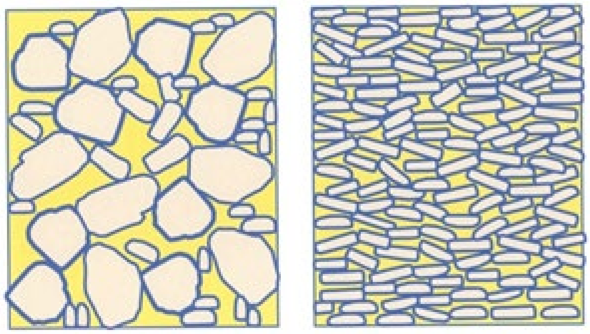
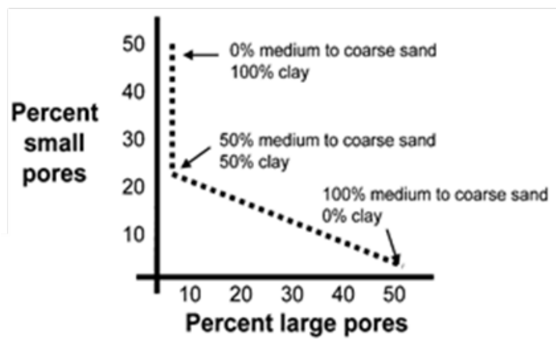


Figure 5.
Comparative pore space.
Left soil with large pore space.
Right soil lacking large pore space.

To help understand pore space, visualize a bottle of golf balls and a bottle of table salt. The pore space between golf balls is large compared to the pore space between the salt grains.

The relative percent of clay size particles versus the percent of medium to coarse sand size particles influences the pore space of a soil. Silt and fine sand particles contribute little to pore space attributes. Note in **Figure 6** how large pore space is minimal until the sand strongly dominates the soil profile. Organic matter also plays a key role in creating large pore space.

Figure 6.
Percent of small versus large pore space as a factor of soil texture.



The quantities of large and small pore spaces directly effect plant growth. On fine-texture, clayey, and/or compacted soils, a lack of large pore spaces restricts water and air infiltration and movement, thus limiting root growth and the activity of beneficial soil organisms. On sandy soils, the lack of small pore space limits the soil's ability to hold water and nutrients.

Water Movement

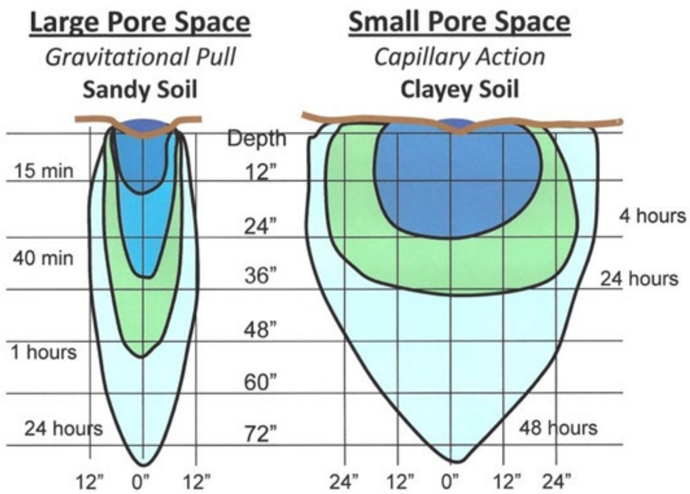
Characteristics of water molecules:

- **Cohesion Force** is where water molecules are attracted to one another. Cohesion causes water molecules to stick to one another and form water droplets.
- **Adhesion Force** is responsible for the attraction between water and solid surfaces. A drop of water can stick to a soil particle surface as the result of adhesion.
- **Surface tension**, from cohesion, causes water surfaces to behave in unusual ways. Water molecules are more attracted to other water molecules, as opposed to air particles, and water surfaces behave like expandable films.
- **Capillary action**, also referred to as capillary motion or capillarity, is a combination of cohesion/adhesion and surface tension forces. Capillarity is the primary force that enables the soil to retain water, as well as to regulate its movement. Water moves upwards (against

gravity) through soil pores, or the spaces between soil particles. The height to which the water rises is dependent upon pore size, with the smaller the soil pores, the higher the capillary rise.

The lack of large pore space leads to drainage problems and low soil oxygen levels. In sandy soils with large pores, water readily drains downwards by ***gravitational pull***. Excessive irrigation and/or precipitation can leach water-soluble nutrients, like nitrogen, out of the root zone and into ground water. [**Figure 7**]

Figure 7. Comparative Movement of Water in Sandy and Clayey Soils



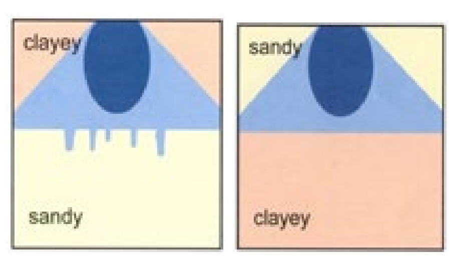
Texture Interface

Within the soil profile, a ***texture interface*** (abrupt change in actual pore space) creates a boundary line that affects the movement of water, air infiltration, and root growth. Water and air are very slow to cross a texture interface. [**Figure 8**]

When a clayey and/or compacted soil layer (primarily small pore space) is on top of a sandy soil layer (primarily large pore space) water accumulates just above the change. Water is slow to leave the small pore space of the clayey soil due to the water properties of cohesion.

Likewise, when water moving down through a sandy soil layer (primarily large pore space) hits a clayey and/or compacted soil layer (primarily small pore space) water accumulates in the soil just above the interface. This back up is due to the slow rate that water can move into the small pore space of the clayey soil. It is like a four-lane freeway suddenly changing into a country lane; traffic backs up on the freeway.

Figure 8.
Left image with clayey soil over sandy soil, water is slow to leave the small pore space of the clay.
Right image with sandy over clayey soil, water is slow to move into the small pore space of the clay.



Perched Water Table

This change in water movement creates a ***perched water table*** (overly wet layer of soil) six inches thick or greater just above the change line. When creating raised bed boxes, mix the added soil with the soil below to avoid creating a texture interface. In tree planting, to deal with the texture interface between the root ball soil and the backfill soil it is imperative that the root ball rises to the surface with no backfill soil over the root ball. In landscape soils that have a texture interface between soil layers, a perched water table may sit just above the interface line. In this situation, be cautious about frequent irrigation creating an oxygen deficiency in the roots below the perched water table. [**Figures 9** and **10**]

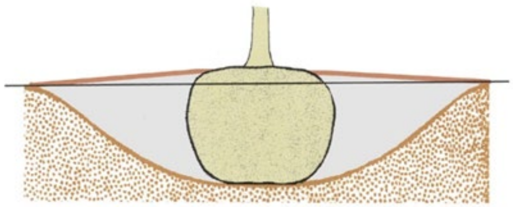


Figure 9.
In tree planting, to deal with the texture interface between the root ball soil and the backfill soil it is imperative that the root ball is above the surface with no backfill soil over top of the root ball.

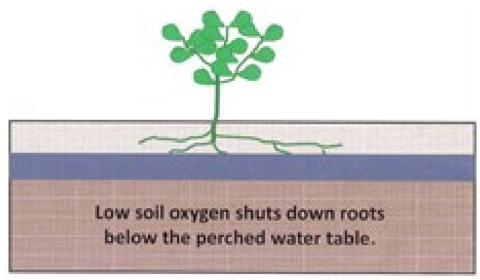


Figure 10.
On landscape soils with a texture interface in the soil profile, too frequent of irrigation creates a perched water table above the interface line. Roots below the perched water table have low soil oxygen levels.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; Catherine Moravec, former CSU Extension Employee; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting unless otherwise noted. Used with permission. Revised October 2015 by Eric Hammond, CSU Extension. Reviewed May 2023 by Mark Platten, CSU Extension.

Reviewed May 2023

CMG GardenNotes #214

Estimating Soil Texture:
Sandy, Loamy, or Clayey

Sand, Silt, and Clay

Texture refers to the size of the particles that make up the soil. The terms ***sand***, ***silt***, and ***clay*** refer to relative sizes of the soil particles. Sand, being the larger size of particles, feels gritty. Silt, being moderate in size, has a smooth or floury texture. Clay, being the smaller size of particles, feels sticky. [**Table 1** and **Figure 1**]

Table 1. The Size of Sand, Silt, and Clay

Name	Particle Diameter
Clay	below 0.002 mm
Silt	0.002 to 0.05 mm
Very fine sand	0.05 to 0.10 mm
Fine sand	0.10 to 0.25 mm
Medium sand	0.25 to 0.5 mm
Coarse sand	0.5 to 1.0 mm
Very coarse sand	1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 mm (~2 inches)

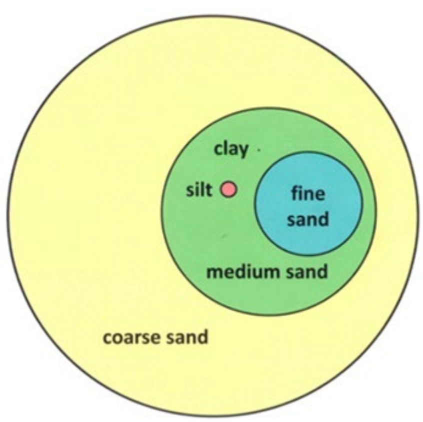
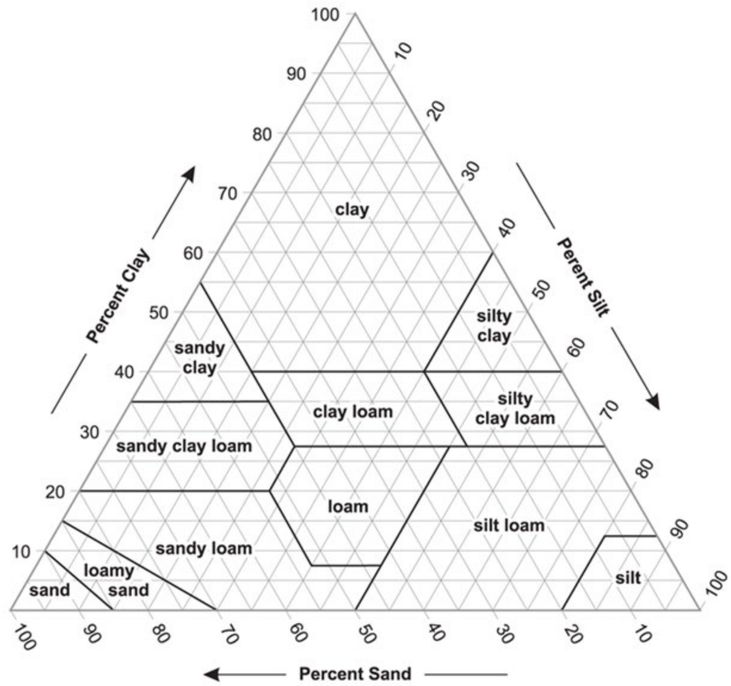


Figure 1.
Comparative size of sands, silt, and clay. If clay was the size of a dot on the page, silt and sands would be a comparative size.

Soil Texture Triangle

The ***soil texture triangle*** gives names associated with various combinations of sand, silt, and clay. A *coarse-textured* or *sandy* soil is one comprised primarily of medium to coarse size sand particles. A *fine-textured* or *clayey* soil is one dominated by tiny clay particles. Due to the strong physical properties of clay, a soil with only 20% clay particles behaves as sticky, gummy clayey soil. The term *loam* refers to a soil with a combination of sand, silt, and clay sized particles. For example, a soil with 30% clay, 50% sand, and 20% silt, is called a *sandy clay loam*. [**Figure 2**]

Figure 2. Soil Texture Triangle. Source: USDA



Identifying Soil Texture by Measurement [Figure 3]

1. Spread soil on a newspaper to dry. Remove all rocks, trash, roots, and such. Crush lumps and clods.
2. Finely pulverize the soil.
3. Fill a tall, slender jar (like a quart jar) one-quarter full of soil.
4. Add water until the jar is three-quarters full.
5. Add a teaspoon of powdered, non-foaming dishwasher detergent.
6. Put on a tight-fitting lid and shake hard for 10 to 15 minutes. Shaking breaks apart the soil aggregates and separates the soil into individual mineral particles.
7. Set the jar where it will not be disturbed for 2 to 3 days.
8. Soil particles will settle out according to size. **After 1 minute**, mark on the jar the depth of the sand.
9. **After 2 hours**, mark on the jar the depth of the silt.
10. **When the water clears,** mark on the jar the clay level. This typically takes 1 to 3 days; some soils may take weeks.
11. Measure the thickness of the sand, silt, and clay layers.
    - Thickness of sand deposit.
    - Thickness of silt deposit.
    - Thickness of clay deposit.
    - Thickness of total deposit.
12. Calculate the percentage of sand, silt, and clay.
    - Clay thickness, divided by total thickness, equals percentage of clay.
    - Silt thickness, divided by total thickness, equals percentage of silt.
    - Sand thickness, divided by total thickness, equals percentage of sand.
13. Turn to the soil texture triangle and look up the soil texture class. [**Figure 2**]

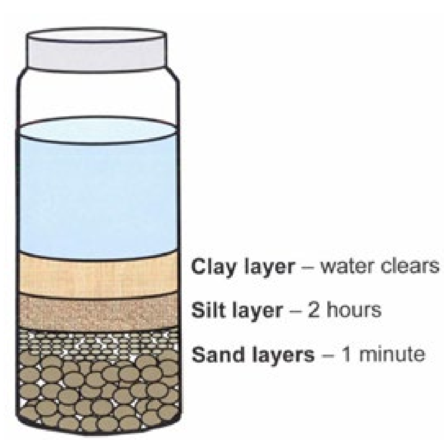


Figure 3. Measuring Soil Texture

Identifying Soil Texture by Feel

Place soil in palm of hand. Add a small amount of water and knead the soil into a smooth and plastic consistency, like moist putty.

Feel test – Rub moist soil between fingers.
- Sand feels gritty.
- Silt feels smooth.
- Clays feel sticky.

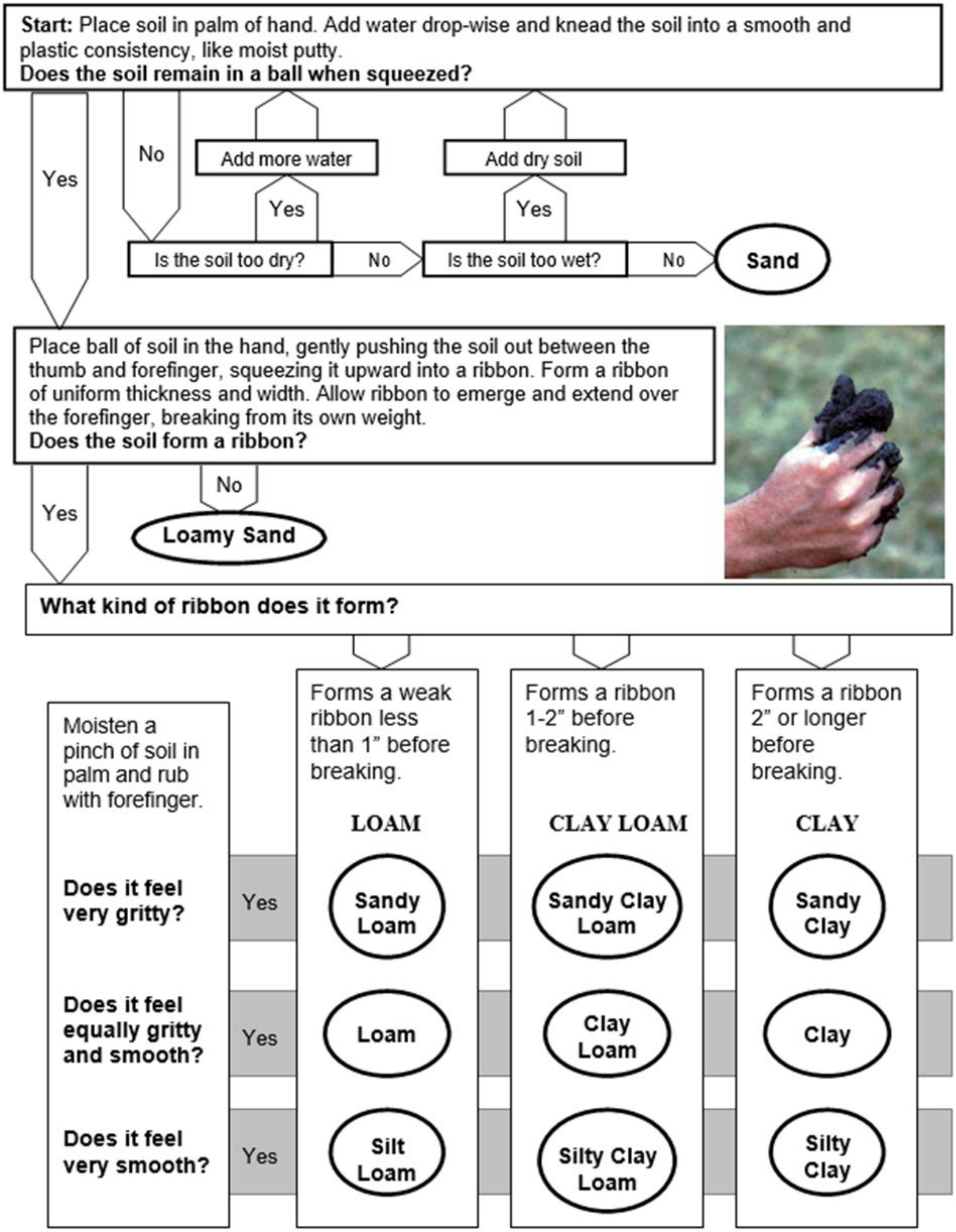
Ball squeeze test – Squeeze a moistened ball of soil in the hand.
- Coarse texture soils (sand or loamy sands) break with slight pressure.
- Medium texture soils (sandy loams and silt loams) stay together but change shape easily.
- Fine textured soils (clayey or clayey loam) resist breaking.

Ribbon test – Squeeze a moistened ball of soil out between thumb and fingers while squeezing upward. Form a ribbon of uniform thickness and width. Allow ribbon to emerge and extend over the forefinger, breaking from its own weight. [**Figure 4**]
- Ribbons less than 1 inch before breaking:
    - Feels gritty = coarse texture (sandy) soil.
    - Not gritty feeling = medium texture soil high in silt.
- Ribbons 1 to 2 inches before breaking.
    - Feels gritty = medium texture soil.
    - Not gritty feeling = fine texture soil.
- Ribbons greater than 2 inches = fine texture (clayey) soil.

Note: A soil with as little as 20% clay will behave as a clayey soil.
A soil needs 45% to over 60% medium to coarse sand to behave as a sandy soil. In a soil with 20% clay and 80% sand, the soil will behave as a clayey soil.

Figure 4, next page.

Figure 4. Soil Texture by Feel



Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Reviewed December 2015 and September 2022 by Eric Hammond, CSU Extension.

Reviewed September 2022

CMG GardenNotes #215

Soil Compaction

What Is Soil Compaction?

Soil compaction is the compression of soil particles. Compaction reduces total pore space of a soil. More importantly it significantly reduces the amount of large pore space, restricting air and water movement into and through the soil. *Low soil oxygen levels caused by soil compaction are a primary factor limiting plant growth in landscape soils*. Soil conditions, primarily soil compaction, contribute to a large portion of plant problems in the landscape setting. **Figure 1** illustrates comparison of large pore spaces in a non-compacted versus a compacted soil. Soil compaction can change a block or aggregate structure with good infiltration and drainage into a massive structure with poor infiltration and drainage. [**Figure 2**]

Figure 1. Comparison of large pore space in non-compacted soil (left) and compacted soil (right).

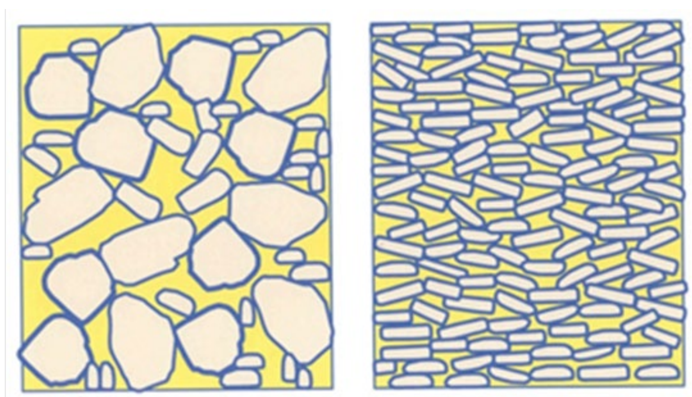
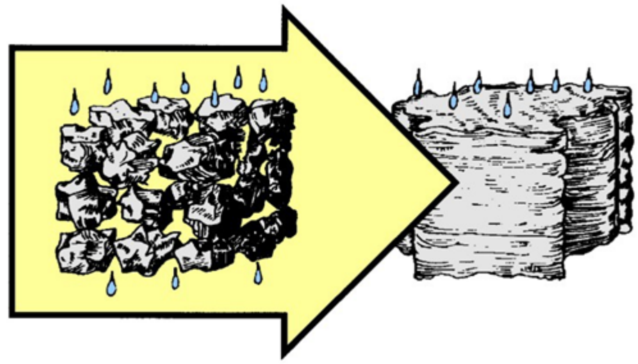


Figure 2.
Soil compaction can change a blocky or granular soil structure with good air infiltration and drainage into a massive structure with poor air infiltration and drainage. Line drawing by USDA.



Soil compaction is difficult to correct, thus efforts should be directed at preventing compaction. Soil generally becomes compacted during home construction or other heavy traffic. Foot traffic on moist soils can also contribute to compaction in the home landscape. The impact of falling raindrops and sprinkler irrigation also compacts the surface of fine-textured clayey soils. [**Figure 3**]

Figure 3.
Foot traffic in the garden bed is a major source of compaction. The impact of raindrops and sprinkler irrigation also compacts fine-textured soils.

Techniques to Minimize Soil Compaction

Adding Organic Matter

To reduce soil compaction, cultivate organic soil amendments into the top six to eight inches of the soil. In compacted/clayey soils, anything less can lead to a shallow rooting system with reduced plant growth, lower vigor, and lower stress tolerance.

General application rates for organic soil amendments are based on the type of product and the salt content. **Table 1** gives standard application rates for compost products. Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems, so higher application rates are safe.

Compost that includes manure or biosolids as a component has a potential for high salts. Excessive salt levels are common in many commercially available products sold in Colorado. For compost made with manure or biosolids, the application rate is limited unless a soil test on that batch of product shows a low salt level. An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable if incorporated six to eight inches deep in a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable.

> **Note:** dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

Do not leave compost in chunks as this will interfere with root growth and soil water movement. As the soil organic content builds in a garden soil, the application rate should be reduced to prevent ground water contamination issues.

Table 1. Routine Application Rate for Compost			
Site	**Incorporation Depth**[2]	**Depth of Compost Before Incorporation**[1]	
		Plant Based Compost and other compost known to be low in salts[3]	**Compost Made with Manure or Biosolids** for which the salt content is unknown[4]
One-time application – such as lawn area	6-8"	2-3"	1"
Annual application to vegetable and flower gardens – **first three years**	6-8"	2-3"	1"
Annual application to vegetable and flower gardens – **fourth year and beyond**	6-8"	1-2"	1"

1. Three cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.
2. Cultivate compost into the top 6-8 inches of the soil. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plant to reduced growth, low vigor, and low stress tolerance. When depth of incorporation is different than 6-8 inches, adjust the application rate accordingly.
3. Plant based composts are derived solely from plant materials such as leaves, grass clippings, wood chips and other yards wastes. Use this application rate also for other compost known, by soil test, to be low in salts.
4. Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado.

Manage Traffic Flow

Traffic over the soil is the major contributor to soil compaction. For example, a moist soil could reach 75% maximum compaction the first time it is stepped on, and 90% by the fourth time it is stepped on.

Raised bed gardening techniques, with established walkways, eliminate compaction in the growing bed. In fine-textured clayey soils, limit routine traffic flow to selected paths.

Soils are more prone to compaction when wet. Soil water acts as a lubricant allowing the soil particles to readily slide together reducing large pore spaces.

Using Mulches

Some types of mulch effectively reduce the compaction forces of traffic. For example, three to four inches of wood or bark chips will minimize the effect of foot traffic.

Mulch minimizes the compaction forces of rainfall and sprinkler irrigation. In fine-textured clayey soil, keep garden beds mulched year-round to minimize the compaction forces of summer and winter storms. Organic mulches create an ideal home for beneficial earthworms and soil microorganisms, which play a key role in improving soil tilth.

Aerate Lawns and Around Trees

In a lawn or tree's rooting area, where organic matter cannot be cultivated into the soil, reduce compaction with soil aeration. Make enough passes with the aerator to have plugs at two-inch intervals. Aim to aerate at least 1-2 times a year, and water well before aerating to achieve plugs that are at least 3" long. Plugs can be left to decompose on the soil surface or removed depending on preference. [**Figure 4**]

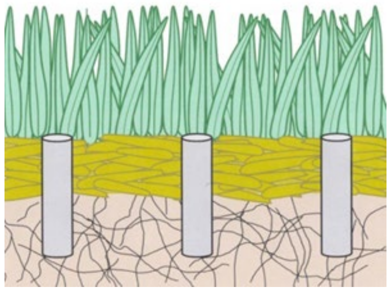


Figure 4.
Lawn aeration helps manage the impact of soil compaction if enough passes are made with the aerator to have plugs at two-inch intervals.

Avoid Excessive Cultivation

Avoid cultivating fine-textured clayey soils except to incorporate organic matter and fertilizer, and to prepare a seedbed. Use mulches to help manage weeds. Cultivation with a garden fork, broad fork, or shovel will disturb the soil less than using a rototiller.

Avoid Cultivating Overly Wet or Dry Soils

Never cultivate clayey soil when wet, as this will destroy soil structure; the clods created by tilling wet clay may last for years. To check dryness, take a handful of soil and gently squeeze it into a ball. If the soil is dry enough to crumble, it may be cultivated. If the ball only reshapes with pressure, it is too wet for cultivation. On some clayey soils, there may be only a few days (or even hours) between the time when the soil is too wet and too dry (too hard) to cultivate. In years when frequent spring rains prevent the soil from drying, planting will be significantly delayed.

Avoid Fill Over Compacted Soil

Adding a thin layer of topsoil over compacted soil is a common practice that leads to future landscape management problems. It is often justified as "a way to get plants established." However, root growth into the compacted layer will be restricted or even minimal.

Do not create a layer with added topsoil that is of a different texture than the soil below. This change in texture, actually, pore space, interferes with water movement and root spread. It is called a soil texture interface, and the upper layer must saturate completely before water can move into the different soil texture. Where additional fill is desirable, lightly mix the fill with the soil beneath.

Long-term landscape management will be much easier by breaking up surface compaction with tilling and organic matter amendments. Before planting a yard, enhance soil organic content to the extent feasible. A minimum of 3 to 4 cubic yards of organic matter per 1,000 square feet is recommended.

What About Adding Sand?

Some gardeners try to improve fine-textured soils by adding sand. The practice may help the gardeners feel that they have done something, but it will have a limited or even negative impact on the soil. Adding sand to clayey soil may reduce large pore space until enough medium-to–coarse-size sand is added to reduce the clay content well below 20%. In clayey soils, this becomes a process of soil replacement rather than soil amendment. In some situations, adding sand to clayey soil can create concrete-like soil properties. To improve the soil, put efforts into adding organic matter, not sand.

What About Adding Gypsum?

Gypsum is a salt also known as calcium sulfate. When added to calcareous clayey soils (typical of Colorado), it simply increases the already high calcium content. Gypsum will not break up compacted soil but can increase the soil's salt levels.

Gypsum is useful when a soil has a high sodium problem. Sodium has a unique physical characteristic that brings soil particles closer together, reducing large pore space and "sealing" soils to water penetration. The calcium in gypsum replaces the sodium on the soil cation exchange site and the freed sodium is then leached out by heavy irrigation. Good quality (low salt) irrigation water must be available to successfully reclaim a high sodium soil.

The use of sulfur has also been incorrectly acclaimed to break up compacted soils. Over time, sulfur may have an acidifying effect on a soil, if the soil is not high in lime. Adding sulfur to a calcareous soil only creates gypsum (calcium sulfate).

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Reviewed December 2015 by Eric Hammond, CSU Extension. Reviewed September 2022 by Cassey Anderson, CSU Extension.

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CMG GardenNotes #218

Earthworms

Regarded by Aristotle as the "intestines of the earth," earthworms aid in soil fertility and structure and contribute to overall plant health.

Earthworm Types

There are three types of earthworms: [**Figure 1**]

Anecic – Greek for "up from the earth" or "out of the earth."

- Capable of burrowing to depths of six feet.
- Builds permanent burrows into the deep mineral layers of the soil.
- Drags organic matter from the soil surface into their burrows for food.
- Includes the familiar bait worm, the nightcrawler or dew worm (Lumbricus terrestris).

Endogeic – Greek for "within the earth."

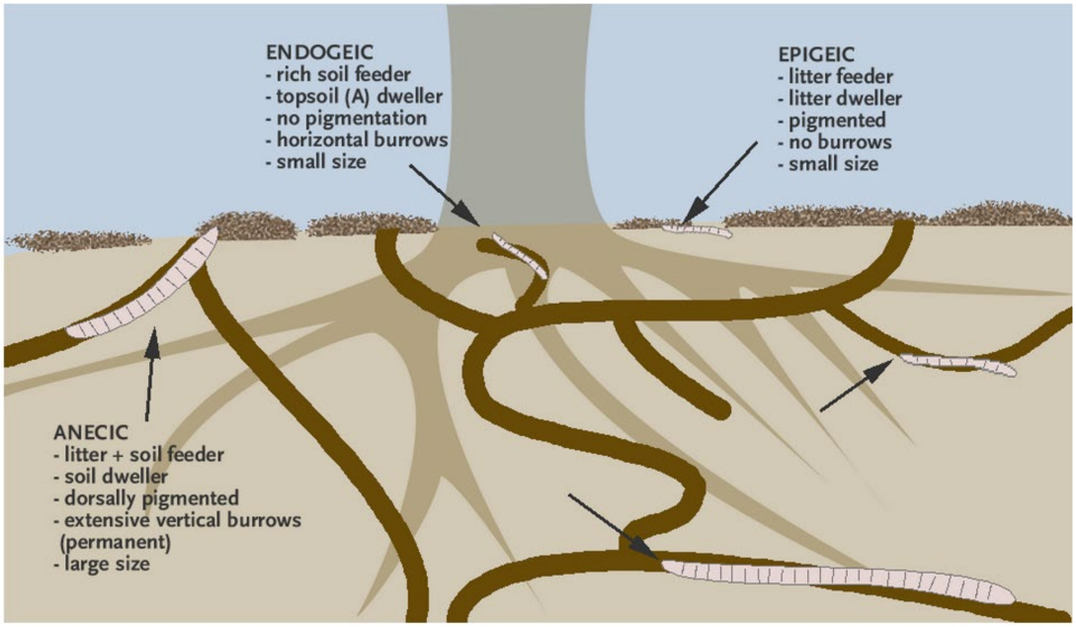
- Builds extensive non-permanent burrows in the upper mineral layer of soil.
- Feeds on the organic matter in the soil.
- Lives exclusively in soil and usually are not noticed, except after a heavy rain when they come to the surface.

Epigeic – Greek for "upon the earth."

- Lives on the soil surface.
- Forms no permanent burrows.
- Feeds on decaying organic matter.
- Common names: red worm, manure worm, brandling worm, red wiggler, and compost worm.

The anecic and endogeic are the types most often noticed in Colorado soils. Because the upper foot of soil freezes here during the winter, the epigeic worms are usually killed. In addition, the low organic matter content of Colorado soils will likely not support the food needs of epigeic earthworms. Anecic are larger than the endogeic.

Figure 1. Three Types of Earthworms. Image from UNM, Natural Resources Research Institute



Biology of Earthworms

Earthworms breathe through their skin and must be in an environment that has at least 40% moisture (at least as damp as a wrung-out sponge). If their skin dries out, they cannot breathe and will die.

Earthworms prefer a near-neutral soil pH.

Instead of teeth, earthworms have a gizzard like a chicken that grinds the soil and organic matter that they consume. They eat the soil microorganisms that live in and on the soil and organic matter.

Worm excrement is commonly called worm casts or castings. These soil clusters are glued together when excreted by the earthworm and are quite resistant to erosive forces. Their castings contain many more microorganisms than their food sources because their intestines inoculate the casts with microorganisms.

Earthworms become sexually mature when the familiar band (the clitellum) appears around their body, closer to their mouth. Each worm with a clitellum is capable of mating with other worms and producing cocoons that contain baby worms. Cocoons are lemon shaped and slightly and slightly smaller than a pencil eraser.

Benefits of Earthworms

Charles Darwin, known for his work with evolution of species wrote a paper on earthworms during his final years. In it he surmised that most all the fertile soil on earth must have passed through the gut of an earthworm. While not entirely accurate, earthworms do play an important role in soil and plant health.

Soil Fertility

Earthworms are part of a host of organisms that decompose organic matter in the soil. As earthworms digest the microorganisms and organic matter in soil, the form of nutrients is changed as materials pass through the earthworm's gut. Thus, worm casts are richer than the surrounding soil, containing nutrients changed into forms that are more available to plants. For example, one study found that in a sample of soil with 4% organic matter, worm casts contained 246 pounds of nitrogen per 1000 square feet while the surrounding soil contained 161 pounds of nitrogen per 1000 square feet (Source: ATTRA, Sustainable Soil Systems).

Soil Structure

The deep burrows of anecic earthworms create passages for air, water, and roots. Burrows provide easy avenues for the exchange of soil gases with the atmosphere. Clay soils with extensive earthworm burrows will allow water to infiltrate and percolate more readily than those without. Plants have the capacity to root deeper and the lower layers of soil can recharge with air more quickly. Air is an essential component of root development.

Anecic worms mix the soil as they create their burrows and build soil organic matter and humus as they drag litter into their burrows and excrete castings in the soil.

Endogeic worm burrows contribute to soil tilth, tying together many of the large pore spaces in the soil and increasing soil porosity.

The mucus from the skin of earthworm's aids in the formation of soil aggregates, which are integral components of the crumb of soil structure. Aggregates are also formed in castings.

Water-Holding Capacity

By increasing the organic matter content, soil porosity and aggregation, earthworms can greatly increase the water-holding capacity of soils.

How to Encourage Earthworm Activity

Earthworms will not go where it is too hot/cold or too dry/wet. Soil temperatures above 70ºF or below 40ºF will discourage earthworm activity. While soil temperature is hard to alter, moisture can be managed. When soil becomes waterlogged, oxygen is driven out of the large pore spaces. Without this free oxygen, earthworms cannot breathe. Conversely, when soil dries beyond half of field capacity, earthworm skin dries in the soil. Maintaining moisture levels that are ideal for optimum plant growth in a landscape or garden will also be ideal for earthworm activity.

Providing a food source in the form of organic matter is also important. Mulching grass clippings into the lawn, putting down a layer of organic mulch in beds, amending the soil with compost, and turning under a green manure are all excellent ways to feed earthworm populations.

Detrimental Practices to Earthworm Activity

- High rates of ammonium nitrate are harmful to earthworms.
- Tillage destroys permanent burrows and can cut and kill worms. Fall tillage can be especially destructive to earthworm populations. Deep and frequent tillage can reduce earthworm populations by as much as 90%.

- Earthworms are also hindered by salty conditions in the soil.
- Some chemicals have toxic effects on earthworm populations. [**Table 1**]

Table 1. Earthworm Population Reduction by Pesticides

Pesticide	Toxicity to Earthworms	Reduction
Sevin (carbaryl) insecticide	Severe	76-100%
Diazinon insecticide	Moderate	26-50%
2,4-D herbicide	Low	0-25%

Study from University of Kentucky Department of Entomology.

Transplanting Earthworms

To create worm populations in a soil without worms simply dig a large spade-full of soil from an area with visible worm numbers and bury this soil in the area where worms are needed.

Asian Jumping Worm

The Asian Jumping Worm, in the genus *Amynthas*, is an invasive worm making its way through the United States. These jumping worms are currently not in Colorado, but in nearby states and are very invasive. The Asian Jumping Worm is typically found in moist areas, like mud along a creek or river, and have been found in Eastern and Northwest states.

If you visit areas where Asian Jumping Worms are found, please note that they and can be transferred on footwear. The current recommendation is to wash footwear. Do not purchase Asian jumping worms for vermiculture, fishing or gardening. As with all purchases, make sure you know what you are purchasing and that you are not bringing a new issue into your garden and community.

Learn more from University of Nebraska Extension:
https://lancaster.unl.edu/pest/resources/asianworms.shtml.

Authors: Adrian Card, CSU Extension. Revised October 2015 by Susan Carter, CSU Extension. Reviewed September 2022 by Adrian Card, CSU Extension and Susan Carter, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #219

Soil Drainage

Outline:

Pore Space Controls Soil Drainage Characteristics

Pore space controls soil drainage characteristics. In other words, drainage problems often arise from lack of large-sized pores in the soil substrate.

In soils dominated by large pores (i.e., sandy soils), water moves rapidly. Soils that allow rapid leaching (water movement down through the soil profile) also pose environmental hazards because rain or irrigation water moving through the soil profile can transport water-soluble pollutants with it. Ground water pollution is a sensitive issue in coarse-textured sandy soils.

In comparison, soils dominated by small-sized pores (i.e., compacted soils and soils with greater than 20% clay content), water is slow to move or may not move at all. Soils easily saturate or become waterlogged.

Roots must have oxygen to survive and root activity shuts down in waterlogged soils. Plants growing in wet soils are typically shallow rooted. Many plants are prone to root rot in wet soils. Prolonged periods of waterlogged soil conditions lead to the decline or even death of most plants.

When water does not leach through the soil profile, salts left behind by surface evaporation can accumulate and create a white crust on the soil. This is frequently observed as a white deposit on low spots of pastures and fields. High soil salt content limits plant growth in some areas of Colorado.

Poor drainage is a common problem in many Colorado soils. In some areas, the upper layers of soil allow water infiltration only to have the water stopped as it reaches a less permeable subsurface soil layer.

A simple test to evaluate soil drainage is to dig a hole twelve inches deep and fill it with water. If the water fails to drain in thirty minutes, the soil has a drainage problem. If the hole fails to drain in twenty-four hours, waterlogged soils may affect plant growth.

Correcting Drainage Problems

Managing Soil Tilth

The term soil tilth refers to the soil's general suitability to support plant growth, or more specifically to support plant root growth. A soil with good tilth has large pore spaces for adequate air infiltration and water movement.

Attention to managing soil tilth plays a key role in soil drainage. On coarse-textured sandy soils, routine applications of organic matter increase the water holding capacity. On compacted and fine-textured clayey soils, application of organic matter forms aggregates of the fine textured clay particles, which create larger pore space, improving drainage.

French Drains

In some situations, a French drain facilitates water drainage. A French drain is a lined ditch-like trench that is filled with rock or gravel, typically with a pipe in the bottom. It catches water runoff and directs it away from structures that can be damaged. The rock should meet grade to prevent soil from covering the drain. The trench must slope at least 1-3% and flow to an outlet. [**Figure 1**]

Figure 1.
A French drain is a ditch-like trench filled with rock. Water must flow downhill to an outlet.

Surface Drainage and Runoff

To minimize surface runoff and soil erosion, sloping areas should be planted with perennial ground covers or turf. Mowed lawns or un-mowed naturalized grass areas make the best ground cover for slowing runoff. Some landscapes may be terraced to control runoff.

To improve surface drainage problems, first identify, and then correct, the contributing factors.

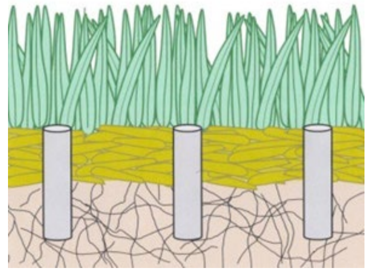
Irrigation – Many surface drainage problems arise from over-irrigation (too much and/or too often).

Compaction – Compaction is difficult to deal with; so, prevention is the key. Soils around new homes is typically compacted from construction traffic. Break up compacted layers by tilling, adding organic matter and planting ground cover. Adding organic matter and organic cover encourages earthworms and beneficial soil organisms, which creates larger pore spaces, improving drainage.

Organic mulches, like wood/bark chips, help manage compaction around trees and shrubs, perennials, small fruits, and garden paths.

Thatch in lawn – A heavy thatch layer in a lawn slows water infiltration. Improve by aerating the lawn, making enough passes so that plugs are at two-inch intervals. See lawn care information for additional details. [**Figure 2**]

Figure 2.
A heavy thatch layer slows water infiltration. Routine aeration may be needed on compacted clayey soil to help reduce thatch and open the soil to air and water.



Grading – Sometimes the grade may be deceiving. Make sure areas are properly graded so there are not low spots and all drainage heads in the right direction.

Standing water – It is common to find standing water in low spots. Fill in the low spot or install a French or underground drain with a gravity-flow outlet. Look at the irrigation schedule; is the area being over-watered? If so, or if irrigation is running off instead of soaking in, aerate and use multiple shorter irrigation cycles.

High water table – Some areas of Colorado have high water tables. The only solution may be to raise the soil level such as raised beds or berm gardening.

Impervious subsoil – In Colorado, we find many soil profiles with an impervious soil layer under the surface. This can be caused by many years of tillage at the same depth, also known as hardpan. Refer to the subsequent discussion on subsurface drainage.

Subsurface Drainage

Subsurface drainage problems are generally correctable only to the extent that large soil pore spaces can be increased to allow for better water movement. Use of soil drainage tiles are only effective to the extent that the soil will allow water to flow through it to the drain tile, and water in the drain tile can flow downhill to an outlet. It is more important to prevent poor drainage and compaction. This can be achieved through reducing traffic, managing soil load, and choosing appropriate equipment when working on soil.

To improve subsurface drainage problems, due to compaction, first identify, and then correct, the contributing factors.

Impervious/Compacted Subsoil Layer Underlain With Permeable Soil

- If less than two feet thick, rip or double dig when soil is dry enough to work.
- Irrigate to settle and do final grade when soil re-dries.
- If greater than two feet thick, bore holes through layer.
- Holes are typically four to six inches in diameter, at six-foot intervals.
- Fill with coarse sand or fine gravel.

Compacted/Impermeable Subsoil

- Increase soil depth through processes such as cultivation, ripping, double digging, or core aeration.
- Use of deep-rooted cover crops depending on depth of compaction layer.
- Select shallow-rooted and water-tolerant plants.

- These soils may have a salt problem.

Change in Soil Texture
A change in soil texture creates water movement problems called a soil textural interface. Even if the pores on the lower layer (such as large rocks in the bottom of a pot) are larger, the upper layer must saturate completely before water can move into the lower layer. This is a common problem when soils are added to a raised-bed box or applied as a top dressing. Cultivate to mix layers.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Susan Carter, CSU Extension. Reviewed September 2022 by Yvette Henson, CSU Extension and Cassey Anderson, CSU Extension.

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CMG GardenNotes #221

Soil Tests

Value of a Soil Test

In the fields of agronomic crops, greenhouse crops, and turf, soil testing is a key tool in crop management for commercial producers.

In the home garden or landscape setting, soil testing is valuable in establishing a baseline, or in tracking changes, in soil limitations related to pH, salt levels, and the need for fertilizers. A special lead test would be of interest to homeowners with lead-based paints on older homes.

In some cases, soil testing may not paint the full picture. For example, soil test results for nitrogen can have limited use for the home gardener because the nitrogen level constantly changes in response to soil organic matter additions, soil microorganism activity, temperature, moisture levels, leaching, and nitrogen consumption by plants and other soil life.

Interpreting soil tests for landscape plants is difficult, as research to obtain general standards for those plants is lacking. A soil test for a maple tree, a native plant, or a gardener's favorite peony, would be difficult to interpret based on standards used for general agronomic crops.

While a soil test provides information about a variety of characteristics important for plant health/growth, a standard soil test will not identify common garden problems related to over-watering, under-watering, poor soil drainage, soil compaction, diseases, insects, weed competition, environmental disorders, too much shade, poor varieties, or simple neglect.

Typical Test

A standard soil test typically includes the following:

- Texture (estimated by the hand – feel method).
- Organic matter (reported as a percent of the total dry soil weight).
    - An estimated half a pound of nitrogen per 1,000 square feet will be released (mineralized to nitrate) during the growing season for each one percent organic matter present. This is dependent on various characteristics, such as climatic and soil conditions.

- pH.
- Lime ($CaCO_3$).
    - In soils with “free lime,” sulfur will not effectively lower the pH.
- Soluble salts (reported in mmhos/cm or dS/m).
- Nutrients (reported in parts per million), not limited to:
    - Nitrate nitrogen.
    - Phosphorus.
    - Potassium.
    - Micronutrients such as copper, iron, manganese, and zinc.

Additional tests could be run for special needs like lead content, heavy metals, or sodium problems. For additional details on soil testing, refer to CSU Extension Fact Sheet #0.502, Soil Test Explanation.

Frequency

For a gardener, a soil test gives a useful baseline on soil salts, phosphorus, potassium, pH, and free lime content (or buffer index if acid).

In the neutral and alkaline soils of Colorado, repeat the test when changes are made to the crop being planted or to the soil (such as addition of larger quantities of manure, biosolids, or compost that may be high in salts), or approximately every one to three years to reestablish the baseline.

In other parts of the country where lime is routinely added to raise the pH on acid soils, a soil test may be needed annually.

Taking a Soil Sample

A soil sample may be taken at any time of year, although spring or fall sampling is usually the most convenient.

The results of a test are no better than the quality of the sample sent to the laboratory. The sample must be representative of the yard or garden being considered. Gardeners who try to shortcut the sampling procedure will not receive a reliable result.

Submit a sample for each area that receives different fertilizer and soil management treatments. For example, if the front and back lawn are fertilized and managed the same, the sample should include subsamples taken from both lawns and mixed together. Because garden areas are managed differently from lawns, the garden should be sampled separate from the lawn. Garden beds that receive differing amounts of fertilizers and soil amendments should be sampled separately from each other as well.

Samples are most easily collected using a soil tube or soil auger. A garden trowel, spade, bulb planter, or large knife also works. Discard any sod, surface vegetation or litter before sampling. Sampling depth is critical and varies for the type of test taken and for various labs. Follow sampling depth directions given by the laboratory. [**Table 1**]

Table 1. Example of Sampling Depth Requirements for Soil Tests

Crop	Sampling Depth
Garden (vegetable & flower)	0 through 6-8 inches
Lawns, new (prior to planting)	0 through 6-8 inches
Lawns, established	0 through 6-8 inches

Based on the CSU Soil Testing Laboratory.

Each sample should be a composite of sub-samples collected from randomly selected spots within the chosen area. Take five or more subsamples from a relatively small area in the home lawn, flower border, or vegetable garden. Take ten to fifteen subsamples for larger areas. [**Figure 1**]

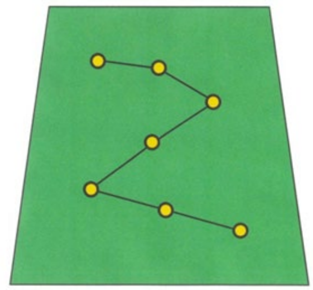

Figure 1.
A proper soil sample is a composite of five to fifteen sub samples.

Collect the subsamples in a clean plastic bucket, thoroughly mixing the subsamples together until you have a homogeneous sample. Do not oven-dry the sample.

Place about two cups of the soil mix into the sample bag or box. Label the sample container with an identifier (e.g., front lawn, vegetable garden, or flowerbed), your name, and sample depth. Keep a record of the area represented by each sample taken. Send the samples to a soil-testing laboratory, along with any forms required by that laboratory.

Climate and soil vary considerably in different parts of the country, so it is important to select a local laboratory that processes the alkaline calcareous soils of the mountain west. Future testing should be done with the same laboratory to make comparisons.

Soil tests are available from many local providers. For a list of laboratories, refer to CSU Extension Fact Sheet #0.520, Selecting an Analytical Laboratory available online at https://cmg.extension.colostate.edu/.

Soil Test Recommendations

In production agriculture, it is common for a grower or fertilizer dealer to split a sample and send it to different laboratories. Because individual laboratories do not necessarily use the same soil test procedures, their **availability indexes** (the reported available nutrients) can, and frequently do, differ.

Laboratories can also differ in the objectives behind their recommendations. For example, are maximum yields the primary objective? In this scenario, the recommendations will likely be for increased fertilizer application, which can mean increased costs, and higher potential for leaching of fertilizers into ground water. In another example, the crop's net return may be the primary objective, involve reducing production costs, (for instance, by reducing fertilizer use).

Plant needs and fertilizer practices may also impact recommendations. For example, before laying new sod add a single dose of fertilizer that is high in phosphorus, since phosphorous is important for the development of new roots. After establishment, the sod is maintained through annual additions of nitrogen fertilizer. Thus, context is critical in determining the appropriate recommendations (e.g., is a single or annual phosphorous application recommended?).

The recommendations resulting from a soil test need to be made by the laboratory doing the work, based on cropping information provided by the grower/gardener.

Home Soil Test Kits

Home soil test kits have questionable value. The accuracy of some tests is based on the pH of the soil being tested (e.g., a common phosphorous test is accurate only for soils with a pH less than 7.3). They may have questionable accuracy when testing the alkaline soils of the west. They also typically do not provide very precise metrics or any recommendations, so making decisions, such as determining fertilizer rates, based on home soil tests can be difficult.

The accuracy in home soil test procedures may, at best, give a ballpark reading but not precise accuracy. For example, the calibration on a home soil pH kit will tell the gardener that the soil has a pH level between 7 and 8. How close to 7 or 8 makes a huge difference for the growth of some plants. More precise measurement requires more expensive equipment.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Eric Hammond. Reviewed September 2022 by Hania Oleszak, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #222

Soil pH

Soil pH

Soil pH is a measurement of the acidity or alkalinity of a soil. On the pH scale, 7.0 is neutral, below 7.0 is acidic, and above 7.0 is basic (otherwise known as alkaline). A pH range of 6.8 to 7.2 is termed **near neutral**.

A soil's pH is a product of the factors which formed it. Primarily, it is a result of the parent material of the soil and of the climate. In Colorado, many of our soils are alkaline with a pH of 7.0 to 8.3. This is largely due to the high calcium carbonate content, known as **free lime**, that has accumulated in our soils through rock weathering and limited rainfall. In contrast, areas of the world with higher rainfall typically have acidic soils because the water leaches ions that contribute to alkalinity out of the soil profile. When soils contain an abundance of free lime, it is often impractical to lower the soil's pH by adding neutralizing acids because the excess free lime will buffer the effects of the acids. Soils with a pH of 8.3 or higher are typically also sodic soils, meaning that they have a very high sodium content.

The quality of irrigation water used can also influence soil pH. In some cases, irrigation water contains high levels of calcium carbonate which will further increase the soil pH. In other cases, irrigation water can promote a near neutral soil pH by leaching out ions that contribute to soil alkalinity. For example, some mountain soils and older gardens that have been irrigated and cultivated for many years have attained near neutral pH.

Soil pH is important to gardeners because it can affect the availability of plant nutrients and the soil ecology. In very acid or alkaline soils, some plant nutrients convert to forms that are more difficult for plants to absorb, which can result in nutrient deficiencies. Plants that have evolved under such soil conditions often develop mechanisms to deal with this issue. As a result, it's important to select plants that are adapted to your soil pH when possible.

Many gardening books list the preferred pH for common plants as 6.0 to 7.2. **Most common landscape plants can tolerate a wider range.** [**Table 1**] The exception is acid-loving plants, like blueberries, azaleas, and rhododendrons. Blue hydrangeas also require a pH lower than 5.0 to induce the blue flower color.

Table 1. Soil pH and Plant Growth

Soil Reaction	pH	Plant Growth
	>8.3	Too alkaline and sodic for most plants
	7.5	Iron availability becomes a problem in alkaline soils
Alkaline Soil	**7.2**	**6.8 to 7.2 is near neutral**
Neutral Soil	**7.0**	**6.0 to 7.5 is acceptable for most plants**
Acid Soil	6.8	
	6.0	
	5.5	Reduced soil microbial activity, especially bacteria
	<4.6	Too acid for most plants

Managing Alkaline Soils

To manage Colorado soils with moderate to high alkalinity (pH above 7.5), increase soil organic matter content by using organic amendments and mulches. Additionally, use proper irrigation to manage soil moisture. Overly wet or dry soils may amplify the issues created by high soil alkalinity.

In Colorado, a major problem with high pH is iron chlorosis. Our soils typically have an adequate supply of iron but, under alkaline conditions, the iron is present in a form that some plants are not able to access, leading to iron deficiencies.

Soils with a pH above 7.3 and/or with free lime cannot be adequately amended for acid-loving plants like blueberries, azaleas, and rhododendrons.

Gardeners may find a slight decrease in soil pH over many decades. This occurs as irrigation leaches out ions (calcium and magnesium) which contribute to higher pH. Many fertilizers also add acidity to soil and plant roots secrete weak acids into the soil which may contribute to a gradual pH change. The presence of free lime in a soil slows this gradual acidification.

Lowering the pH

Applications of elemental sulfur are often recommended to lower a soil's pH. This is effective in many parts of the country. **However, it is not effective in many Colorado soils due to their high levels of free lime.** In alkaline soils which contain free lime, drastically modifying the pH of the soil is impractical.

To test for free lime, place a heaping tablespoon of crumbled dry soil in a cup. Moisten it with vinegar. If the soil-vinegar mix bubbles, the soil has free lime. **In soils with free lime, a gardener will not be able to effectively lower the pH.**

In soils without free lime, the following products may help lower the pH.

> **Elemental sulfur** is one chemical that can be used to lower soil pH. The soil type, existing pH, and the desired pH are used to determine the amount of elemental sulfur needed. [**Table 2**] Incorporate sulfur to a depth of six inches. It may take several months to over a year for the sulfur to react with the soil, lowering the pH. Test soil pH again three to four months after initial application. If the soil pH is not in the desired range, reapply.

Table 2. Pounds of Sulfur Needed to Lower Soil pH[1]

Material	pH Change	Pounds per 100 Square Feet[2]
Sulfur	7.5 to 6.5	1.5
	8.0 to 6.5	3.5
	8.3 to 6.5	4.0

1. Effective only on soils without free lime - do the vinegar test.
2. Higher rates will be required in fine-textured, clayey soils and soils with a pH 7.3 and above.

Aluminum sulfate will lower pH, but it is not recommended as a soil acidifying amendment because of the potential of aluminum toxicity to plant roots.

Fertilizers – Use of **ammonium sulfate, ammonium nitrate or urea as nitrogen** fertilizer sources will also have a small effect on lowering soil pH in soils without free lime. For example, ammonium sulfate fertilizer, 21-0-0, at ten pounds per one thousand square feet (maximum rate for crop application) may lower the pH from 7.3 to 7.2. However, do not use these fertilizers at rates greater than those required to meet the nitrogen needs of the plants.

Raising the pH

In acidic soils, the pH can be raised by adding lime (calcium carbonate). The amount to add depends on the cation exchange capacity (nutrient-holding capacity) of the soil, which is based on the soil's clay content. Soil higher in clay will have a higher cation exchange capacity and will require more lime to raise the pH.

Lime is commonly sold as ground agricultural limestone. It varies in how finely it has been ground. The finer the grind, the more rapidly it will raise the pH. **Calcitic lime** mostly contains calcium carbonate (CaC03). **Dolomitic lime** contains both calcium carbonate and magnesium carbonate [MgCa(CO3)2]. On most soils, both are satisfactory. However, on sandy soils low in organic matter, dolomitic lime may supplement low magnesium levels. Low soil magnesium levels should be verified with a soil test prior to applying dolomitic lime as excess levels of magnesium can lead to calcium deficiencies in some vegetables.

A laboratory test called a **buffer index** measures the responsiveness of the soil to lime applications. The soil test will give recommendations on application rates based on the buffer index rather than just the pH. **Table 3** gives an estimated amount of lime to apply to raise a soil's pH.

Table 3. Limestone Application Rates to Raise Soil pH to Approximately 7.0 for Turf
Lime Application Rate (pound per 1,000 square feet)

Existing Soil pH	Sandy	Loamy	Clayey
5.5 to 6.0	20	25	35
5.0 to 5.5	30	40	50
3.4 to 5.0	40	55	80
3.5 to 4.5	50	70	80

- Lime application rates shown in this table are for dolomite, ground, and pelletized limestone and assume a soil organic matter level of approximately 2% or less. In soils with 4 to 5% organic matter, increase limestone application rates by 20%.
- Individual applications to turf should not exceed 50 pounds of limestone per 1,000 square feet.
- Avoid the use of hydrated or burned lime because it is hazardous to both humans and turf (can seriously burn skin and leaves). If hydrated lime is used, decrease application rates in the above table by 50% and apply no more than 10 pounds of hydrated or burned lime per 1000 square feet of turf.

Home pH Test Kits

In alkaline soils, home pH kits have questionable value. Inexpensive kits cannot be calibrated accurately enough to be meaningful when used on alkaline soils. Small changes in techniques, such as how much water is used and the pH of the water used in the sample, can change results. Most home soil test kits are designed for acid soils.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Revised October 2015 by Eric Hammond, CSU Extension. Reviewed February 2023 by Hania Oleszak, CSU Extension.

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MASTER GARDENER
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CMG GardenNotes #223

Iron Chlorosis of Woody Plants

Outline:

Symptoms

The term **chlorosis** means a general yellowing of leaves. Many factors contribute to chlorosis.

Iron chlorosis refers to a yellowing caused by an iron deficiency in the leaf tissues. The primary symptoms of iron deficiency are **interveinal chlorosis**, a general yellowing of leaves with veins remaining green. In severe cases, leaves may become pale yellow or whitish, but veins retain a greenish cast. Angular shaped brown spots may develop between veins, and leaf margins may scorch (become brown along the edge). [**Figure 1**]

Figure 1. Symptoms of iron chlorosis include yellowing of the leaf with veins remaining green.

Iron is necessary for the formation of chlorophyll, which is responsible for the green color in plants and necessary for photosynthesis (sugar production in plants). Any reduction in chlorophyll during the growing season reduces plant growth, vigor, and stress tolerance. Plants with reduced vigor from iron chlorosis are more prone to winter injury, and winter injury may aggravate an iron chlorosis problem. Weakened plants are also more susceptible to other diseases and insect infestations.

Iron is not very mobile within plants. Plants use their stores of iron in new leaves as they create them, so iron chlorosis shows first and more severely on the newer growth at branch tips. Leaves may be smaller than normal and may eventually curl, dry up, and fall. Fruits may be small with a bitter flavor. Mildly affected plants become unsightly and grow poorly. In severe cases individual limbs or the entire plant may die.

It is common for iron chlorosis to show on a single branch or on one side of a tree. This is particularly common for plant species with marginal winter hardiness following winter injury. Plant species and varieties vary in their susceptibility to iron deficiency.

On junipers, pines, and other evergreens, chlorosis usually develops as an overall yellowing of needles.

Similar Symptoms

Iron chlorosis symptoms can be confused with other problems. In the high pH soils of Colorado, a suspected iron chlorosis problem may be a combination of iron and manganese deficiencies. It is common for chlorotic trees to show a response to both iron and manganese treatments.

Zinc and manganese deficiencies result in similar leaf symptoms, but typically appear first on older, interior leaves. Iron chlorosis appears first on the younger or terminal leaves but may progress into older and lower leaves under severe conditions.

Nitrogen deficiency shows as a uniform yellowing of the entire leaf including the veins. It appears first in the older leaves, while iron chlorosis appears first in the newer growth.

Damage from soil sterilants (e.g., Pramitol, Atrazine, Simazine, Ureabor, and Diuron) used to prevent weeds results in similar symptoms. With these weed killers, the leaf tissue along the vein remains green. With iron chlorosis, just the vein itself remains green.

Natural aging of tissues may create similar symptoms in some plants. Root and trunk damage, some viruses, phytoplasmas, and vascular wilt diseases may cause similar leaf symptoms.

Causes and Complicating Factors

The factors leading to iron chlorosis are complex and not fully understood. Several chemical reactions govern iron availability and contribute to the complexity of iron chemistry in soils.

Many environmental factors also create or contribute to iron deficiency which need to be evaluated and alleviated to the extent possible. In many situations, attention to watering and soil conditions will satisfactorily correct minor iron chlorosis problems.

Calcareous Soils

Many Colorado soils are naturally high in lime (calcium carbonate and other calcium compounds) which raises the soil pH above 7.5. In these calcareous soils, iron chlorosis is common on susceptible plants.

Colorado soils are abundant in iron, as evidenced by the common “red rock” formations. In alkaline soils (pH above 7.0), iron is rapidly fixed through a chemical reaction into insoluble, solid forms that cannot be absorbed by plant roots. Such iron will be tied up indefinitely unless soil pH changes. Soil applications of iron alone are ineffective, as the applied iron will quickly be converted to these unavailable solid forms.

Over-Watering

Iron chlorosis is a common generic symptom of overwatering. Overly wet or dry soils predispose plants to iron chlorosis. It is more prevalent following wet springs, or when gardeners overwater in the spring. In western calcareous soils, iron chlorosis can be moderated by eliminating springtime overwatering.

Overly dry soils can also lead to nutrient deficiencies since many nutrients are absorbed in solution with water. Severe cases of iron chlorosis involving "acid-loving" plants may not be corrected through improved irrigation practices.

It is common for gardeners to allow sprinkler control settings to remain unchanged from the high summer water needs to the lower water needs of spring and fall. In this situation, the yard could receive as much as 40% more water than needed in the spring and fall. Such overwatering can contribute to iron chlorosis.

Soil Compaction

Soil compaction and other conditions that limit soil air infiltration (like surface crusting and use of plastic mulch) predispose plants to iron chlorosis by limiting effective rooting area and soil oxygen levels. Plants that have smaller root systems have less chance of "finding" available iron. These are key contributing factors in clayey soils. Using organic mulch (like wood or bark chips) helps prevent and reduce soil compaction. Avoid the use of plastic under rock mulch around landscape plants.

Trunk Girdling Roots

Iron chlorosis is a common early symptom of trunk girdling roots in trees. The primary cause of trunk girdling roots is planting trees too deep. Trunk girdling roots can lead to decline and death some twenty years after planting.

In tree planting standards, the top of the root ball should rise slightly above grade (e.g., one to two inches above grade) for newly planted trees. At least two structural roots should be in the top one to three inches of the root ball.

On established trees, the trunk-to-root flare should be noticeable. If the trunk goes straight into the ground, expect planting problems and possible development of trunk girdling roots over time. To check, perform a root collar excavation (carefully removing the soil around the base of tree) and examine the trunk/root flare.

Other Contributing Factors

Plant Competition – In susceptible plants, competition from adjacent lawns or flowers may aggravate iron chlorosis. Replace the grass under the tree canopy with wood/bark chip mulch.

Winter Injury – Trees with cankers and other winter injuries are prone to iron deficiency. (Winter bark injury on tree trunks is caused by winter drought.)

Soil Organic Matter – Organic matter is essential to successfully gardening in Colorado's soils. Ideally, the soil's organic content should be increased to 5%. However, excessive amounts may aggravate iron problems.

Excessive Salt Levels – High soil salt levels adversely affect uptake of water and nutrients, including iron. For details, refer to CMG GardenNotes #224, Saline Soils.

Soil Temperature and Light Intensity – Extreme soil temperatures and high light intensity may increase iron chlorosis problems. Use organic mulch to moderate soil temperature. Shading may help some crops.

Acid-Loving Plants – Acid loving plants are highly susceptible to iron chlorosis and not suited to Colorado's soil conditions. These include blueberries, azaleas, rhododendron, flowering dogwood, and heather.

Nutrients – Excessive levels (from over-application) of phosphate, manganese, copper, or zinc may aggravate iron chlorosis.

Plant Selection – Right Plant, Right Place

In Colorado's high pH soils, the best method to prevent iron chlorosis is to select plant species tolerant of high soil pH and less affected by low iron availability. Avoid planting the more susceptible species on soils prone to iron chlorosis problems [**Table 1**] (pH above 7.5, compacted, clayey, or wet soils).

Table 1. Examples of Plants with High Susceptibility to Iron Chlorosis

Amur maple	Dawn redwood	Northern red oak
Apple	Douglas fir	Peach
Arborvitae	Elm	Pear
Aspen	Flowering dogwoods	Pin oak
Azalea	Grape	Pine
Beech	Honeylocust	Raspberry
Birch	Horse chestnut	Red maple
Boxelder	Juniper	Rhododendron
Bumald spiraea	Linden	Silver maple
Cherry	London plane tree (sycamore)	Spruce
Cotoneaster	Magnolia	
Crabapple	Mountain ash	

Iron Additives

Unfortunately, there is no easy, inexpensive, or long-term correction for iron chlorosis. Treatments may be expensive and give disappointing results. Since plant and soil conditions vary, there is no single approach that is consistently best. Reducing springtime overwatering and soil compaction along with knowledge of other contributing factors can be effective in mitigating iron chlorosis in some situations.

The first step in using iron additives is to know the soil pH and free lime (calcium carbonate) content. These factors directly affect the success of any approach.

Determine soil pH by a soil test. When the pH is above 7.5, effective approaches are limited.

To check for free lime, place a rounded tablespoon of dry crumbled soil in a small cup and moisten the soil with vinegar. (The soil needs to be thoroughly moistened, but not swimming in vinegar.) If the soil-vinegar mix fizzes or bubbles, it has free lime. High lime content is typical of soils with a pH above 7.5. A standard approach in treating iron chlorosis is to lower the soil's pH, but **lowering the pH is impractical to impossible if the soil contains free lime.**

There are four general approaches to iron treatments: 1) lowering the soil's pH, 2) soil iron treatments, 3) foliar sprays, and 4) tree injections. Each has advantages, disadvantages, and gives variable results depending on plant species and soil conditions.

The two principal types of iron-containing products used for iron application include iron chelates and inorganic iron compounds (such as iron sulfate and ferrous sulfate). Several types of iron chelate are marketed under a variety of trade names. Soil pH dictates the type of chelate to use. Treatment with any iron product made mid-season may not produce satisfactory results.

Lowering Soil pH with Sulfur Products

A standard approach used in many products is to lower the soil pH. This approach merits consideration only if the soil does NOT have free lime (high calcium carbonate) and may show effectiveness over a period of years.

Due to the high pH and lime content of many Colorado soils, this approach seldom merits consideration. If irrigation water is hard, the calcium carbonate (lime) in the water will counter any acidifying effect. (As a side note, it has been observed that in some older gardens the pH has dropped below natural levels as the lime content is slowly leached out with decades of irrigation.)

The pH is lowered by soil applications of sulfur products. See the product labels for specific application rate. (Use of aluminum sulfate to lower soil pH is not recommended due to a potential for aluminum toxicity.) For details on lowering pH, refer to the CMG GardenNotes #222, Soil pH.

Soil Applications of Iron Sulfate Plus Sulfur

A simple approach is to apply a mixture of equal amounts of iron (ferrous) sulfate and sulfur to the soil. Examples of products include Copperas, Jirdon Super Iron Green, Hi-Yield Soil Acidifier Plus Micros, and Fertilome Soil Acidifier Plus Iron. Over a period of months to years, an improvement may be noticed. When it is effective, treatments may last up to three or four years, depending on soil conditions.

This approach merits consideration only on soils without free lime.

For trees, apply the mixture in holes around the dripline of the tree, as described for chelates (see below). Over time, the sulfur reacts to lower soil pH in a localized area. Broadcast applications, which dilute the material over a larger area, are less likely to give satisfactory results. Treat rows of berries or small shrubs by placing the mix in a furrow four inches deep and twelve to twenty-four inches away from the plant. See specific label directions for application rates. For the best results, treat the soil in spring.

Soil Applications of Iron Chelates

Soil application of iron chelates may give a rapid response if the correct chelate is used and other contributing factors are minimal. Applications after May 1st are less likely to show results. Treatments may last less than a season to two years.

Treat trees by placing the iron product in rings of holes in the ground beneath the dripline (outer reaches of the branches). Make holes one and a half to two inches in diameter, six inches deep and twelve inches apart in rings two feet apart. For smaller trees, make two to three rings of holes. For large trees, create four to five or more rings of holes which may need to extend beyond the drip line. No holes should be made within two and a half to four feet of the tree trunk on established trees. [**Figure 2**]

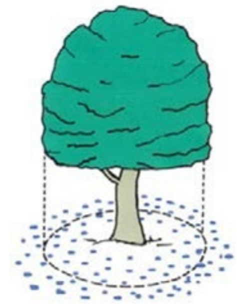

Figure 2. Place soil additive in a ring of holes around the drip line of the tree.

Drill holes in the soil with a power or hand auger, bulb planter, or small trowel, removing the soil core. Using a punch bar that makes holes by compacting the surrounding soil may be less effective. To avoid damage to shallow utility lines, call 811 before starting to have any buried lines marked. [**Figure 2**]

> **In soils with a pH above 7.5**, only special chelates formulated for a high pH are effective. Examples include EDDHMA (Miller's Ferriplus®) or EDDHA (Fe Sequestrene™ 138). Due to their higher cost, these products have limited availability. See product label for specific application rates.
>
> **In acid to slightly alkaline soils**, try other chelates like EDTA (Fe Sequestrene® 330, Fertilome Liquid Iron) and DTPA (Miller's Iron Chelate DP). They lose effectiveness quickly as the pH rises above 7.2 to 7.5. See product label for specific application rates.

Soil Applications of Iron Sucrate

Iron sucrate, a relatively new iron source, is manufactured from iron oxide and molasses to form an iron-containing organic complex with limited water solubility. It is less prone to staining due to its low solubility.

Iron sucrate merits consideration in high pH soils, and additional scientific evaluation is warranted for Colorado soils. It is marketed as Lilly Miller Iron Safe.

Foliar Sprays

Foliar sprays of iron sulfate or iron chelates may provide a quick response, often in a matter of days. However, the treatment is often spotty and only temporary. Multiple applications per season may be needed and the effects will not carry over into subsequent years.

Both types of products are equally effective, but iron chelates are more expensive. See product labels for specific application rates and instructions. With foliar applications, spray in the evening or on cloudy days when drying time is slower. A few drops of liquid dishwashing soap or commercial wetting agent will enhance sticking properties.

Foliar applications are not recommended due to application limitations. Complete coverage of all leaves is essential, individual leaves not treated may remain chlorotic. Coverage on large trees is impractical to impossible.

There is a small margin between an iron concentration that will green up the leaves and a concentration that will cause leaf burn. Leaf tissues are prone to turn black from an iron burn. Following an iron sulfate foliar treatment, it is common to see leaves that remain chlorotic, leaves that green up, and leaves with black burn spots on the same plant. Spray hitting the sidewalk, house, and other objects may leave a permanent rusty discoloration. Chelated iron sprays are inactivated by sunlight.

Trunk Injections

Professional arborists have trunk implant or injection methods available for treating iron chlorosis on large trees and they may last from one to five years. Refer to product information for application details. Injections may create pathways for decay organisms to enter a tree.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, PhD, USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015. Reviewed June 2023 by Tamla Blunt, PhD, CSU Extension.

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CMG GardenNotes #224

Saline Soils

Soluble Salts

Salts are mineral compounds made up of ions (+ charge cations and - charge anions). **Soluble salts** are the salt ions dissolved in the soil's water. Some salts such as gypsum (calcium sulfate) are less soluble. Limestone (calcium carbonate) dissolves only in acidic water. Table salt (sodium chloride) dissolves very easily and bonds with water molecules, making it hard for plants to absorb the water.

Salts are another soil factor limiting crop growth in some areas of Colorado, especially in the Western Colorado Valleys. The salty layer of the Grand Valley is Mancos shale that can have a depth up to 4,150'. Some salt ions, such as boron, chloride, and sodium, can be toxic to plants even when the overall salt content of a soil is not very high.

Impact of High Salt on Plant Growth

High salt levels can reduce water uptake by plants, restrict root growth, cause marginal burning of the foliage, inhibit flowering, limit seed germination, and reduce fruit and vegetable yields. Irregular bare spots in gardens and uneven crop growth suggest salinity problems. Crop yields may be reduced as much as 25% without easily visible damage to plants. Salt injury generally is more severe during periods of hot dry weather, when water use is high.

Sensitivity to soluble salts differs among plant species/cultivars and is dependent on their state of growth. Seed germination and seedling growth are more sensitive to salt stress than mature plants. [**Table 1**]

Salt Burn on bean leaf from high salts in compost.

Table 1. Relative Salt Tolerance of Cultivated Plants

Non-tolerant 0-2 dS/m	**Slightly Tolerant** 2-4 dS/m	**Moderately Tolerant** 4-8 dS/m	**Tolerant** 8-16 dS/m
begonia	apple	beet	arborvitae
carrot	cabbage	black locust	asparagus
cotoneaster	celery	boxwood	juniper
green bean	cucumber	broccoli	Russian olive
onion	grape	chrysanthemum	Swiss chard
pea	forsythia	creeping bentgrass	
radish	Kentucky bluegrass	geranium	
raspberry	lettuce	marigold	
red pine	linden	muskmelon	
rose	Norway maple	perennial ryegrass	
strawberry	pepper	red oak	
sugar maple	potato	spinach	
viburnum	red fescue	squash	
white pine	red maple	tomato	
	snapdragon	white ash	
	sweet corn	white oak	
		zinnia	

Note: dS/m is the unit used to measure salt content. It measures the electrical conductivity of the soil. dS/m = mmhos/cm.

Factors Contributing to Salt Problems

Drainage

A common sign of salt problems is the accumulation of salts at the soil surface due to limited percolation in compacted and/or clayey soils. Soluble salts move with the soil water. Deep percolation of water down through the soil profile moves salt out of the rooting zone. Surface evaporation concentrates the salts at the soil surface. Salt deposits can sometimes be seen as a white crust on the soil surface. As you drive around Colorado, it is common to see these soils with the white salt accumulation in low spots of fields and natural areas.

In some areas, salt naturally accumulates due to limited rainfall to leach the salt out. Salt levels drop when the soil undergoes irrigation. In other areas, salts may build-up when poor soil drainage prevents precipitation and irrigation water from leaching the salt down through the soil profile. In this case, corrective measures are limited to improvements in soil drainage.

Soil Amendments

Manure, biosolids, and compost made with manure or biosolids may be high in salt. When using manure or compost made with manure, routinely monitor salt levels. For more information, see section on Adding Soil Amendments, page 4.

Excessive/Unnecessary Fertilizer Applications

Unwarranted application of fertilizers (such as phosphate or potash) increases soil salt levels. On soils marginally high in salts, potash fertilizers should be avoided unless a potassium deficiency is identified by soil tests. Over-fertilization also has other environmental impacts.

Placing fertilizer and salty soil amendments too close to seeds or plant roots creates a salt burn of the tender roots. Germination failure or seedling injury can result.

De-Icing Salts

The use of **de-icing salts** on streets and sidewalks frequently results in high salt levels in adjacent soils. Along roads, salt injury has become a major concern. Highway salts may reach plants in two ways: movement to soil and uptake by plant roots, or movement onto plant stems and foliage through the air as vehicle “splash-back.” Salts deposited on both soil and foliage have high potential to cause plant injury. Highway salts in road-melt runoff is another concern for plants and the wider environment.

Pet Urine

Damage by pet urine, which contains alkaline salts and nitrogen, is also salt problem. Water moves by osmotic pressure from the roots to the high salt concentration in the soil, dehydrating and killing roots. Train your pet to eliminate in a plant free zone or follow other salt management methods below.

Measuring Soil Salt Levels

Bean plants are rather salt sensitive and can be used to help assess salt problems. In a garden, if beans are doing well, soluble salts are not a problem. If the beans are doing poorly, consider salts as a possibility. Beans, tomatoes, and other easily germinated seeds can be used in a “pot test” on a windowsill to live assay the salt content of a soil. Assess plants’ performance considering **Table 1**.

The amount of salt in a soil can be quantified only by a soil test. A soil test for soluble salts can be useful when investigating the cause of poor plant growth, determining the suitability of a new planting site, or monitoring the quality of fill soil or soil amendments for use on a landscape area.

Soil tests for soluble salts are based on electrical conductivity. Pure water is a very poor conductor of electric current, whereas water containing dissolved salts conducts current approximately in proportion to the amount of salt present. Thus, measurement of the electrical conductivity, (**ECe**), of a soil extract gives an indication of the total soluble salt concentration in the soil. The ECe is measured in deciSiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm). 1 dS/m = 1 mmhos/cm. [**Table 2**]

Table 2. Soluble Salt Test Values and Relative Sensitivity Levels of Plants

Electrical Conductivity[1] (dS/m)	Salinity Level	Effect on Plant Growth
0 to 2	non-saline	none
2.1 to 4	very slight saline	sensitive plants are inhibited
4.1 to 8	moderately-saline	many plants are inhibited
8.1 to 16	strongly-saline	most cultivated plants are inhibited
over 16	Very strongly-saline	few plants are tolerant

[1] Saturated paste extract

Managing Soil Salts

Leaching Salts

Leaching is the only practical way of removing excess salts. This is effective only to the extent that water moves down through the soil profile and beneath the root zone (drainage must be good). The amount of salts removed depends on the quantity and quality of water leached through the soil profile during a single irrigation period. Water should be low in salts (high quality) and must not run off the surface. It should be applied slowly so amounts do not

exceed the ability of the soil to take in water (infiltration rate). If you see pets urinate on a plant, rinse, and flush with water within 8 hours.
The following amounts of water applied in a single, continuous irrigation will dissolve and decrease soil salts by these fractional amounts:

- 6 inches of water will leach about 1/2 the salt.
- 12 inches of water will leach about 4/5 of the salt.
- 24 inches of water will leach about 9/10 of the salt.

Salty soils are not reclaimable when the soil's clay content, compaction, or hardpan prevents leaching.

Adding Soil Amendments

Because manure, biosolids, and compost made from manure or biosolids may be high in salts, do not add more than 1 inch per season without a soil test to evaluate salt levels. An amendment with up to 10 dS/m total salts is acceptable if mixed through the upper six to eight inches of a low-salt soil (less than 1 dS/m). Amendments with a salt content greater than 10 dS/m are questionable. Avoid these soil amendments in soils that are already high in salts (above 3 dS/m) and when growing salt sensitive plants.

Note: Because soil amendments are not regulated in Colorado, do not assume that products sold in bags or by bulk are necessarily low in salt content and good for the garden's soil. Many commercially available sources of manure, biosolids, and compost made with manure or biosolids have excessively high levels of salt. Some companies do test, so ask if they have recent salt levels of the amendment.

On marginally salty soils, concentrate on gradually improving the soil organic content and activity of soil microorganisms and earthworms. Do not exceed recommended rates per application as large quantities of organic matter can hold salts next to plant roots and cause injury. Organic amendments applied over time improve soil tilth, which then will improve the potential for effective leaching as well as plant growth.

Other Management Techniques

Plants grown on salty soils are less tolerant of dry soil conditions because high salt levels make it difficult for plants to uptake water. Plants will require more frequent irrigation, with reduced amounts of water.

Within pedestrian and vehicle safety limits, avoid the use of de-icing salts. Consider the use of sand or other abrasive materials for use on slick sidewalks and pavement. Where de-icing salts are routinely used, expect to find salt problems in adjacent soils and drainage swales where the snowmelt runs. Because soil salt levels from de-icing salts easily rise above the tolerance of even the most salt- tolerant plants, a rock mulch area without plants may be a better landscape design solution in salt use areas.

For additional details on soil salt issues, refer to the following CSU Extension Fact Sheets:
- #7.227, Growing Turf on Salt-Affected Sites.
- #0.503, Managing Saline Soils.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Susan Carter, CSU Extension. Reviewed August 2022 by Sarah Schweig, CSU Extension.

CMG GardenNotes #231

Plant Nutrition

Outline:

Nutrition and Fertilization

Plant nutrition refers to the chemical elements required for plant growth and reproduction. Most plants require at least sixteen different elements. Those that are used in greater amounts (Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulfur) are known as ***macronutrients***; those used in smaller amounts as ***micronutrients*** (Iron, Manganese, Zinc, Copper, Boron, Molybdenum, Chlorine, Nickel, and Cobalt). Both macro- and micro-nutrients are essential to plant growth; the prefixes refer to *amount required* rather than importance.

The term ***fertilization*** refers to the application of plant nutrients to supplement the nutrients naturally occurring in the soil. Nutrients may be applied as synthetic fertilizers, organic fertilizers, and/or as a component of other soil amendments, e.g., compost. Organic fertilizers and soil amendments are typically lower in plant-available nutrient content than their synthetic counterparts, i.e., more is required for the same nutritional benefit. Fertilizers are standardized and labeled with their nutritional content; soil amendments are not.

Adequate soil fertility is only one of the many soil-related factors affecting plant growth. Fertilizers will increase desirable plant growth only if the plant is deficient in the nutrient(s) applied and other growth factors are also not significantly limiting. **Fertilization will not compensate for poor soil preparation, the lack of water, weed competition, or other non-nutrient growth limiting factors!** Fertilization will not enhance desired growth if the nutrients applied are not deficient.

Plants obtain the macronutrients carbon, hydrogen, and oxygen from the air and water. The remaining plant nutrients must be absorbed as ionic forms from the soil. Typically, these ions are made available to the plant by the activity of soil microbes, though a few are provided by chemical reactions not requiring mediation by other organisms. A plant cannot “tell” if applied nutrients come from a manufactured fertilizer or a natural source. Soil microorganisms must break down organic soil amendments, organic fertilizers, and many manufactured fertilizers before the nutrients become usable by plants.

From a nutritional perspective, the primary difference between synthetic and organic fertilizers or soil amendments is the concentration of nutrients and the speed at which they become available for plant use.

A non-nutritional benefit of certain organic fertilizers and soil amendments includes improved soil tilth (suitability of the soil to support plant growth). This should not be confused with fertilization, a distinctly different soil management objective.

Plant Nutrients

Because nitrogen, phosphorus, and potassium are used in the largest amounts by plants, they are often the most supplemented in the form of fertilizers, particularly in agriculture or intensive growing. [**Table 1**]

Micronutrients are needed in amounts typically available in most soils and are only supplemented in situations where soil chemistry particular to a place renders them less available, or in soilless growing systems like containers or hydroponics. [**Table 1**]

Table 1. Essential Plant Nutrients

Nutrient, Chemical Abbreviation	**Ions Absorbed by Plants**
Macronutrients	
Carbon, C	CO_2
Hydrogen, H	H_2O
Oxygen, O	O_2
Nitrogen, N	NO_3^-, NH_4^+
Phosphorus, P	$H_2PO_4^-$, HPO_4^{-2}
Potassium, K	K^+
Calcium, Ca	Ca^{2+}
Magnesium, Mg	Mg^{2+}
Sulfur, S	SO_4^{-2}
Micronutrients	
Boron, B	H_3BO_3; $B(OH)_4^-$
Chlorine, Cl	Cl^-
Cobalt, Co	Co^{+2}
Copper, Cu	Cu^{+2}
Iron, Fe	Fe^{+2}, Fe^{+3}
Manganese, Mn	Mn^{+2}
Molybdenum, Mo	MoO_4^{-2}
Zinc, Zn	Zn^{+2}

Roots take up nutrients as *ions* dissolved in the soil's water. The ions may be positively charged (***cations***) or negatively charged (***anions***). The nutrient ion soup in the soil water is in a constant state of flux as the variety of ions dissolve into and precipitate out of solution.

Clay particles and organic matter in the soil are negatively charged, attracting the positively charged cations (like ammonium, NH_4^+, and potassium, K^+) and making the cations resistant to leaching.

The ***Cation Exchange Capacity, CEC***, is a measurement of the soil's capacity to hold cation nutrients. More precisely, it is a measurement of the capacity of the negatively charged clay and organic matter to attract and hold positively charged cations. CEC is useful in comparing the potential for different soils to hold and supply nutrients for plant growth.

Negatively charged anions (like nitrate, NO_3^-) are prone to leaching from soil, quickly becoming unavailable to plants. They can become a water pollution problem.

Colorado Soils and Plant Nutritional Needs

While any particular soil could have a wide range of mineral concentrations and potential deficiencies for any given crop, a few more commonly cause problems for gardeners in much of the state.

Nitrogen

Nitrogen is the one nutrient most often limiting plant growth. The need for nitrogen varies from plant to plant. For example, tomatoes and vine crops (cucumbers, squash, and melons) develop excessive vine growth at the expense of fruiting with excess nitrogen. Potatoes, corn and cole crops (cabbage, broccoli, and cauliflower) are heavy feeders and benefit from high soil nitrogen levels. Bluegrass turf and many annuals also benefit from routine nitrogen applications. Trees and shrubs have a low need for nitrogen compared to vegetables and annuals, and many drought-tolerant plants are not limited by nitrogen in most cases. Plants growing in Colorado soils benefit from nitrogen fertilization of the right amount and frequency to meet plant needs. General symptoms of nitrogen deficiency are shown in **Figure 1**.

Figure 1. Symptoms of Nitrogen Deficiency

Leaves
- Uniform yellowish green.
- More pronounced in older leaves.
- Small, thin leaves.
- Fewer leaflets.
- High fall color.
- Early leaf drop.

Shoots
- Short, small diameter.
- May be reddish or reddish brown.

Soil tests have limited value in indicating nitrogen needs for a home garden or lawn because the nitrogen levels are constantly changing due to microbial activity, plant uptake, and changes in temperature and water. Soil tests for nitrogen need to be repeated at regular intervals through the growing season to be of use.

Plants can absorb nitrogen in its three ionic forms: **ammonium** (NH_4^+), **nitrite** (NO_2^-), and **nitrate** (NO_3^-). Ammonium is generated when microbes break down organic matter in the soil. Being positively charged, ammonium is attracted to the negatively charged soil particles and thus is resistant to leaching (movement down through the soil profile). Because microbial activity is closely tied to soil conditions, the temperature, moisture, pH, and soil oxygen can all have significant effects on soil nitrogen availability. Other soil microorganisms quickly convert ammonium to nitrate in well oxygenated soils. Nitrite and nitrate, being negatively charged, readily leach below the root zone. Nitrite is toxic to plants but extremely short-lived, usually being quickly further oxidized to nitrate, so is not absorbed by plants in most cases. Most plant nitrogen is absorbed as nitrate. Nitrate either quickly is absorbed by plant roots or is leached from the soil profile, so it is rarely found in soil tests of the root zone. Prevent water pollution by avoiding over-fertilization with nitrogen. Certain plants (legumes) develop mutualistic relationships with nitrogen-fixing bacteria and can therefore access elemental nitrogen (N_2) directly from the atmosphere.

Soil microorganisms release nitrogen tied up in organic matter over a period of time. Release rates from compost are very slow (years). The need for nitrogen fertilizer is based on the organic matter content of the soil. [**Table 2**]

Table 2. Need for Nitrogen Fertilizer Based on Soil Organic Content

Soil Organic Content	Routine Application Rate For Gardens
1%	2 pounds actual N / 1000 square feet
2-3%	1-pound actual N / 1000 square feet
4-5%	0

Iron

Most of the iron in soil is in the form of stable mineral compounds. At high pH, iron oxides (rusts) are resistant to entering the soil water solution. Only at lower pH can iron be reduced to a form that can be absorbed by plants. For every unit of increase in pH, the solubility of iron decreases by a factor of 1,000. Many soils in Colorado have high pH, making some plants grown in them susceptible to iron chlorosis. ***Iron chlorosis*** refers to a yellowing of leaves caused by an iron deficiency in the leaf tissues. Primary symptoms include ***interveinal chlorosis*** (yellowing of leaves with veins remaining green). Because iron is not readily moved within plants once incorporated, symptoms appear on younger leaves and on new growth. In severe cases, leaves may become pale yellow or whitish, while veins retain a greenish tint. Angular brown spots may develop between veins and the leaf margins may ***scorch*** (become brown along the edge). Symptoms may show on a portion or on the entire plant. General symptoms of iron chlorosis are shown in **Figure 2**.

Figure 2. Symptoms of Iron Chlorosis

Leaves
- General yellowing of leaf with veins remaining green.
- More pronounced in younger leaves and new growth.
- Angular brown spots and marginal scorch.
- Smaller.
- Curl, dry up, and fall early.

Branches
- May show on a single branch or the entire plant.

In western, high pH soils, iron is not deficient in an absolute sense, rather, it is unavailable for plant uptake due to the soil's high pH. At high pH, iron is quickly oxidized into rust compounds. Plant-available iron is the result of microbial activity generating local supplies of reduced iron (that is, not oxidized into rusts) in the soil profile. In addition to high pH, iron chlorosis can be exacerbated by conditions that reduce soil microbial activity, including the following:

- **Cool, wet soils in spring**. Attention to irrigation management can help correct iron chlorosis.
- **Soil compaction** and low soil oxygen (which limit microbial activity).

Furthermore, iron chlorosis can be a symptom of physical damage to trees and shrubs, including trunk-girdling roots and bark injury associated with winter sunburn.

Attention to these contributing factors can solve a chlorosis issue without the need for adding iron products.

Iron fertilizers typically take the form of ***chelated*** (KEY-lated) ***iron***; iron that is part of a soluble complex of organic molecules. Not all chelation products are effective at high soil pH; in soils with a pH above 7, as in much of Colorado, only the product abbreviated EDDHA is capable of supplying iron to plants. Many plants, particularly those native to the arid regions of the western USA, are naturally able to extract iron from high pH soils and rarely display iron chlorosis.

Phosphorus

Phosphorus, **P**, is a primary nutrient in plant growth. ***Phosphate***, P_2O_5, is an ionic compound containing two atoms of phosphorus and five atoms of oxygen. The *phosphorus* content of fertilizer is measured in percent *phosphate*.

Phosphorus may be present in high concentrations in soils; however, it may not be in a plant available form. Deficiencies are most likely to occur in new gardens where the organic matter content is low, and the soil has a high pH (7.8 to 8.3). A soil test is the best method to determine the need for phosphorus fertilizers.

Phosphorus deficiency is difficult to diagnose because other growth factors will give similar symptoms. General symptoms include sparse, green to dark green leaves. Veins, petioles, and lower leaf surface may be reddish, dull bronze, or purple, especially when young. Phosphorus deficiency may be observed on roses in the early spring when soils are cold, but the condition corrects itself as soils warm.

Excessive phosphorus fertilizer can aggravate iron and zinc deficiencies, and increase the soil salt content. Many home gardener soils are significantly over fertilized with phosphates, aggravating soil salts and iron chlorosis. Typically, the over fertilization results from over application of compost.

Potassium

Potassium*, K**, is a primary nutrient in plant growth. The word ***potash, refers to various mined or manufactured potassium salts, including potassium chloride and potassium sulfate. The potassium content of fertilizer is measured in percent potash.

Potassium levels are naturally adequate and even high in most Colorado soils. Unlike nitrogen and phosphorus, which are usually found in soils in organic compounds, potassium is usually in minerals or mineral lattices and can therefore still be largely unavailable to plants, even if absolute potassium levels are high. Deficiencies more commonly occur in sandy soils low in organic matter. Organic matter and clay particles, with their many negatively charged binding sites, provide a reservoir of potassium that is available to plants.

A soil test is the best method to determine the need for potassium fertilizers.

Potassium deficiency is difficult to diagnose because other growth factors, including nitrogen deficiency, will cause similar symptoms. General symptoms include marginal and interveinal chlorosis (yellowing), followed by scorching that moves inward. Older leaves are affected first, because potassium is highly mobile within plants. Leaves may crinkle and roll upward. Shoots may show short, bushy, zigzag growth, with dieback late in the season.

Excessive potassium fertilizer can aggravate soil salt levels. Many home garden soils are over fertilized with potash, leading to salt problems.

Zinc

Zinc concentrations in the soil are naturally quite low, and particularly low in soils with high pH and that contain calcium carbonates.

Sweet corn, beans, and potatoes are the most likely vegetables to be affected by zinc deficiency. Symptoms include a general stunting of the plant due to shortening of internodes (stem length between leaves). Leaves on beans typically have a crinkled appearance and may become yellow or brown. On young corn, symptoms include a broad band of white-to-translucent tissue on both sides of the leaf midrib starting near the base of the leaf, but not extending to the tip.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised October 2015 by Dan Goldhamer, CSU Extension. Reviewed August 2023 by John Murgel, CSU Extension.

Reviewed August 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #232

Understanding Fertilizers

Outline:

Fertility is only part of the soil management process. Colorado soils are naturally low in organic matter. To maximize productivity, our soils also need routine applications of organic matter to improve soil tilth. For flower and vegetable gardens, it is desirable to raise the soil organic content, over time, to 4-5%.

Manufactured fertilizers are popular with gardeners because they are readily available, inexpensive, easy to apply, and generally provide a quick release of nutrients for plant growth. Application rates depend on the nutrient need of the soil and the percentage of nutrients in the specific fertilizer. **In products containing multiple nutrients, the application rate is always based on the nitrogen content.**

Fertilizer or Soil Amendment?

By legal definition, the term **fertilizer** refers to a soil amendment that guarantees the minimum percentages of nutrients (at least the minimum percentage of nitrogen, phosphate, and potash).

An **organic fertilizer** refers to a soil amendment derived from natural sources that guarantees, at least, the minimum percentages of nitrogen, phosphate, and potash. Examples include plant and animal by-products, rock powders, seaweed, inoculants, and conditioners. These are often available at garden centers and through horticultural supply companies.

These should not be confused with substances approved for use with the **USDA National Organic Program (NOP).** The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute, https://www.omri.org/, and the Washington Department of Agriculture (WSDA), https://agr.wa.gov/, review and approve brand name products made with ingredients from the "national list" for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances.

Many of the organic fertilizers listed here will meet NOP standards based on the National List. Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

The term **soil amendment** refers to any material mixed into a soil. **Mulch** refers to a material placed on the soil surface. In Colorado, soil amendments contain no legal claims about nutrient content or other helpful or harmful effects they will have on the soil and plant growth. In Colorado, the term **compost** is also unregulated, and could refer to any soil amendment regardless of active microorganism activity.

Many gardeners apply organic soil amendments, such as compost or manure, which most often do not meet the legal requirements as a "fertilizer" but add small amounts of nutrients.

What is in a Fertilizer?

Analysis or Grade

By law, all products sold as fertilizer require uniform labeling guaranteeing the minimum percentage of nutrients. The three-number combination (fertilizer **grade** or **analysis**) on the product identifies percentages of nitrogen, N, phosphate, P_2O_5, and potash K_2O, respectively. For example, a 20-10-5 fertilizer contains 20% nitrogen, 10% phosphate, and 5% potash.

Note: **Phosphorus, P**, is a primary nutrient in plant growth. The word **phosphate**, P_2O_5, refers to the ionic compound containing two atoms of phosphorus with five atoms of oxygen. The phosphorus content of fertilizers is measured in percent phosphate.

Note: **Potassium, K**, is a primary nutrient in plant growth. The word **potash**, K_2O, refers to the ionic compound containing two atoms of potassium with one atom of oxygen. The potassium content of fertilizers is measured in percent potash.

The product may also identify other nutrients, such as sulfur, iron, and zinc, if the manufacturer wants to guarantee the amount. This may be done by placing a fourth number on the product label and identifying what nutrient was added in the ingredients.

Ratio

Fertilizer **ratio** indicates a comparative proportion of nitrogen to phosphate to potash. For example, a 15-10-5 fertilizer has a ratio of 3-2-1, and an 8-12-4 fertilizer has a ratio of 2-3-1. **Fertilizer recommendations from a soil test are given in ratios.**

When shopping for a fertilizer, select a product with a ratio somewhat similar to what is desired. For example, if a soil test recommended a 2-1-0 ratio, the ideal fertilizer would be something like 8-4-0, 10-5-0, or 20-10-0. However, if you cannot find that exact fertilizer, an 8-4-2 would be similar. If a garden soil test calls for a 1-0-0 ratio, a 21-0-0 or 24-2-2 fertilizer would be similar.

Formulation

The **formulation** tells what specific kinds of fertilizer are in the product. **Table 1** gives examples of manufactured fertilizers that could be mixed to derive any specific analysis, ratio, or brand name.

Table 1. Examples of Manufactured Fertilizers

Product	N%	P_2O_5%	K_2O%
Ammonium nitrate	34	0	0
Ammonium sulfate	21	0	0
Urea	48	0	0
Ammoniated super-phosphate	3-6	48-53	0
Di-ammonium phosphate	11	48	0
Mono-ammonium phosphate	11	48	0
Super-phosphate	0	18-50	0
Triple super phosphate	0	46	0
Potassium chloride	0	0	60
Potassium nitrate	13	0	44
Potassium sulfate	0	0	50
Potassium-magnesium sulfate	0	0	22

What else is in the fertilizer? In a manufactured fertilizer, the grade does not add up to 100% because the fertilizer also contains other elements like carbon, hydrogen, oxygen, sulfur, iron, zinc, etc. For example, ammonium nitrate, NH_4^+ NO_3, has a grade of 34-0-0 with 34% of the content from nitrogen and 66% from hydrogen and oxygen. Ammonium sulfate, NH_4^+ SO_2^- , has a grade of 21-0-0 with 21% from the nitrogen and 79% from the hydrogen, sulfur, and oxygen.

Time release or **slow-release** fertilizers contain coatings or are otherwise formulated to release the nutrients over a period of time as water, heat, and/or microorganisms break down the material. [**Table 2**]

Table 2. Examples of Quickly and Slowly Available Nitrogen

Quickly available nitrogen • Lasts 4-6 weeks	Ammonium sulfate Ammonium nitrate Calcium nitrate Potassium nitrate Urea
Slowly available nitrogen • Available over weeks to months • Regulated by solubility or microorganism activity	Resin-coated urea Sulfur-coated urea Isobutylidene diurea (IBDU) Methylene urea Urea formaldehyde Manure Poultry wastes Blood meal

In an "organic" type fertilizer, the base is decomposed or processed plant and/or animal by-products. For example, fish emulsion is ground and processed non-edible fish or fish scraps. Its nutrient content would be around 8-4-2, with 8% from nitrogen, 4% from phosphate, and 2% from potash.

Some manufactured and "organic" fertilizers contain fillers, which are used to prevent caking, control dust, derive the desired grade, or to facilitate ease of application.

Complete fertilizer is a term used to identify fertilizers that contain nitrogen, phosphorus, and potassium. In the national home garden trade, most fertilizers are complete. However, in Colorado many gardens do not need phosphorus or potassium. It is advisable to avoid heavy applications of phosphate and potash when unneeded as they contribute to soil salts.

Nitrogen Applications

Nitrogen is the nutrient needed in largest quantities as a fertilizer. Nitrogen is annually applied by manufactured fertilizer, organic fertilizers, and/or organic soil amendments. **Application rates are critical, because too much or too little directly affects crop growth.**

Application rate is based on the soil organic content. As the organic content increases, nitrogen will be slowly mineralized (released) by the activity of soil microorganisms. Standard application rates for gardens are given in **Table 3**.

Nitrogen fertilizer can be broadcast and watered in or broadcast and tilled into the top few inches of soil. It can be banded 3-4 inches to the side of the seed row. Do not place the fertilizer in the seed row or root injury may occur.

For additional information on fertilizers refer to the CMG GardenNotes #234*,* Organic Fertilizers, and GN#711*,* Vegetable Gardens: Soil Management and Fertilization.

Table 3. Nitrogen Fertilizer Application Rates for Home Gardens

	Soil Organic Content		
	Typical garden soil low in organic matter (0-1% organic matter)	Moderate level of organic matter (2-3% organic matter)	High level of organic matter (4-5% organic matter)
Nitrogen needed	**0.2 lb. actual N per 100 square feet**	**0.1 lb actual N per 100 square feet**	**0**
Fertilizer to apply			
Ammonium sulfate 21-0-0	1 lb. fertilizer per 100 square feet approximately 2 cups	0.5 lb. fertilizer per 100 square feet approximately 1 cup	0
OR			
Ammonium nitrate 34-0-0	0.6 lb. fertilizer per 100 sq. ft. approximately 1 1/3 cups	0.3 lb. fertilizer per 100 sq. ft approximately 2/3 cup	0
OR			
Urea, 45-0-0	0.4 lb. fertilizer per 100 sq. ft. approximately 1 cup	0.2 lb. fertilizer per 100 sq. ft approximately ½ cup	0

Phosphate and Potash Applications

A soil test is the best method to determine the need for phosphate and potash. When a fertilizer contains a combination of nitrogen with phosphate and/or potash, the application rate is always based on the nitrogen percentage, because nitrogen levels are most critical to plant growth. Phosphate and potash fertilizers are best applied in the spring or fall when they can be tilled into the soil.

Phosphorus

Phosphorus may be present in high concentrations; however, it may not be in a plant available form. With annual applications of compost or manure, phosphorus levels will likely be adequate. Deficiencies are most likely to occur in new gardens where the organic matter content is low and in soils with a high pH (7.8 to 8.3).

Excessive phosphorus fertilizer can aggravate iron, zinc deficiencies, and increase soil salt content.

Where phosphate levels are believed to be low, the standard application rate without a soil test is ¼ to 1 pound triple super phosphate (0-46-0) or ammonium phosphate (18-46-0) per 100 square feet.

When a phosphate fertilizer is applied to a soil, the phosphorus is quickly immobilized in the soil profile. It typically moves only about an inch. Therefore, it needs to be tilled into the rooting zone to be most effective.

Phosphorus and Water Quality

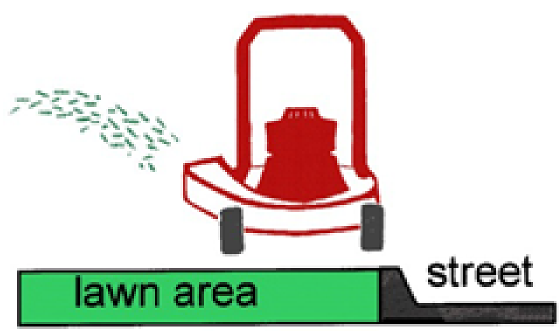
In surface water, low phosphorus levels limit the growth of algae and water weeds. However, when the phosphorus content of surface water increases, algae and water weeds often grow unchecked, a process called eutrophication. This significant decrease in water quality is a major problem related to manure management in production agriculture and the handling of yard waste from the landscape environment.

Popular press articles often incorrectly point to phosphorus-containing lawn and garden fertilizers as the major source of phosphate water pollution. Phosphate fertilizers are rather immobile when applied at correct rates to lawn and garden soils.

However, high rates of manure applied year after year will build soil phosphorus content where leaching becomes a water quality problem. In sandy soils coupled with high rainfall/irrigation, excessive application rates of organic or manufactured fertilizers may also lead to water quality concerns.

The primary source of water polluting phosphorus in the landscape environment is the mowing, sweeping, or blowing of lawn clipping and leaves onto the gutter and street. When mowing, mow in a direction that blows the clippings onto the lawn rather than onto the sidewalk or street. Also sweep any grass on the sidewalk/driveway onto the grass. Avoid blowing autumn leaves into the street. [**Figure 1**]

Figure 1.
Grass clippings and leaves mowed or blown into the street are the major source of phosphate pollution from the landscape environment. Mow in a direction to discharge clippings back onto the lawn and not into the street.



Phosphate in fertilizer is immobilized upon contact with soil and is not a source of phosphate pollution when applied to a lawn (or garden) soil. However, fertilizer over-spread onto the sidewalk, driveway, and street moves with surface runoff into local lakes, streams, and ponds. Exercise caution when fertilizing to keep the phosphate out of the street.

It is also important to leave an un-mowed buffer strip edging all lakes, streams, ponds, and wetlands rather than mowing plant residues into the water.

Second to yard waste management, over-spreading fertilizers onto hard surface (sidewalks, driveways, and streets) adds to surface water pollution. When applying fertilizer, avoid spreading the fertilizer onto hard surfaces where it will wash into local surface water through the storm sewer system. Sweep any fertilizer that landed on the sidewalk/driveway onto the lawn area.

Another particularly important source of phosphorus pollution in the landscape setting is soil erosion from new construction sites, unplanted slopes, and poorly maintained landscapes. When the soil moves, it takes the soil bound phosphorus with it. For good water quality, sloping ground needs to be planted with year-round plant cover to prevent soil erosion.

Potassium

Potassium levels are naturally adequate to high in most Colorado soils. With annual applications of compost or manure, potassium levels will likely be adequate. Deficiencies occasionally occur in new gardens low in organic matter and in sandy soils low in organic matter. A soil test is the best method to determine the need for potassium.

Excessive potash fertilizer can increase soil salt content.

Where potash levels are believed to be low, the standard application rate without a soil test is ¼ to ½ pound potassium chloride (0-0-60) or potassium sulfate (0-0-50) per 100 square feet.

Movement of potassium in soils is dependent on soil texture. As the clay content increases, movement decreases. For most soils, it is important that applied potash be tilled into the root zone. In sandy soils, potassium could leach down past the root zone.

Specialty Fertilizers

Specialty fertilizers may be preferred for specific purposes. For example, slow-release fertilizers are recommended for lawns (see lawn care information for details). Slow release or time release fertilizers give out small quantities of nutrients over a period of time. The release may be controlled by water, temperature, or microbial activity. For trees and shrubs, use only slow-release products.

For planters and hanging baskets, two popular specialty fertilizers include time release products (e.g., Osmocote) and water solubles (e.g., Miracle-Gro, Peters, etc.).

Time release fertilizers such as Osmocote are designed for indoor and outdoor potted plants. Each time the soil is watered, a small amount of nutrients is released. Depending on the specific formulation, it would be applied to the soil once every 3 to 9 months. In outdoor pots watered daily, it releases faster, having about half the life span of the product used on indoor plants. Gardeners sometimes see the Osmocote pellets in potted plants and mistake them for insect eggs.

Numerous brands of water solubles are popular in the home garden trade, (e.g., Miracle-Gro, JR Peters, Schultz Plant Food, Fertilome Root Stimulator, etc.). Water soluble fertilizers are mixed with irrigation water, typically giving a blue or green color. This can be done in a bucket or hose-on fertilizer applicator. It is important to water the soil with the fertilizer water, not just wet the leaves. Water solubles are the standard in greenhouse production where the fertilizer is injected into the irrigation water.

Note: Hose-on fertilizer applicators and hose-on pesticide sprayers are not the same thing.

Fertilizer applicators apply a higher volume as the purpose is to water the soil. Pesticide applicators release a lower volume, as wetting the leaf is the objective.

For herbaceous transplants (flowers and vegetables), water soluble fertilizers are recommended at planting and two and four weeks after planting, depending on soil organic matter content. These are often marketed as root stimulators. It is the nitrogen content that promotes growth rather than any hormones or vitamins in the product. In cool springtime soils, the readily available phosphate may also be helpful. Woody plants - trees and shrubs, do not respond to water soluble fertilizer at planting. Always read the label directions to avoid over-fertilization.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Revised 2015 and reviewed July 2022 by Dan Goldhamer, CSU Extension.

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CMG GardenNotes #233

Calculating Fertilizer Application Rates

Outline: Steps to Calculating Fertilizer Application Rate, page 1
Fertilizer Application Rate Table, page 2

Steps to Calculating Fertilizer Application Rate

Example is for a 40-foot by 100-foot lawn area, using a 20-10-0 fertilizer.

1. **Calculating size of area to be fertilized**

   Feet long x feet wide = square feet

   Example: 40 feet x 100 feet = 4000 square feet

2. **Calculating fertilizer application rate**

   $$\frac{\text{Pound nutrient per square foot}}{\text{\% nutrient in fertilizer}} = \text{pounds fertilizer/ square feet}$$

   Example:
   $$\frac{\text{1 pound nutrient per 1000 square feet}}{\text{20\% nutrient in fertilizer}} = \text{5 pounds fertilizer/1000 square feet}$$

3. **Calculating pounds of fertilizer to apply**

   Lawn or garden area x application rate = pound of fertilizer per garden or lawn

   $$\frac{\text{\_\_\_\_ square foot}}{\text{garden or lawn}} \times \frac{\text{\_\_\_\_ pounds fertilizer}}{\text{\_\_\_\_ square foot}} = \frac{\text{pounds fertilizer}}{\text{garden or lawn}}$$

   Example:
   $$\frac{\text{4000 square feet}}{\text{lawn}} \times \frac{\text{5 pounds fertilizer}}{\text{1000 square feet}} = \frac{\text{20 pounds fertilizer}}{\text{lawn}}$$

Because soil test recommendations for any given soil do not exactly match a fertilizer, select a fertilizer that gives comparative amounts of nitrogen, phosphorus and potassium as recommended by the soil test. In fertilizer application, it is most important to match the nitrogen requirement and compromise some for the phosphorus and potassium. The amount of fertilizer to apply that will give the recommended amount of nitrogen can be obtained from the following table:

Table 1. Fertilizer Application Rate Table

Amount of Fertilizer to Apply Based on Actual Nitrogen Recommendations			
Nitrogen Rate:	0.1 pound nitrogen per 100 square feet	0.2 pound nitrogen per 100 square feet	1 pound nitrogen per 1000 square feet
Fertilizer Grade	Pounds fertilizer to apply per 100 square feet	Pounds fertilizer to apply per 100 square feet	Pounds fertilizer to apply per 1000 square feet
45-0-0 (urea)	0.2	0.4	2.2
37-3-3	0.3	0.5	2.7
36-6-6	0.3	0.6	2.8
33-0-0	0.3	0.6	3.0
32-4-4 32-3-10	0.3	0.6	3.1
30-4-4 30-0-10	0.3	0.7	3.3
28-3-3 28-4-6	0.4	0.7	3.6
27-7-7 27-3-3	0.4	0.7	3.7
25-5-5 25-3-12	0.4	0.8	4.0
24-8-16 24-0-15	0.4	0.8	4.2
22-4-4 22-6-3	0.5	0.9	4.5
21-0-0 21-3-12	0.5	1.0	4.8
20-20-20 20-4-8	0.5	1.0	5.0
19-19-19 19-11-12	0.5	1.0	5.3
18-6-12 18-3-6	0.6	1.1	5.6
16-8-8 16-4-8	0.6	1.3	6.3
15-15-15 15-5-5	0.7	1.3	6.7
13-3-9 13-25-12	0.8	1.5	7.7
12-12-12 12-4-4	0.8	1.7	8.3
10-10-10 10-20-10	1.0	2.0	10.0
10-5-5 10-10-20	1.0	2.0	10.0
6-12-12 6-2-0	1.7	3.3	16.7
5-10-10 5-10-5	2.0	4.0	20.0

Example: If the N (nitrogen) recommendation is for 0.1 lb. N/100 square foot and the fertilizer grade selected has a ratio of 18-6-12 (column 1), apply 0.6 lb. of this fertilizer per 100 square feet.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; and Carl Wilson, CSU Extension, retired. Reviewed October 2015 and July 2022 by Eric Hammond, CSU Extension.

Reviewed July 2022

CMG GardenNotes #234
Organic Fertilizers

Terms

The term ***soil amendment*** refers to any material mixed into a soil to improve soil properties.

Mulch refers to a material placed on the soil surface and is, therefore, not a soil amendment.

Fertilizer refers to a product that contains at least one essential available plant nutrient.

An ***organic fertilizer*** refers to a product derived from natural sources that contains at least one essential available plant nutrient. Examples include plant and animal by-products, rock powders, and seaweed. Organic fertilizers are often available at garden centers and through horticultural supply companies. Nutrients in organic fertilizers are often in a form inaccessible to plant uptake and need to be converted by soil microorganisms into bioavailable forms before plants can uptake these nutrients. As a result, organic fertilizers often result in the slower release of nutrients, compared to inorganic (or synthetic) fertilizers, and can also improve soil properties through the addition of organic matter.

These should not be confused with substances approved for use with the ***USDA National Organic Program (NOP).*** The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute, https://www.omri.org, and the Washington Department of Agriculture (WSDA), https://agr.wa.gov, review and approve brand name products made with ingredients from the "national list" for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited, refer to https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances. Many of the organic fertilizers listed here will meet NOP standards based on the National List. Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

Many gardeners apply *organic soil amendments*, such as ***compost*** or manure, which typically do not meet the legal requirements as a "fertilizer" but adds small amounts of nutrients. The term **compost** refers to organic matter that has been biologically degraded. While Colorado requires that commercial compost be sufficiently composted to reduce pathogens and vector transfer (C:N ratio must be 18:1 or less), there is no standard regarding the compost's state of decomposition.

Two important terms related to the use of all soil amendments are the release time and the application of the product:

- **Release Time** – Organic products require the activity of soil microorganisms before nutrients are available for plant uptake. Microorganism activity is dependent on soil temperatures greater than 50ºF in the presence of sufficient soil moisture. Dry and/or cold soil conditions will delay the release of nutrients from these organic sources. This period refers to how long these products are available if applied to the soil. Use this information to time the application of the product.
- **Application** – Products may be applied in various ways. Some may be tilled in (worked into the soil with a machine or hand tool), others may be applied as a foliar spray (mixed with a surfactant and sprayed in a fine mist on the leaf surface while temperatures are below 80ºF), and some may be injected into a drip or overhead irrigation system (fertigation with a siphon mixer). Application rates in this fact sheet are generalized and based on some manufacturers' recommendations. Over- or under-fertilization may occur using these recommendations.

Before applying a fertilizer, conduct a soil test to determine what deficiencies your soil might have.

Plant By-Products

Alfalfa Meal or Pellets

Alfalfa meal or pellets are often used as animal feed. They are used primarily to increase organic matter in the soil but do offer nutrients and a high availability of trace minerals. They contain triacontanol, a natural fatty-acid growth stimulant.

Alfalfa Meal or Pellets	
Typical NPK analysis	2-1-2
Release time	1-4 months
Pros	Available at feed stores
Cons	May contain seeds
Application	Till in 2-5 pounds per 100 square feet

Corn Gluten Meal

Corn gluten meal has a high percentage of nitrogen. Products carry a warning to allow one to four months of decomposition in the soil prior to seeding. Allelopathic properties will inhibit the germination of seeds. However, there is no danger to established or transplanted plants.

This product is also marketed as a pre-emergent weed control for annual grasses in bluegrass lawns.

Corn Gluten Meal	
Typical NPK analysis	9-0-0
Release time	1-4 months
Pros	Very high nitrogen
Cons	Germination inhibitor, some are GMOs
Application	Till in 20-40 pounds per 1000 square feet

Cottonseed Meal

Cottonseed meal is a rich source of nitrogen. Buyers should be aware that many pesticides are applied to cotton crops and residues tend to remain in the seeds. Pesticide-free cottonseed meal is available.

Cottonseed Meal	
Typical NPK analysis	6-0.4-1.5
Release time	1-4 months
Pros	High nitrogen
Cons	Pesticide residues, most are GMOs
Application	Till in 10 pounds per 100 square feet

Soybean Meal
Soybean meal is used primarily as an animal feed product. It is available bagged at many feed stores. Soybean meal may inhibit the germination of seeds, so it should be applied several weeks before planting.

Soybean Meal	
Typical NPK analysis	7-2-1
Release time	1-4 months
Pros	High nitrogen, available at feed stores
Cons	Almost ½ the conventionally grown soy is GMO
Application	8 pounds per 100 square feet

Animal By-Products

Bat Guano
Bat guano (feces) harvested from caves is powdered. It can be applied directly to the soil or made into a tea and applied as a foliar spray or injected into an irrigation system. Bat guano can have a high nitrogen content, or it can also be processed for high phosphorus content.

Bat Guano – High N	
Typical NPK analysis	10-3-1
Release time	4+ months
Pros	Stimulates soil microbes
Cons	Cost
Application	Till in 5 pounds per 100 square feet or as a tea at 3 teaspoons per gallon of water

Bat Guano – High P	
Typical NPK analysis	3-10-1
Release time	4+ months
Pros	Stimulates soil microbes
Cons	Cost
Application	Till in 5 pounds per 100 square feet or as a tea at 3 teaspoons per gallon of water

Blood Meal
Blood meal, made from dried slaughterhouse waste, is one of the highest non-synthetic sources of nitrogen. If over-applied, it can burn plants due to excessive ammonia.

Blood Meal	
Typical NPK analysis	12-0-0
Release time	1-4 months
Pros	Available at feed stores
Cons	Can burn. Expensive at garden centers
Application	Till in 5-10 pounds per 100 square feet

Bone Meal
A well-known source of phosphorus, bone meal is steam processed and widely available at feed stores and in garden centers. If purchased at feed stores, phosphorus is expressed on the label as elemental phosphorus and is 2.3 times higher than numbers shown on garden center labels for phosphate (i.e. – 12% phosphate is the same as 27% phosphorus). **However, recent CSU research has shown that phosphorus from bone meal is only available to plants in soils that have a pH below 7.0.**

Bone Meal

Typical NPK analysis	3-15-0
Release time	1-4 months
Pros	High plant available form of phosphorus
Cons	Cost
Application	Till in 10 pounds per 100 square feet

Feather Meal
Sourced from poultry slaughter, feather meal has fairly high nitrogen levels but is slow to release the nitrogen.

Feather Meal

Typical NPK analysis	N varies 7-12% on process
Release time	4+ months
Pros	Long term fertilizer
Cons	Cost versus speed of nitrogen release
Application	Till in 2.5-5 pounds per 100 square feet

Fish Emulsion
Infamous for its foul smell, emulsions are soluble, liquid fertilizers made of fish waste that have been heat and acid processed.

Fish Emulsion

Typical NPK analysis	5-2-2
Release time	1-4 months
Pros	Adds needed micronutrients
Cons	Some have foul smell
Application	Mix 6 tablespoons per gallon of water

Enzymatically Digested Hydrolyzed Liquid Fish
Enzymatically digested hydrolyzed liquid fish products use enzymes to digest the nutrients from fish wastes instead of using heat and acids. This retains more of the proteins, enzymes, vitamins, and micronutrients than emulsions.

Enzymatically Digested Hydrolyzed Liquid Fish

Typical NPK analysis	4-2-2
Release time	1-4 months
Pros	More nutrients than emulsions
Cons	More expensive than emulsions
Application	Mix 5 tablespoons per gallon of water

Fish Meal
Fish meal is ground and heat dried fish waste.

Fish Meal

Typical NPK analysis	10-6-2
Release time	1-4 months
Pros	N and P source
Cons	Heat processed
Application	Till in 5-10 pounds per 100 square feet

Fish Powder
Fish powder is dried with heat and turned into water-soluble powder. It is a high source of nitrogen. It can often be mixed into a solution and injected into an irrigation system.

Fish Powder

Typical NPK analysis	12-0.25-1
Release time	Immediate to 1 month
Pros	Adds micro-nutrients
Cons	Heat processed
Application	Till in 1-2 ounces per 100 square feet OR mix at 1 tablespoon per gallon of water

Rock Dust or Rock Powders

Rock dust or rock powders are made of finely crushed rock and can be used to supply the soil with certain minerals. A common example of rock dust is gypsum or lime, which is used as a source of calcium. Gypsum and lime are typically not needed in Colorado due to the naturally high calcium levels of many of our soils.

Rock powders that serve as a potassium source (greensand, feldspar, potassium sulfate, biotite, etc.) are typically not necessary here either, as many Colorado soils are naturally high in potassium.

For phosphorus deficiencies, home gardeners can use colloidal phosphate. Colloidal phosphate releases a small and steady supply of available phosphate (2-3%) and other micronutrients over several years. However, CSU research concluded that no rock phosphorus, regardless of mesh size, is available for plant use unless the soil pH is below 7.0. As a result, most Colorado gardeners will benefit from using plant or animal sources of phosphorus rather than rock phosphorus. If you are making annual applications of manure and/or compost to your garden to add nitrogen, you should have sufficient levels of phosphorus in your soil.

Seaweeds

Kelp is the most common form and is valued not for its macronutrient (nitrogen, phosphorus, and potassium) contributions but for its micronutrients.

Kelp is often mixed with fish products to enhance growth.

Three processes are available: extracts (as kelp meal or powder), cold-processed (usually liquid), and enzymatically digested (liquid).

In regard to quality of content and plant availability, they are ranked (highest to lowest) as 1) enzymatically digested, 2) cold-processed, and 3) extracts.

Kelp Meal
Kelp meal, a product of the ocean, is used primarily as a trace mineral source. It is often combined with fish meal to add nitrogen, phosphorus, and potassium.

Kelp Meal	
Typical NPK analysis	Negligible
Release time	4+ months
Pros	Adds micro-nutrients
Cons	Insignificant nitrogen, phosphorus, potassium
Application	Till in 1 pound per 100 square feet

Kelp Powder
Kelp powder is similar to kelp meal but it is ground fine enough so that it can be put into a solution and applied as a foliar spray or injected into an irrigation system.

Kelp Powder	
Typical NPK analysis	1-0-4
Release time	Immediate to 1 month
Pros	Adds micronutrients
Cons	Insignificant nitrogen, phosphorus, potassium
Application	Mix ¼ to ½ teaspoon/gallon of water

Liquid Kelp
Usually cold processed, liquid kelp will have higher levels of growth hormones than extracts. Some may also be enzymatically digested, making the growth hormones even more available to the plants.

Liquid Kelp	
Typical NPK analysis	Negligible
Release time	Immediate to 1 month
Pros	Adds micronutrients plus helps plants with stress
Cons	Insignificant nitrogen, phosphorus, potassium
Application	Mix 1-2 Tablespoons per gallon of water

Authors: Adrian Card, CSU Extension; David Whiting, CSU Extension, retired; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Revised October 2015 by Dan Goldhamer, CSU Extension. Reviewed March 2023 by Hania Oleszak, former CSU Extension employee.

Reviewed March 2023

CMG GardenNotes #241

Soil Amendments

Terms

The term ***soil amendment*** refers to any material mixed into a soil to improve soil properties or plant growth.

Mulch refers to a material placed on the soil surface, often to suppress weeds, retain moisture, or reduce erosion.

Compost refers to organic matter that has been biologically degraded. While Colorado requires that commercial compost be sufficiently composted to reduce pathogens and vector transfer (C:N ratio must be 18:1 or less), there is no standard regarding the compost's state of decomposition.

Fertilizer refers to a product that contains at least one essential available plant nutrient.

Organic fertilizer refers to a product derived from natural sources that contains at least one essential available plant nutrient. Examples include plant and animal by-products, rock powders, seaweed, and inoculants. These are often available at garden centers and through horticultural supply companies. Nutrients in organic fertilizers are often in a form inaccessible to plant uptake and need to be converted by soil microorganisms into bioavailable forms before plants can uptake these nutrients. As a result, organic fertilizers often result in the slower release of nutrients, compared to inorganic (or synthetic) fertilizers, and can also improve soil properties through the addition of organic matter.

These should not be confused with substances approved for use with the ***USDA National Organic Program (NOP).*** The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute, https://www.omri.org/, and the Washington Department of Agriculture (WSDA), https://agr.wa.gov/, review and approve brand name products made with ingredients from the "national list" for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances. Many of the organic fertilizers listed here will meet NOP standards based on the National List. Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

Managing Soil Texture and Structure

Routine applications of organic matter should be considered an essential component of gardening and soil management. Organic matter improves the water and nutrient holding capacity of coarse-textured sandy soil. In a fine-textured clayey soil, the organic matter helps to bind the tiny clay particles into larger chunks, called aggregates, creating greater porosity. This improves water infiltration and drainage, air infiltration (often the most limiting aspect of plant growth) and allows for deeper rooting depths (allowing the plant to tap a larger supply of water and nutrients). Plants vary in their soil condition preferences, so consider those preferences and soil test results *before* adding organic matter or amending soils. For additional discussion, refer to CMG GardenNotes #213, *Managing Soil Tilth: Texture, Structure, and Pore Space*.

When using organic soil amendments, it is important to remember that only a portion of the nutrients in the product are available to plants in any one growing season. Soil microorganisms must first process the organic compounds into chemical ions ($NO3^-$, $NH4^+$, $HPO4^{-2}$, $H2PO4^-$, K^+) before plants can use them.

Cultivate or hand-turn the organic matter thoroughly into the soil. Never leave it in chunks as this will interfere with root growth and water movement.

Table 1. Routine Application Rate for Compost

Site	Incorporation Depth[1]	Depth[2] of Compost[3] Before Incorporation
One-time application for lawns.	6 inches.	1-2 inches.
First-time application when installing vegetable or flower gardens.	8-12 inches.	3-4 inches.
Annual application to existing vegetables or flower gardens.	8-12 inches, or as deep as possible.	0.25 inch.

1. According to the indicated incorporation depth, cultivate compost into the top of the soil profile using a digging fork, spade, or rototiller if necessary. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plant to reduced growth, low vigor, and low stress tolerance. If the actual incorporation depth is different, adjust the rate accordingly.
2. Three cubic yards (=81 cubic feet) covers 1,000 square feet approximately 1 inch deep.
3. These application rates are based on the use of plant-derived compost (compost made solely of plant materials, such as leaves, grass clippings, wood chips and other yard wastes) or compost known, by soil test, to be low in salts. For compost made with manure or biosolids and compost known, by soil test, to be high in salts, application rates will need to be reduced substantially. Excessive salts are common in many commercially available products sold in Colorado.

When consistently repeating annual applications, application rates can be lowered over time. An annual soil test will be the best measure for the need for compost.

Selecting Soil Amendments

Desired Results – In selecting soil amendments, first consider the desired results. To improve the water and nutrient holding capacity on sandy, gravelly, and decomposed granite soils, select well decomposed materials like finished compost and aged manure. To improve aeration and infiltration (improve structure on clayey soils) select fibrous materials like composted wood chips and straw.

Potential for Routine Applications – Another important consideration is the potential for routine applications to improve the soil over time, as in a vegetable garden or annual flowerbed. In many landscape settings, the amendment is a one-time application added before planting lawns, perennials, trees, and shrubs.

Longevity – Products that decompose rapidly (like grass clippings and manure) give quick results, while products that decompose slowly (like wood chips and bark chips) provide longer lasting results. For quick improvement that lasts, use a combination of materials. Longevity of the product merits consideration.

Salts – Products made with manure and/or biosolids are often very high in salts, which can stress and/or kill plants if over-applied. Salt levels may increase in the composting process, although water moving through the compost pile can leach out the salts. Use with caution! Plant-based products are naturally low in salts.

Regulations – When purchasing products, gardeners need to understand that there are no regulations about the quality of the product, salt content, or other beneficial or harmful qualities of bagged products. Use with caution, as many soil amendments sold in Colorado are high in salts! Voluntary standards for bulk products may help in product evaluation. For example, the US Composting Council provides lab testing, labeling, and information disclosure that can help gardeners judge the quality of compost products.

Need for Nitrogen Fertilizer – Over time, soil microorganisms break down organic matter and, through this process, release nitrogen that is tied-up in organic matter. Nitrogen release rates from organic matter are very slow (can occur over a period of years) and organic matter typically has low nitrogen content, so compost is usually not an effective substitute for fertilizer.

The need for nitrogen fertilizer generally depends on the soil organic matter content of the soil. The more organic matter a soil contains, the greater its nitrogen content and the less nitrogen it requires from a fertilizer. **Table 2** provides approximate recommendations for N application rates based on soil organic matter content. However, soil organic matter content is not the only factor that affects the need for nitrogen fertilizer. The type of crop, level of production, and soil nitrate levels should also be considered when determining the N application rates.

Table 2. Approximate Recommendations for N Fertilizer Based on Soil Organic Matter Content

Soil Organic Matter Content	Routine Application Rate for Gardens
0%	3 pounds N / 1,000 square feet
1%	2.5 pounds N / 1,000 square feet
2%	2 pounds N / 1,000 square feet
3%	1.5 pounds N / 1,000 square feet
4%	1 pound N / 1,000 square feet
>5%*	0 pounds N / 1,000 square feet

These are approximate recommendations based on soil organic matter content. When determining application rates, consider crop, level of production, and soil nitrate levels as well.

* If there are low nitrate levels in the soil when OM is 5% or higher, it is recommended to apply N.

Over Amending

Over-amending is a common problem. Some gardeners try to fix their soil limitations by adding large quantities of amendment in a single season. This can result in the following problems:

- High salts.
- High nitrogen.
- Low nitrogen (from the tie-up of nitrogen due to a high carbon to nitrogen ratio imbalance).
- Holding too much water.
- High ammonia (burns roots and leaves).

Problems may also arise, over time, from the continual application of high rates. This can result in the following problems:

- High salts.
- Excessive nitrogen, phosphorus, and potassium.
- Ground water contamination.
- Micronutrient imbalance.

Evaluating the Quality of Organic Amendments

The quality of organic amendments can be determined by both visual evaluation and laboratory testing.

Visual Evaluation

- **Color** – Dark brown to black.
- **Odor** – Earthy, no ammonia smell.
- **Texture** – Less than one to two inch particle size; lawn top dressing less than 3/8 inch.
- **Foreign Materials** – Less than 1% and smaller than ½ inch size.
- **Uniformity** – Observed within the batch.
- **Consistency** – Observed between different batches.
- **Raw Materials** – Concern of heavy metals (biosolids), human pathogens (manure), and salts (manure and biosolids).
- **Weed Seeds** – Test by germinating some material.

Laboratory Testing

C:N Ratio – Ratio of carbon to nitrogen.

- Less than 20:1 is acceptable, while 12:-1 – 15:1 is desirable.
- Woody composts may have C:N ratios above 20:1 and may tie-up nitrogen.

Organic Matter

- 40-60% is desirable, based on % dry weight basis.
- Organic matter content under 25% may indicate large amount of soil/sand, whereas over 65% organic matter content may indicate the product has not been composted enough.

pH

- May be higher in manure.
- Near neutral (6.8 to 7.2) is best for most plants.

Electrical Conductivity (EC) – A measure of soluble salts. Acceptable levels depend on use, but are typically recommended to be between 0-4 mmhos/cm.

- Potting grade: < 2.5 mmhos/cm.
- Potting media amendment: < 5 mmhos/cm.
- Top dressing: < 5 mmhos/cm.
- Soil amendment in a low salt soil: <10 mmhos/cm.

Moisture Content – Amendments with moisture contents above 60% may be difficult to spread, while amendments with moisture contents below 40% may be dusty.

Nitrate Nitrogen (NO_3-N) – A plant available form of nitrogen.

- Levels from 200-500 mg/kg or ppm are typically recommended.
- Higher levels of ammonium may damage sensitive plants.

Ammonium Nitrogen (NH_4-N) – A plant available form of nitrogen.

- Levels <500 mg/kg or ppm are typically recommended.
- Lower levels indicate a lack of plant available nitrogen.

Heavy Metals – A concern with biosolids. Colorado has specific compliance standards for commercial soil amendments in regard to levels of various heavy metals.

Pesticide Residues – Generally not a problem as they breakdown in composting.

Pathogens – *E. coli*, salmonella, and other human pathogens are a concern, particularly in manure. Colorado has specific compliance standards for commercial soil amendments regarding *E. coli* and salmonella levels.

Stability (Respiration Rate) – Less than 2 mg CO_2-C per g organic matter per day, preferred. Relative measurement of the completeness of microbial activity. The lower the number, the more completely composted the product.

Maturity – Broad classification that indicates a product is suitable for use. Stability is one measure of maturity.

Nutrient Content – This varies greatly from product to product.

Germination Test – Seeds are started to check potential of toxic chemicals.

Bacterial and Fungal Diversity – Some studies have indicated that compost with higher microbial diversity may suppress plant diseases.

Examples of Soil Amendments

There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that is or was alive. Inorganic amendments, on the other hand, are either mined or manufactured. Organic amendments include sphagnum moss/peat moss, coconut coir, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust, and wood ash. Inorganic amendments include vermiculite, perlite, tire chunks, pea gravel, and sand.

Sphagnum Moss and Peat Moss

Generally, bogs consist of **sphagnum moss**, the living layer of moss, and **peat moss**, the sunken, decaying layer of moss that builds up over time. Both sphagnum moss and peat moss are used as soil amendments to promote water retention, particularly in sandy soils. However, the use of these amendments has negative environmental consequences. Bogs sequester large amounts of carbon through the buildup of peat so, by harvesting and draining peatlands, we are eliminating carbon sinks that are critical to combat global warming.

Because peat moss is created over decades to centuries, it is not possible to harvest sustainably. Sphagnum peat, however, may be commercially farmed and sustainably harvested. Coconut coir is a popular soil amendment that can be used as an alternative to sphagnum moss and peat moss.

Colorado mountain peat should not be used as a soil amendment. Mountain peat is mined from high-altitude wetlands, which provide homes for many rare species. This mining is extremely disruptive to these species, as well as to hydrologic cycles.

Coconut Coir

Coconut coir is a by-product of the coconut fiber industry. It is renewable and lasts longer than peat but may be more expensive due to transportation costs. Coir has a higher pH (5.5-6.8) and more soluble salts than peat. Additionally, it is easier to wet than peat. Depending on fertilization practices, coir can become acidic.

Coir can be blended as a high proportion of mixes (up to 80% reported in the literature with success). Coir is commonly blended with perlite and compost.

Biosolids

Biosolids (sewage sludge, Milorganite®) add slow-release nutrients and organic matter to soil. They are available from some communities or sewer treatment districts in bulk and from garden stores in bags.

Some biosolids are extremely high in salts. For example, tests on MetroGro report a salt content of 38.3 mmhos/cm, which is considerably above acceptable tolerances for soil amendments. (A soil amendment above 10 mmhos/cm is considered questionable.) For details on salty soil amendments, refer to CMG GardenNotes #224, *Saline Soils*.

Biosolids typically have 5-6% nitrogen content. Annual applications should be made only when the biosolids and garden soil are routinely tested for salt content.

Worm Castings

Worm castings (i.e., worm feces) have a slow-release performance due to a mucus covering which is slowly degraded by microorganisms. Castings are neutral in pH and contain highly available forms of plant nutrients that are water-soluble, as well as trace elements, enzymes, and beneficial microorganisms. Nutrients within the castings are generally released over the course of several months. For continual release of nutrients, repeat applications approximately at four-month intervals.

Castings can be used in potted plants, soil mixes, and in garden beds. Castings can be harvested every three to four months from a vermicompost bin, and then applied as a top dressing (1/2 to 1 inch deep) to potted plants or incorporated into a soil mix (casting should make up no more than 25% of the mix by volume). Avoid direct contact between the castings and plants, as castings may have a higher soluble salt content. Some batches made from livestock manure may have high salts depending on whether the animals producing the manure had access to a salt lick and if the vermicompost maker leached them out or not.

Due to the high cost in Colorado, castings are generally used in small gardens or potting mixes.

Perlite and Vermiculite

Perlite and vermiculite are common inorganic amendments used in potting soils and planter mixes.

Vermiculite is made from heat expanded silica. It helps increase pore space and has a high-water holding capacity.

Perlite is made from heat expanded volcanic rock. It is used to increase pore space and promote drainage.

Summary: Considerations in Selecting Soil Amendments

Choosing a soil amendment depends on your specific situation. What is practical and available varies from place to place. The important points are that 1) soils are routinely amended to improve soil tilth and 2) the gardener follows the limitations for the specific product used. The following summarizes selection considerations:

Goals:
- Purpose of amending soil.
- Longevity of amendment (fast-acting vs slow-release; one-time addition vs. routine applications).

Cost/Availability:
- Local availability.
- Cost of product.
- Quantity needed (based on size of area to be treated, depth of incorporation, and application rate).
- Transportation costs.
- Difficulty in incorporating product (established perennials, hardscapes, etc.).

Need for Fertilizer After Amending:
- Soil organic matter content.
- Nitrogen content of soil.

Precautions With Specific Products:
- Salts (manure and biosolids).
- Weed seeds (manure and compost).
- Plant pathogens (compost).
- Human pathogens (manure).

Alternatives to Amending:
- Accepting a reduction in plant growth and vigor.
- Accepting increased maintenance requirements.
- Selecting plants more tolerant of poor soils.
- Avoid crowding plants competing for limited soil resources.

- Mulching with organic mulch slowly improves soil over time.
- Container and raised-bed gardening.
- Prevent compaction forces.

For more information, please refer to these additional resources:
CSU Fact Sheets, https://extension.colostate.edu/topic-areas/yard-garden/:

- #7.214, *Mulches for Home Grounds*.
- #7.235, *Choosing a Soil Amendment*.

CMG GardenNotes, https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/:

- #218, *Earthworms*.
- #232, *Understanding Fertilizers*.
- #234 *Organic Fertilizers*.
- #243, *Using Compost in the Home Garden*.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Catherine Moravec, former CSU Extension employee; Carl Wilson, CSU Extension, retired; and Jean Reeder, PhD, USDA-ARS, retired. Revised October 2015 by Dan Goldhamer, CSU Extension. Revised September 2023 by Dan Goldhamer, CSU Extension; Hania Oleszak, former CSU Extension employee; and Chris Hilgert, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #242

Using Manure in Colorado Gardens

For some gardeners in Colorado, manure is readily available as a source of organic matter to build soils and add small amounts of nutrients. However, follow precautions with manure applications or they could become more detrimental than beneficial.

E. coli, a Health Issue

Due to the potential of transmission of human pathogens such as *E. coli*, animal-based manures should only be used on fruits and vegetables when specific precautions are taken. Apply non-composted (fresh) animal manures in the fall and mix it into the soil. Do not leave it on the soil surface. When applying fresh animal manure, it is best to wait three to four months from application to harvest in order to give plenty of time for the manure to break down and reduce any pathogen threats. Never apply fresh manure to growing food crops. Plant-based composts can be used safely during the growing season and does not pose the same health risks as animal manures.

Nitrogen Release Rate is Slow

Manure contains small amounts of plant nutrients and micronutrients. The nutrient composition of farm manure varies widely depending on bedding material, moisture content, exposure, and aging, even for the same species of animal. Where manure is routinely added, garden soils will likely have adequate phosphorus and potassium. Manure is a great source of micronutrients like zinc. **Table 1** gives approximate amounts of nitrogen, phosphate, and potash.

The nitrogen in manure is not all available to growing plants the first year as much of it may be tied up in organic forms. Organic nitrogen becomes available to plants when soil microorganisms decompose organic compounds, such as proteins, and then convert the released N to NH_4. This process, known as mineralization, begins almost immediately, but fully occurs over a period of years. [**Table 2**]

Table 1. Approximate Nutrient Content of Manure*			
Type	**N**	**P2O5**	**K2O**
Beef:			
With bedding.	1.1%	0.9%	1.3%
Without bedding.	1.1%	0.7%	1.2%
Dairy Cattle:			
With bedding.	0.5%	0.2%	0.5%
Without bedding.	0.5%	0.2%	0.5%
Horse:			
With bedding.	0.7%	0.2%	0.7%
Poultry:			
With litter.	2.8%	2.3%	1.7%
Without litter.	1.7%	2.4%	1.7%
Rabbit:	2.0%	1.3%	1.2%
Sheep:			
With bedding.	0.7%	0.5%	1.3%
Without bedding.	0.9%	0.6%	1.3%
Swine:			
With bedding.	0.4%	0.4%	0.4%
Without bedding.	0.5%	0.5%	0.4%
Turkey:			
With litter.	1.0%	0.8%	0.7%
Without litter.	1.4%	1.0%	0.9%

*At time of land application.
Sources: CSU Extension Bulletin 552A, Utilization of Animal Manure as Fertilizer except for rabbits from Western Fertilizer Handbook of the California Fertilizer Association.

Table 2. Approximate Percentage of Organic N Mineralized in First Year After Application	
Manure Source	**Percent of Organic N Mineralized**
Beef	35%
Dairy	35%
Horse	20%
Poultry	35%
Sheep	25%
Swine	50%

Source: Nebraska Cooperative Extension Bulletin EC89-117, Fertilizing Crops with Animal Manures.

The amount mineralized in the first year depends upon the manure source, soil temperature, moisture, and handling. **In general, about 30% to 50% of the organic nitrogen becomes available the first year. Thereafter, the amount gradually decreases. A general estimate is 50% the first year, 25% the second year, 12.5% the third year, and so forth.**

In gardens low in organic matter, it is common to find nitrogen deficiencies when the gardener relies solely on manure and/or compost due to the slow-release rates. The gardener may need to supplement with a high nitrogen organic or manufactured fertilizer. As the soil organic matter builds over the years, the problems with low nitrogen levels will improve.

Salts

Salt content may be high in fresh manure and decreases with exposure to rains and irrigation as salts are leached out. **Continual and/or heavy applications of manure can lead to a salt build-up.**

To avoid salt problems associated with the use of manure or compost made with manure, limit applications to one inch per year and thoroughly cultivate the manure or compost into the soil six to eight inches deep. When cultivation is less than six to eight inches deep, lower the application rate accordingly. Have a soil test for salt content before adding large amounts.

Manure or compost made with manure containing up to 10 dS/m (10 mmhos/cm) total salt is acceptable if cultivated six to eight inches deep into a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Manure with a salt content greater than 10 dS/m (10 mmhos/cm) is questionable. Avoid use of manure on soils that are already high in salts (above 3 dS/m (3 mmhos/cm).

Note: dS/m or mmhos/cm are the units used to measure salt content. It measures the electrical conductivity of the soil.

Other Disadvantages of Farm Manure

Other disadvantages of farm manure include:

- Potential burning of roots and foliage from high ammonia.
- Potential residual herbicide damage to crops.
- High potential for weed seeds.
- Labor and transportation necessary to apply the manure to the garden.

Horse manure is legendary in its potential to introduce a major weed seed problem into a garden. Composting the manure before application may kill the weed seeds if the pile heats to above 145ºF and the pile is turned to heat process the entire product.

Horses eating grass hay treated with broadleaf herbicides containing clopyralid and aminopyralid can convey the herbicide in their manure. If grasses were treated with these herbicides in the eighteen months prior to cutting and baling as hay, then the risk of horse manure containing the herbicide is present. Gardeners can test a small sample of the manure by mixing an amount proportional to what would be applied to soils into a large flowerpot with garden soil. Plant seeds of crops intended for that growing season in the flowerpot and observe for any signs of herbicide stress or injury such as: low germination, yellowing, twisted growth, dead leaves, stunting, or death of entire plant. These are clear signs that the herbicide is still active in the manure.

Feedlot manure is often high in salts if a salt additive is used in the livestock diet.

Poultry manure is particularly high in ammonia and readily burns if over-applied. The ammonia content will be higher in fresh manure compared to aged manure. Laying hen manure can raise soil pH due to the calcium supplements in their diet. Occasionally, gardeners may want to "fix" their soil by adding large quantities of organic matter at one time. Excessive applications of manure can lead to a reduction of plant growth due to excessive levels of nitrogen, ammonia burn, and salt damage to the roots.

Composted Manure

A growing trend in the use of manure is to compost it before application. Bagged composted manure is readily available in garden stores and nurseries. Composted manure has fewer odors. It is easier to haul and store than fresh manure because of the reduction in the weight of water and a decrease in overall volume by four to six-fold. The composting process may kill weed seeds and pathogens if the pile heats above 155ºF and the pile was turned to heat-process the entire product. Salts can be concentrated during composting as moisture is lost and volume is reduced. Many bagged manure products sold in Colorado are high in salts.

In composted dairy manure, only 5-20% of the nitrogen will be available the first year. In soils low in organic content, this can lead to a nitrogen deficiency unless an additional quick release nitrogen source is added. This could be supplied with blood meal (one to two pounds per one hundred square feet) or with a manufactured fertilizer like ammonium nitrate (2/3 cup per 100 square feet) or ammonium sulfate (one cup per 100 square feet). The ammonia content drops due to volatilization during composting, thereby reducing the burn potential.

Fresh manure without bedding materials is difficult to compost, because of the high ammonia and moisture content. To speed decomposition and minimize foul odors from anaerobic decay, add some high carbon material, such as sawdust, straw, dried leaves, or wood chips. Depending on climatic conditions, on-farm manure composting takes six to ten or more weeks if turned weekly.

Follow the same residual herbicide risk precautions with composted manure as detailed above.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Revised October 2015 by Dan Goldhamer CSU Extension. Reviewed June 2023 by Adrian Card, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #243

Using Compost in Colorado Gardens

For information on home composting see Colorado State University Extension Fact Sheet #7.212, *Composting Yard Waste.*

Compost Products

The term ***compost*** refers to organic matter that has been biologically degraded. Organic matter, which is essentially anything that is made of carbon, is a critical component in soils for numerous reasons. For one, organic matter is the food source for the soil organisms that form the base of the soil food web. Soil life slowly mineralizes the nutrients in organic matter through decomposition, making the nutrients available for plants to use. Organic matter also promotes the aggregation of soil particles, which can ultimately improve the physical characteristics, like porosity and water infiltration, of the soil over time. Additionally, organic matter has a high water and nutrient holding capacity, which can improve sandy soil's tilth. Having adequate levels of soil organic matter supports a healthy soil ecology and, ultimately, benefits gardeners.

Compost can be made at home using kitchen scraps and garden waste. Making homemade compost is an environmentally sustainable way to convert both kitchen and yard wastes, which would otherwise be taken to a landfill, into valuable soil-building resources. One of the main advantages of homemade compost is that the gardener controls what goes into the compost pile and, therefore, can avoid weed seeds, diseased plants, and salt problems.

There are also many compost-based products available in the retail trade. Compost can be purchased either in bags from a variety of retailers, or in bulk from large compost producers or landscape supply companies. They can be derived from any combination of plant residues, manure, and/or biosolids, and may also have added fertilizers or animal by-products. Many suppliers of compost will have information on what the product is made from and may even have a laboratory analysis of the product available upon request.

While Colorado requires that commercial compost be sufficiently composted to reduce pathogens and vector transfer (C:N ratio must be 18:1 or less), there is no standard regarding the compost's state of decomposition. As a result, it is important to be mindful when purchasing a compost since the quality of compost will vary based on the materials being composted, the process being used, the duration of composting, etc.

Application Rates and Salt Problems

Routine application rates of organic soil amendments depend on the desired results, type of amendment, salt potential of the material, and the depth to which it will be cultivated into the soil. Before applying any amendment, it is best to do a soil test. **Table 1** gives approximate application rates for plant-derived compost.

Table 1. Routine Application Rate for Compost

Site	Incorporation Depth[1]	Depth[2] of Compost[3] Before Incorporation
One-time application for lawns.	6 inches	1-2 inches
First-time application when installing vegetable or flower gardens.	8-12 inches	3-4 inches
Annual application to existing vegetable flower gardens.	8-12 inches, or as deep as possible	0.25-1 inch

1 According to the indicated incorporation depth, cultivate compost into the top of the soil profile using a digging fork, spade, or rototiller if necessary. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plant to reduced growth, low vigor, and low stress tolerance. If the actual incorporation depth is different, adjust the rate accordingly.

2 Three cubic yards (=81 cubic feet) covers 1,000 square feet approximately 1 inch deep.

3 These application rates are based on the use of plant-derived compost (compost made solely of plant materials, such as leaves, grass clippings, wood chips and other yard wastes) or compost known, by soil test, to be low in salts. For compost made with manure or biosolids and compost known, by soil test, to be high in salts, application rates will need to be reduced substantially. Excessive salts are common in many commercially available products sold in Colorado.

* When consistently repeating annual applications, application rates can be lowered over time. An annual soil test will be the best measure for the need for compost.

Compost derived from manure or biosolids has the potential to have a high salt content, so application rates will need to be reduced substantially unless a laboratory analysis of the compost shows a low salt level.

An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable when incorporated into a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable. Note: dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

Generally, compost needs to be thoroughly mixed into the upper six to eight inches of the soil profile. Do not leave compost in chunks, as this will interfere with root growth and soil water movement.

As the soil organic content builds in a garden soil, the application rate should be reduced. A soil test is suggested every few years to establish a baseline on soil organic matter content.

Nitrogen Release Is Limited and Slow

The typical macronutrient content of compost is 1.5% to 3.5% nitrogen, 0.5% to 1% phosphate, and 1% to 2% potassium, plus micronutrients. As with other organic soil amendments, the nitrogen release rate from compost is very slow (i.e., over a period of years). Thus, compost is not considered an effective substitute for fertilizer due to the low levels of nutrients present and the slow rate of release. In gardens where compost is routinely added, phosphorus and potassium levels are likely to be adequate to high.

The need for nitrogen fertilizer generally depends on the soil organic matter content of the soil. The more organic matter a soil contains, the greater its nitrogen content and the less nitrogen it requires from a fertilizer.

4-5% Organic Matter – Soils with 4-5% organic matter from compost will mineralize (release to plants) about 0.2 pound of nitrogen per one hundred square feet per year. This should be sufficient for plant nitrogen needs.

2-3% Organic Matter – Soils with 2-3% organic matter from compost will mineralize about 0.1 pound of nitrogen per one hundred square feet per year. Additional nitrogen fertilizer will be needed for high nitrogen crops like broccoli, cauliflower, cabbage, potatoes, and corn.

<2% Organic Matter – In soils with less than 2% organic matter, the release rate for nitrogen will be too low to adequately provide the nitrogen needed for crop growth. A supplemental organic or manufactured nitrogen fertilizer may be needed.

However, soil organic matter content is not the only factor that affects the need for nitrogen fertilizer. The type of crop, level of production, and soil nitrate levels should also be considered when determining the N application rates.

Beware of Unfinished Compost

Using unfinished compost can be problematic for several reasons. For one, the carbon to nitrogen (C:N) ratio of unfinished compost may be too high. Ideally, a finished compost will have a C:N ratio of approximately 20:1. However, depending on the kinds of materials that the compost is derived of, the C:N ratio of compost can be as high as 600:1. When C:N ratios are high, the microbes performing decomposition don't have enough nitrogen to break down the high amount of carbon, so they will scavenge nitrogen from other places. If those other places happen to be your garden soils because you applied unfinished compost with a high C:N, the microbes may immobilize nitrogen in your garden soils from plant uptake. To prevent nitrogen immobilization, compost with a high C:N ratio must be sufficiently composted.

However, C:N ratio does not necessarily indicate the maturity of compost. Compost derived from vegetable wastes, for example, will naturally have a low C:N ratio (approximately 10-20:1). Immature compost with low C:N has a higher proportion of nitrogen which, if not finished properly, may be available in the form of ammonium. At high levels, ammonium can be toxic to plants, burning plant roots (when applied to the soil) or plant leaves (when applied as mulch).

Furthermore, microbes consume oxygen (O2) during decomposition so, if applying unfinished compost near plants, the microbes can potentially consume all of the O2 from the root zone as they continue to decompose the compost and, as a result, can greatly inhibit root growth.

Additionally, unfinished compost may not have fully destroyed any potential pathogens or weed seeds present in the compost.

Finished compost will have an earthy smell and will not resemble its original contents anymore. Compost maturity can be assessed in a laboratory by measuring the carbon dioxide (CO2) production by the microorganisms living in the material. Lower levels of CO2 indicate more mature compost (i.e., microbial activity is low because they have used the available nitrogen to decompose the carbon in the compost). Conversely, if microbes are producing CO2, they are still actively decomposing the material in the compost.

When making compost at home, it is advisable to turn the pile when the compost pile temperatures drop below 120ºF and before the compost pile temperatures exceed 160ºF. To encourage active microorganism processing, moisten the pile so that it feels like a wrung-out sponge. When temperatures do not rise above 120ºF after turning to reheat, compost has entered its curing stage. It should cure for at least forty-five days before being considered finished so that the compost can reach a chemically stable end point.

Weed Seeds and Diseased Plants

It is advisable not to compost diseased plants or weeds loaded with seeds. If the compost pile did not heat adequately or was not turned, the compost could be a source of weed seeds or plant disease pathogens. All parts of the compost should reach 145ºF to kill weed seeds and plant disease pathogens. Because only the inner layers of the pile will reach this temperature, it is important that the outer layers are folded into the inner layers and the pile is allowed to reheat to 145ºF. These temperatures must be maintained for at least 3 days. Temperatures of 130ºF will somewhat minimize weed seeds and pathogens.

Livestock manure (horse, sheep, cow, swine, etc.) can also be a source of weed seeds if the animals were fed hay that contained weed seeds or if seeds blew into a pile of manure.

Pet Manure

Do not add companion animal (cat, dog, etc.) feces to compost as this can increase disease transmission to humans, as well as the incidence of nuisance animals rummaging through the compost pile.

Authors: David Whiting, CSU Extension, retired; Adrian Card, CSU Extension; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS, retired. Reviewed December 2015 by Dan Goldhamer, CSU Extension. Revised May 2023 by Hania Oleszak, CSU Extension and Eric Hammond, CSU Extension.

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CMG GardenNotes #244

Cover Crops and Green Manure Crops

Terms: Green Manure and Cover Crop

A ***cover crop*** is a vegetative cover used to improve soil health, erosion or degradation in quality that is seeded annually in a garden or field. Cover crops can include grasses, legumes, or herbaceous plants. When the cover crop is tilled into the soil it is referred to as a ***green manure*** crop. These two terms are often used interchangeably.

Why Is a Cover Crop Beneficial?

Cover crops can protect the soil from wind and water erosion, suppress weeds, fix atmospheric nitrogen, build soil structure, and reduce insect pests.

Erosion Protection – The primary erosive force for Colorado is wind. Winter winds are especially destructive, carrying away small particles of topsoil from the soil surface. Another source of erosion can be from water movement, especially on sloped surfaces without much vegetative cover to hold the soil in place. A thick stand of a cover crop protects the soil surface from wind erosion and the cover crop's roots hold soil in place against water erosion during heavy downpours.

Weed Suppression – Cover crops left in place for all, or part, of a growing season can suppress most annual and some perennial weeds. Among the grasses, annual rye has allelopathic properties that prevent weed seeds from germinating and suppresses weed seedlings around the root zone of the rye.

Nitrogen Fixation – Legumes, inoculated with their specific Rhizobium bacteria, will take nitrogen out of the air (present in the soil), and store it in their plant tissues via nodules on the roots of the legume. This is a symbiotic relationship, as the bacteria uses the plant's sugar in return for nitrogen. Some of this nitrogen is available as roots die, but the majority becomes available when the legume is tilled under as green manure.

Soil Structure Creation – Plant roots exude a sticky substance that glues soil particles together, creating structure. Grasses are exceptional in their ability to do this.

Insect Pest Reduction – Cover crops encourage beneficial insect populations, often minimizing or eliminating the need for other insect control measures when cover crops are in place.

Why Is a Green Manure Crop Beneficial?

The use of green manure enhances soil fertility and soil structure by feeding soil organisms and gluing together soil particles into aggregates.

Soil Fertility – When fresh plant material decomposes in the soil, its carbon-to-nitrogen ratio becomes low, allowing the nitrogen to be easily released into the soil chemistry by bacteria. **Table 1** shows how nitrogen accumulation is greater with legumes, which have nitrogen-fixing Rhizobium bacteria growing in nodules on the legume roots. Notice the lower figure for rye.

Table 1. Nitrogen Accruement of Selected Cover Crops	
Cover Crop	**Nitrogen Accruement ***
Hairy Vetch	3.2 lbs./1000 ft^2
Crimson Clover	2.6 lbs./1000 ft^2
Austrian Winter Pea	3.3 lbs./1000 ft^2
Winter (Annual) Rye	2.0 lbs./1000 ft^2
* Nitrogen accumulated in growing crop prior to tilling under. Source: ATTRA: Overview of Cover Crops and Green Manures.	

Table 2 shows values of nitrogen fixation for legumes. Rates vary due to differences in the activity level of the Rhizobium bacteria.

Table 2. Potential Nitrogen Fixation Rates of Selected Legumes for Colorado	
Legume Crop	**Pounds N per 100 ft^2**
Crimson Clover	1.6-3.0
Field Peas	2.0-3.4
Hairy Vetch	2.0-4.6
Medics	1.1-2.8
Red Clover	1.6-3.4
Sweet Clover	2.0-3.9
White Clover	1.8-4.6
Source: *Managing Cover Crops Profitability*, Sustainable Agriculture Network	

Soil Structure – Microorganisms decomposing plant material and the plant material itself produce substances that glue soil particles together. These substances include slime, mucus, and fungal mycelia, which contain gums, waxes, and resins. These are aggregate soil particles, thereby enhancing the tilth, porosity, and water holding capacity.

Basic Recipes for Cover Crops and Green Manure Crops in the Garden

Spring-Planted

Most gardeners do not have enough area to surrender the space to a cover crop for an entire growing season. However, if you do, a spring seeded clover would give your soil a great boost. Some seed companies will “rhizo-coat” seed with the specific Rhizobium bacteria or apply

Rhizobium as specified on the bag. Rhizobium comes in a black powder specific to the species of clover and has a definite shelf life, so check the expiration date. To apply, you would broadcast the seed-Rhizobium mix at a specified rate after the last frost has passed using either a handheld broadcaster or other broadcasting method. The mixture should be applied to a loose seedbed and shallowly incorporated and watered consistently, until germination and seedling growth have occurred. Monitor water as you would in a lawn.

Till the cover crop under at least two weeks prior to planting. Decomposing plant material consumes soil oxygen and can create plant health problems if not tilled in ahead of time. More than one tilling may be necessary to get an acceptable kill of the clover.

Fall-Planted for Spring Till

Most will opt for a fall cover crop that is then tilled under as a spring green manure. Seeding dates for fall planted cover crops should be done by mid-October. Mid-September is ideal for the Colorado Front Range and the western valleys. In mountain elevations, plant in August or earlier. A rye-Austrian winter pea or rye-hairy vetch mixture will overwinter in Colorado. Hairy vetch is hardier than winter pea. Rye is extremely winter hardy.

Newer winter cover crops include Daikon radish, tillage radish, and turnips. There are many cover crop mixes available as well, usually referred to by the number or species per mix (for example, a 3-way mix). Prepare as above and broadcast at the rates in **Table 3**.

Table 3. Seeding Rates for Selected Winter Cover Crops

Cover Crop	Ounces per 100 Square Feet	Pounds per 1000 Square Feet
Winter Rye	4-6	2.5-3.75
Austrian Winter Pea	4-6	2-4
Hairy Vetch	2-3	1-2
Radish, Daikon	-	8-12 lbs./acre

Source: *Managing Cover Crops Profitability*, Sustainable Agriculture Network

Over-wintered cover crops become readily available salad-bar to geese and deer when other food resources are scarce. A cover crop that is well established prior to winter temperature extremes should rebound from wildlife grazing in late winter/early spring.

Till the cover crop in mechanically or turn it under with a spade one month before you plan to plant to seed into that area. Decomposing plant material consumes soil oxygen and can create plant health problems if not tilled in ahead of time.

Landscape Uses

Bare soil presents erosion and aesthetic issues. During droughty periods, watering restrictions and the lack of natural precipitation may make plants or turf establishment difficult or impossible. A temporary cover crop or long-term xeric grass may be the answer. In this scenario, the homeowner must understand that a cover crop will not look or feel like a healthy Kentucky bluegrass lawn but should satisfy the need to cover the soil.

Establishment and Care

Before Seeding – Prepare a seedbed for fine grass seed, ideally amending the soil with compost and tilling as deeply as possible. If possible, fence off the area from traffic.

Seeding – Water the area prior to seeding, if possible, to establish ample soil moisture levels. Broadcast the correct number of seed per area onto a loosely tilled, fine (no soil pieces bigger than 1/4 inch) seedbed. Shallowly incorporate seed with garden rake (not a leaf rake) to a depth of 1/4 to 3/4 inch deep.

For larger areas consider hydromulching the seed. This will save time and increase germination of seeds. When seed is applied with the mulch (hydroseeding) typically consists of applying a mixture of wood fiber, seed, fertilizer, and stabilizing emulsion with hydromulching equipment.

After Seeding – Consider laying a thin layer (<1" deep) of seed-free straw to hold in moisture and increase germination and survival of grass seedlings. Bird netting over the straw fastened to the ground with landscape fabric staples will keep the straw from blowing away.

Check moisture levels in the upper inch of soil at least every other day (soil should feel as moist as a wrung-out sponge) and water if necessary (and if possible).

Mowing – If necessary, mow as high as possible or use a weed eater to reduce the height or remove seed heads.

Removing Cover Crops – For most cover crops, either till under, mow and mulch heavily, or spray herbicide before it goes to seed.

Choosing a Cover Crop for Colorado

There are several options of cover crops for use in Colorado, however, they differ in their attributes and life cycles.

Cereal rye, winter wheat, and oats can all be grown as a thick mat to help prevent erosion and weed suppression. Oats will not survive the winter, whereas winter and cereal rye can be planted in the fall, overwinter as dormant plants and begin growth again in the spring. This ability for cover crops like winter wheat or cereal rye to remain in place over many months makes them a good fit to use in conjunction with warm-season crops such as tomatoes. This is done by removing the cover crop just prior to planting and seeding it again in the fall once the warm season crops are finished for the summer season.

Clovers can be used for cover-crops as they are readily available, easy to grow and add nitrogen to the soil through nitrogen fixation. Many species are cold-tolerant and will survive a mild winter, however red and crimson clover have low survivability with Colorado winters. Avoid white clover as a perennial crop as it is difficult to remove.

Buckwheat and rapeseed are both broadleaf cover crops that grow well in warmer temperatures and are effective at weed suppression. However, it is very important not to allow flowering or seed set of these crops, as they are very prolific with hundreds of seedlings emerging from dropped seed. Rapeseed is moderately cold hardy and may survive a mild winter, whereas buckwheat has no frost tolerance.

Alfalfa and hairy vetch also fix nitrogen and will survive our Colorado winters and regrow with warmer spring temperatures. However, alfalfa is a high-water crop with complex management needs and is also difficult to remove due to being a deep-rooted perennial. Hairy vetch should be terminated prior to setting flowers to prevent it from becoming weedy.

Peas and beans are another type of legume that fixes nitrogen and can be used as cover crops. In addition, they can be grown as green manures or edible crops by harvesting the pods and turning under the plants. Most will not survive Colorado winters.

Authors: Adrian Card, CSU Extension; David Whiting, CSU Extension, retired; Carl Wilson, CSU Extension, retired; and Jean Reeder, Ph.D., USDA-ARS retired. Revised October 2015 by Susan Carter, CSU Extension. Reviewed August 2023 by Amy Lentz, CSU Extension.

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CMG GardenNotes #245
Mulching

Mulch and Soil Amendments

The term ***mulch*** refers to a material placed on the soil surface. By contrast, a ***soil amendment*** refers to any material **mixed into** a soil.

Benefits of Mulching

Depending on the materials used, mulches can have many benefits. Mulch can:

- Reduce evaporation from soil surface.
- Increase soil microorganism activity, which in turn, improves soil tilth and helps lessen soil compaction.
- Stabilize soil moisture.
- Prevent soil compaction.
- Suppress weeds.
- Moderate soil temperature extremes.
- Control erosion.
- Increase water infiltration.
- Give a finished look, improving aesthetic quality.

Edging and Soil Grade

It is a common practice to add mulch above grade level. Without a defined edge, the mulch can spread off the bed onto lawns or sidewalks, creating a mowing or trip hazard. [**Figure 1**]

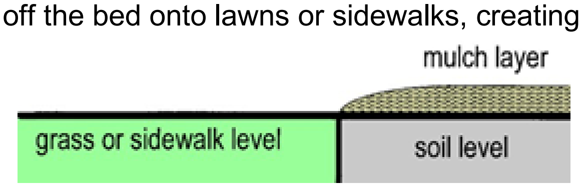

Figure 1.
Mulch added above grade spills out onto the lawn or sidewalk.

An effective alternative is to drop the soil level on the mulch bed three inches, so the top of the mulch is at grade level. However, ensure that the mulched bed does not fill with water draining from higher areas. [**Figure 2**]

Figure 2.
To keep mulch in place, drop the soil level in the mulch bed so the top of the mulch is at the grass or sidewalk level.

Another effective alternative is to round down the soil level along the edge of the bed. This gives a nice, finished edge at grade level, creates a raised bed effect for the flowerbed, and saves a lot of digging! [**Figure 3**]

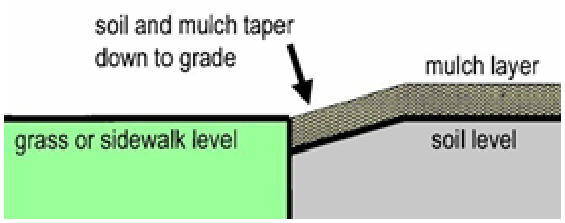

Figure 3.
An alternative is to taper the soil level along the edge of the bed.

Wood Chip and Bark Mulch

Wood chip or bark mulch can be great around trees, shrubs, perennials, and small fruits as seen in **Figure 4**. Wood chip and bark mulches can create a favorable environment for earthworms and soil microorganisms. Over time, this helps reduce soil compaction.

In perennial and shrub beds, wood chip mulch can reduce the need for irrigation by as much as 50%. Mulching materials that mesh are more effective at reducing water evaporation from the soil. However, these same mulches are also effective at reducing precipitation infiltration into the soil. Be sure to install irrigation beneath the mulch and understand how water moves (or does not move) through your mulch for the best success. Bark mulches, particularly shredded bark products, are more resistant to water transmission than wood chips.

An important consideration for wood chip and bark mulch stems from the intense sunlight and typically dry conditions across much of Colorado. Wood chips exposed to high surface temperatures from intense sunlight can become hydrophobic, preventing water infiltration to the soil. Wood chip or bark mulch, therefore, is not recommended for use in xeriscapes or with open planting plants unless it can be frequently checked and distributed to maintain its ability to conduct water to the soil. Wood chips under a canopy of leaves or in regularly irrigated settings are typically not affected by hydrophobicity.

Figure 4. Wood chip or bark mulch in the perennial and shrub bed enhances soil tilth over time.

Wood chips or bark mulch can be less effective in areas with persistent winds, as even relatively large pieces can be blown away in gusty conditions. Plant cover and wind breaks reduce the susceptibility of the mulch to being blown out of landscapes.

Sometimes people can be concerned that wood chips and bark mulch will reduce nitrogen availability in the soil or that plant diseases or plant defense compounds that are present in the wood chips and bark mulch could harm landscape plants. Thankfully, claims of infertile soils and toxic mulch are not supported by much evidence.

When placed on the soil surface as mulch, wood chips and bark mulch do not tie-up soil nitrogen. However, incorporating wood chips or bark mulch into a soil can create a nitrogen deficiency. Soil microbes, which consume the wood, also require nitrogen; wood or wood products mixed into the soil can cause a population boom for microbes and result in a lack of nitrogen available for plants.

Buried wood can take ten or more years to decompose. Using nitrogen fertilizer can compensate for the nitrogen used in the decomposition process in order to remediate soils with wood chips or bark mulch already incorporated.

In vegetable or annual flowerbeds where the soil is routinely cultivated to prepare a seedbed, be sure to keep wood mulch from mixing into the soil. Rake the mulch away thoroughly before beginning and replace it when seedlings have sprouted (or once plants have been planted).

Plant pathogenic fungi can persist on un-composted wood chips but would need to travel into the soil in order to infect healthy roots of susceptible landscape plants. Wood chips that have been dried, as in the case of most purchased mulch, do not carry pathogens. Fresh mulch or mulch that remained damp from production to application could transfer pathogens into above-ground wounds or to roots if they were to come into contact with the mulch. This is another reason to avoid mixing mulch into the soil and to keep mulch from piling up around the stems and trunks of landscape plants. Furthermore, most common plant pathogenic fungi are ubiquitous in the environment and opportunistic. Susceptible plants in the right environmental conditions will likely develop disease regardless of the mulch. Keeping plants healthy by minimizing stress is a more fruitful way to prevent disease than fretting about mulch contamination.

In addition to pathogens, claims that plant secondary compounds from mulch will leach into soils and kill plants can be found in the popular press. “Cedar mulch” and mulch made from the wood of black walnut trees are often specifically cited. No evidence supports that any tree going by the common name “cedar,” including *Juniperus*, *Cedrus*, or *Thuja* produces allelopathic chemicals (compounds that function as herbicides on neighboring plants). While juglone, the compound in black walnut trees, can have harmful effects on certain plants, the compounds do not persist long in mulch. Using aged mulch and/or leaching mulch with water quickly mitigates any possible problems. Seedlings and shallowly rooted plants are more susceptible to allelopathic compounds; mature landscape plants are not likely to be affected in any case.

Rock Mulch

Rock and gravel mulch are often maligned as not beneficial to plant growth. Because they are sometimes grouped together as a single product, conclusions about them from research can be hard to draw. For example, many studies do not specify rock size when discussing “rock mulch” in comparison to wood mulches. In studies that have differentiated among rock sizes, though, mulch with gravel less than one centimeter in diameter has been shown to suppress weed growth and reduce water loss from evaporation similarly to wood chip mulch. Additionally, surface temperatures in planting beds mulched with gravel remain cooler than paved surfaces or surfaces mulched with wood chips.

Landscapes in dry climates are most likely to benefit from gravel mulches. Pea gravel has been shown to improve water infiltration into the soil, especially in short, intense precipitation events like thunderstorms; larger rocks increase runoff. Even a thin layer of gravel mulch has been shown to double the amount of precipitation that infiltrates the soil; a three-inch layer can increase water infiltration manyfold. In order to function as mulch, though, stones must be small enough – no more than around a half-inch in diameter. Larger stones do not confer the benefits of mulch.

Gravel mulch can improve the soil too – by increasing the available soil moisture and warming the soil temperature beneath it, plant roots and microbes get a boost. The increased biologic activity can result in improved organic matter content and subsequent tilth, even though the mulch itself does not decompose.

Grass Clippings or Leaf Mulch

Grass clippings and leaves make good mulch when applied dry or when applied gradually in thin layers and allowed to dry between applications. Grass clippings and leaves decompose rapidly, requiring additional layers during the growing season but providing nutrients to soil microorganisms as they "compost in place." A grass clipping or leaf mulch recycles its nutrients into the garden bed or lawn that generated it.

Figure 5. Grass clipping are great for the vegetable garden and around annual flowers. Directly from the bag, place them around the plants in thin layers, allowing each layer to dry before adding more.

They are not as resistant to compaction as wood chips or gravel mulch.

Do not apply fresh grass in thick layers as it will mat, produce foul odors, reduce air- and water infiltration, and even become hydrophobic. Do not use clippings from lawns that have been treated with herbicides or other pesticides.

Grass clippings and leaves are an excellent choice in vegetable and annual flower beds that receive annual cultivation to prepare a seedbed. [**Figure 5**]

Product Selection

The selection of a mulch depends on its intended use. Consider your goals and the size of the area in relation to the cost of materials and availability.

If the main objective is soil improvement, consider an organic mulch that gradually breaks down, like wood chips. If the area is used primarily for annual flowers, it often is more practical to use a quickly decomposing organic mulch, such as composted leaves or grass clippings, that can be turned under each fall. Make sure these materials have not been treated with persistent herbicides or they may damage your landscape plantings.

If the main objective is water infiltration or xeriscaping, consider rock mulch. Any stones used for mulch should be smaller than a half-inch in diameter for the benefits of water conservation and weed suppression. Larger stone sizes do not function well as mulches and can actually inhibit plant growth but may provide landscape interest.

Mulch changes the way that heat is transferred to the ground and surrounding structures. Gravel mulch transfers more heat to underlying soil than wood chip mulch. This may serve to keep landscape plants in better overall health in cold-winter temperate climates like ours. On the other hand, it can also transfer heat to buildings and utilities or cause some tender plants to begin growing too early in the spring. Wood chip mulch insulates the soil against temperature swings, but the surface temperature of sun-exposed wood mulch can be hotter than that of gravel mulch. Match your mulch to your situation.

Black plastic (polyethylene) and woven plastic weed barrier fabrics (polypropylene) are not recommended beneath mulch in landscape areas. Black plastic is impermeable therefore no oxygen exchange can occur to the soil. Lack of oxygen to the roots and soil microbes significantly reduces plant growth. Black plastic also prevents water penetration. Woven weed barrier fabrics initially allow some minor oxygen and water exchange to the soil, but eventually become clogged and create the same issues. Weeds easily germinate on top of the fabric and root into or through it. Both plastic and woven plastic fabrics disrupt the life cycles of many pollinators and other soil invertebrates. Synthetic fabrics and plastic sheeting, *used alone,* can be good choices for large-scale vegetable production where regular maintenance and replacement is easily performed. In gardens and landscapes, the correct application of other mulches is a better option.

General Use

- **Depth**
  In order to suppress weed growth, wood chip, gravel, grass clipping, and other mulch should be four inches deep. More is not better, though! Applying mulch too deeply can reduce air exchange to the soil and reduce the growth of your desirable plants.

  Mulch applied to the correct depth does not require underlayment with fabric, newspaper, cardboard, etc.; these products can interfere with water and air exchange in the soil. Choose the correct mulch, apply it deeply enough, and forget the fabric or newspapers.

- **Around Trees**
  Wood chip mulch is great for trees and shrubs, protecting trees from lawnmower damage. However, do not make “mulch volcanoes” around tree trunks by applying chips up against a tree’s trunk, as seen in **Figure 6**. Wet chips piled up against the trunk can cause bark problems and interfere with growth. Keep the mulch back at least six inches from the trunk, and do not apply too deeply.

Figure 6. Never make a “mulch volcano.” It leads to decay of the bark and interferes with trunk taper. Keep mulch back six inches from the trunk.

Converting Lawn to a Mulch Area

If a lawn will be changed over to a mulched garden bed, again consider timing, expense, and end-goal. Many techniques can be successful. Once a lawn is dead and gone, be sure to apply mulch in the new garden.

- **Spray With a Non-Selective Herbicide**
  This method is a relatively fast, inexpensive, and easy way to kill your lawn. It maintains the soil’s structure and microbiology and leaves the organic content (dead grass and roots) in place to decompose. Because you are not disturbing the soil, weed seeds are not brought to the surface to germinate. Different herbicides have different risks and effectiveness. Read and follow the label instructions for safe application.

- **Solarize**
  Water thoroughly and cover the area you want to kill with clear plastic, making sure that the edges are sealed. Leave it there for four to eight weeks. This method is most effective in the hottest months from June through August. It is not aesthetically pleasing and may invite complaints from the neighbors, but it is a low-effort option. Leave the dead grass or rake it

up. Avoid disturbing the weed seed bank by not tilling it in. Research has shown that there is only a temporary reduction in soil microbial activity from solarizing – the soil microbes quickly recover.

- **Mow Close and Cover**
  In early spring, scalp the grass by mowing it as short as possible. A weed whacker works well for this. Then cover the area with a thin layer of compost and an eight to twelve inch layer of woodchip mulch. Water well to encourage decomposition. Many gardening sites recommend using layers of newspaper or overlapping pieces of cardboard. This will slow down an already lengthy process, and it temporarily reduces soil microbial activity which is important for soil and plant health. Be aware that this will take a season or more and still may not kill all of the grass.

- **Use a Sod Cutter or Dig It Up**
  If your lawn is in good condition, you can cut strips with a sod cutter, roll them up and give them away. First, mow and water your lawn. Cut overlapping strips of sod and roll them up. Cut strips short enough to be moved easily. This method is quick but requires heavy equipment and you are left with the dilemma of how to get rid of the rolls of sod. Alternatively, you can flip the sod over to decompose in place, keeping the organic matter in your yard or garden. You then treat it like the 'mow and cover' method. Cover with compost, mulch, and water, to promote decomposition.

Mulch and Fire-Resistant Landscaping

Mineral mulch (gravel) is the best option for making landscapes more fire-resistant. Organic mulch materials have a broad spectrum of flammability, particularly if ignition is from point sources like cigarette butts or spent fireworks. In low-wind conditions, moistened wood mulch resists ignition from such sources; dry wood chips, bark, pine needles, and other small-particle organic mulches are more ignitable. Larger and denser mulch pieces make for the most fire-resistant wood mulch. Rubber mulch will always burn and should be avoided.

The continuous, wind-driven accumulation of embers, as occurs in wildfires, will ignite any organic mulch. One study showed ignition and combustion of wood mulch with 83% moisture content in winds of only eighteen miles per hour. In rural areas and in the wildland-urban interface (WUI), choosing the right mulch (e.g., gravel or rocks) is an important component of creating defensible space.

Summary: Considerations in Selecting Mulch

Gardeners often inquire about the best mulch. No one mulch is best for every situation. What is practical and available varies from gardener to gardener and within different communities. The following summarizes considerations in selecting mulches to ask yourself:

Site
- Plants: trees, shrubs, perennials, annuals, specialty crops.
- Annual soil preparation: annual flowers versus perennial beds.
- Landscape goals and maintenance.

Function
- Soil improvement goals and potential.
- Frequency of reapplication.
- Water infiltration and irrigation method.

- Depth needed for weed management.
- Appearance.
- Soil temperature (heating or insulation).
- Off-site movement by wind, water, and gravity.
- Safety (children, lawn mowers).

Cost

- Local availability.
- Cost of product.
- Size of area to be treated.
- Depth of application.
- Transportation costs.

Authors: David Whiting, CSU Extension, retired; Carl Wilson, CSU Extension, retired; Catherine Moravec, former CSU Extension employee; and Jean Reeder, Ph.D., USDA-ARS, retired. Artwork by David Whiting. Used with permission. Revised December 2015 by Eric Hammond, CSU Extension. Reviewed April 2023 by John Murgel, CSU Extension, and Deryn Davidson, CSU Extension.

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MASTER GARDENER
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CMG GardenNotes #246

Making Compost

Essential ingredients for the composting process include microorganisms, organic matter, water, and air (oxygen). The microbes that cause decomposition naturally occur on plant wastes. Compost starters or inoculums are not needed to start decomposition. The compost needs to be moist to the touch, but not soggy (excluding air). Air (oxygen) is essential for microbes. Too fine of particle size, excessive water, large amount of soil, and packing of materials may decrease oxygen levels.

What Items Should and Should Not be Composted?

Materials To Use

- Leaves.
- Garden debris free of diseases and weed seeds (i.e., carrot tops, chopped corn stalks, pea vines, spent flowers, etc.).
- Weeds, free of seeds.
- Kitchen scraps free of meat, dairy, fats, and oils.
- Shrub and tree trimmings smaller than one-quarter inch in diameter.
- Hay, straw, and other plant residues.

Materials To Avoid

- Weeds with seeds; seed may not be killed if compost pile(s) do not heat to 145°F.
- Diseased plants, including tomato and potato vines and potato peelings.
- Tree branches greater than quarter inch in diameter; large sizes should be run through a chipper first, as they will be very slow to decompose.
- Fats, oils, grease, meat, and dairy products (slows decomposition and attracts pests.)
- Kitchen scraps with meat, dairy, fats, oils, or grease.
- Pet or human feces may transmit diseases.
- Synthetic or plastic fiber does not decompose.
- Wood ash and lime drive up the pH of the soil.

Materials To Use With Limitations

Large amounts of grass clippings. Due the small particle size and high nitrogen of grass clippings, they tend to smell unless mixed with brown materials. Instead recycle the nutrients back into the lawn by not bagging.

Manure. Manures may contain strains of *Escherichia coli* and other bacteria that cause human illness. If manure is composted for food gardens, a four-month curing process following composting is necessary to reduce pathogens.

Large amounts of plants/weeds treated with pesticides (including herbicides, insecticides, and fungicides). Most pesticides readily break down in the composting process and present no threat as long as the decomposition process has been completed.

Large amounts of high tannin-containing leaves (oak and cottonwood). These are slow to decompose but can be used in small quantities if chopped well and mixed with other materials.

Large amounts of juniper, pine, spruce, and arborvitae trimmings. Resins in these highly resinous wood and leaf cuttings protect these materials from decomposition and extend the time needed for composting in comparison with other plant materials.

Large amounts of paper products. Newsprint is best recycled through recycling collection operations rather than converted to compost. If paper is composted due to a shortage of dry materials, add no more than 10% of the total weight of the material being composted. Higher amounts create imbalances in the carbon to nitrogen ratio. Do not use color printed glossy magazines as inks may not be safe as a soil additive.

Large amounts of soil. Some gardeners like to sprinkle small amounts of soil into the compost bin as a source of microbes. However, this is not necessary as small amounts of soil are routinely added with the roots of weeds and other plants. Large amounts of soil increase weight, decrease oxygen infiltration, and can suffocate microorganisms.

What Is the Carbon to Nitrogen Ratio?

For optimum processing, the ratio of carbon to nitrogen in the compost needs to be around thirty to one. This is typically the combination of two parts green materials with one-part brown materials. Compost piles too high in carbon will be slow to process or may not decompose. Piles too high in nitrogen develop strong ammonia odors. [**Table 1**]

Processing works best if the green and brown materials are mixed before adding to the pile. An alternative is to layer the green and brown materials. Layers should not be more than two inches deep for fine materials and six inches deep for coarse materials.

When only brown materials are used, nitrogen fertilizer may be added to supply the needed nitrogen for decomposition. The standard rate is one half cup ammonium sulfate (or equivalent) per bushel of brown materials.

Table 1. Examples of Green and Brown Materials

Green Materials	Brown Materials
Vegetable wastes (12–20:1)	Dry leaves (30–80:1)
Coffee grounds (20:1)	Corn stalks (60:1)
Grass clippings (12-25:1)	Straw (40–100:1)
Cow manure (20:1)	Bark (100–130:1)
Horse manure (25:1)	Paper (150–200:1)
Poultry manure, fresh (10:1)	Wood chips and
Poultry manure, with litter (13–18:1)	Sawdust (100–500:1)

What Is the Ideal Location for the Compost Bin?

Choose a composting site carefully. Considerations include the following:

- **Partial shade** avoids baking and drying in summer but provides some solar heating to start the composting action.
- **Wind protection** prevents too much moisture loss.
- **Water source** to keep the pile moist but not soggy.
- **City ordinances** often prohibit compost bins within ten to twenty feet of property lines.
- **Convenience** for loading and unloading of materials away from yard activities.

What Is the Ideal Size and Type of Compost Bin?

Structures are not necessary for composting but do help prevent wind and marauding animals from carrying away plant wastes. Open compost piles can be used in less-populated rural locales, but structures are necessary in urban areas. Many composting structures can be purchased or built. They vary in how well they can be managed to meet the requirements for effective decomposition under Colorado environmental conditions.

Wire and wood structures are common for home composting. An inexpensive, easy-to-build type is made from hardware cloth (a stiff, lightweight wire mesh found with fencing materials at many hardware stores). A four-foot high by thirteen-foot length will make a small bin four feet across. Use wire to hold the length of hardware cloth into a round hoop. To unload the bin, unhook the wires holding the hoop in the circle.

Structures built of wire dry out faster, depending on exposure to drying winds. Plastic covers or tarps are often used to protect the outer layer from drying out. Covers are removed to add water and plant materials and to aerate the pile.

Figure 1.
Simple compost bin made with wooden pallets for $5 to $25.

Wood structures do not dry out as much but are more expensive to purchase or build.

An inexpensive and easy to build bin is made from a wooden pallet. Use wire and deck screws to fasten sides, add hinges to the front section for easy access. The cost runs between $5 and $25. [**Figure 1**]

An efficient wood structure is the three-chambered bin system that allows plant material to be aerated by turning it from one bin to the next as it decomposes. New materials are put in the first bin to begin decomposition. After a few weeks, it is turned to the second bin for active decomposition. As the process naturally slows, it is turned to the third bin for further curing. [**Figure 2**]

Figure 2.
Three chambered compost bin build for $20 to $80.

Many brands of small home compost bins are available commercially typically running $80 to over $100. Some are manufactured from recycled plastics. They work well for small yards that produce few plant wastes. [**Figure 3**]

Figure 3.
Earth Machine™ compost bin.

Size – A minimum volume of material is necessary to build up the heat for efficient composting. When materials are heavy in green materials, keep the bin smaller to allow for better aeration. Three feet by three feet by three feet is considered the minimum size to allow for heating. This small size may be adequate for small yards with limited materials to compost. If composting fall leaves and materials high in brown materials, a larger bin (measuring five feet by five feet) may keep the processing going through the winter months.

In-ground pit composting presents problems with turning or aerating the plant material and can pool water, which leads to undesirable low oxygen conditions.

What Is the Routine Care of a Compost Pile?

The breakdown of organic yard wastes is a biological process dependent on microorganism activity. Like most living things, these microbes require favorable temperatures, moisture, oxygen, and nutrients.

Temperature – Plant-digesting microbes operate in a temperature range of 70°F to 140°F, with breakdown occurring slowly at the lower temperatures. Well-managed compost rapidly breaks down in summer when compost temperatures quickly reach 120°F to 130°F. If summer heat plus the heat produced by active microbes causes the temperature of the plant mass to exceed 160°F, the microbes will die.

In Colorado winter temperatures, a well-constructed five foot by five-foot pile will continue processing throughout the winter. Smaller piles will cool, stopping microbe activity and extending the time required to produce a finished product. In the spring, small piles may need to be turned and mixed with additional materials to enhance processing.

Moisture and Oxygen – Moisture and oxygen are essential to microbial activity. In a region with limited rainfall such as Colorado, add moisture regularly to maintain composting. If parts of the composting material dry out, many microorganisms in the dry areas die. Even when moisture is added, the microbes that remain require time to multiply and resume plant digestion. The net result is slower composting. However, excess moisture displaces air and slows breakdown. Surplus water creates low oxygen conditions, favorable for certain microbes to multiply and produce foul odors. The best description of the proper moisture level is moist or damp but not soggy. The entire mass of plant wastes should be moistened uniformly to the point where only a few drops of water can be squeezed from a fistful of plant material.

The size of plant particles that go into the compost also affects aeration. Large particles allow a lot of air to circulate around the plant chunks, but breakdown is slow because microbes can act only on the outside, not on the inside of the large chunks. Particles chopped into smaller chunks increase the surface area for microbes to operate. Particles chopped too small will compact and restrict air flow. Moderate-sized plant pieces of 0.5 to 1.5 inches are the best size to use and can be produced by hand or machine shredding. Chop woody materials into a smaller size. Leave soft plant parts in larger pieces for effective composting. Fluff or turn the material with a pitchfork or aerator tool at regular intervals to provide additional aeration and to distribute microbes throughout the compost.

Nutrients – The microbes that break down plants use the plants for food. Nitrogen is the most important food nutrient because a nitrogen shortage drastically slows the composting process. Woody and dried plant materials tend to contain little nitrogen in comparison to the total mass of the material. However, green plant material contains a high percentage of nitrogen. A mix of two parts green to one-part brown material yields the best nitrogen balance. Add a plant fertilizer high in nitrogen when green materials are scarce.

Maintenance

How should materials be layered in the compost pile?
Mixing of green and brown materials before placing it in the bin speeds decomposition. Otherwise, alternate layering of green and brown materials.

Does a compost pile require turning?
No, but turning speeds decomposition and turns weed seeds and diseased plants into the center of the pile where temperatures are higher. Use an aeration tool to reach into the compost and lift and move plant materials. Turn the entire mass occasionally to provide uniform aeration.

What other routine care does a compost pile require?
Keep it moist but not soggy. If overly wet, it will stink. Being dry stops the activity of microbes. The compost should feel moist to touch. However, it is too wet if more than a few drops of water can be squeezed out.

Will the compost process kill plant disease organisms and weed seeds?
Only if the pile heats above 145°F and is turned regularly. Few home compost piles heat adequately; thus it is advisable not to compost weeds with seeds and diseased plants.

Can fresh materials be added to the bin during processing?
Yes, if small amounts are occasionally added. However, if a lot of materials are available, it would be better to start a new pile rather than combining a lot of fresh materials with nearly finished compost.

How can you tell when compost is finished? It will reduce in size by about half, will have lost the identity of the materials, and will smell “earthy.” It typically takes three to nine months, depending on type of materials, climatic conditions, and tending.

Compost Troubleshooting [Table 2]

Table 2. Compost Troubleshooting		
Problem	**Cause**	**Solution**
Rotten Odor	• Anaerobic conditions (the lack of oxygen). • Excess moisture. • Compaction. • Small particle size.	• Turn the pile. • Make smaller pile. • Add dry porous materials.
Ammonia Odor	• Too much nitrogen (low C:N ratio).	• Mix in brown materials. • Note: If compost high in ammonia is used as mulch, it may burn tender foliage. If mixed into soil as an amendment, it can burn roots.
Outside Couple of Inches Is Dry	• Dry Colorado air.	• Water regularly and cover outer edge with tarp.
Low Temperature	• Pile too small. • Insufficient moisture. • Poor aeration. • Lack of nitrogen. • Cold weather.	• Make larger pile. • Add water when turning pile. • Turn pile to aerate. • Mix in green materials or add N fertilizer. • Increase pile size in winter.
Pests (Rats, Bears, Raccoons, Insects)	• Presence of meat, dairy, or fatty wastes.	• Do not compost kitchen scraps with meat, dairy, fats, oils, or grease.

Authors: David Whiting, CSU Extension, retired. Artwork by David Whiting. Used with permission. Reviewed October 2022 by Sherie Shaffer, CSU Extension.

MASTER GARDENER
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CMG GardenNotes #251

Asking Effective Questions About Soils

Outline:

Communications

Education, the product of Colorado State University Extension, is about communication. Are there ways we can make our communications with clients more effective? One way is to improve our questioning technique. Another is to focus on soil conditions, which contribute to a large percentage of landscape plant disorders. If we don't know how to ask our clients effective questions about their soils, we will have difficulty diagnosing their plant problems.

Many of the questions asked should be about physical soil properties, not chemical ones. Poor physical soil conditions for plant growth make up the bulk of soil concerns. Soil tests tell us about texture but little else relating to soil's physical conditions. A routine soil test is often a poor tool for figuring out a plant growth problem. Compaction, poor drainage, and low oxygen levels are the most frequent causes of poor root growth, which are not assessed by a soil test.

Physical properties of soil include texture (mineral solids), soil structure, and pore space of a soil.

Ask Open Ended Questions

Ask questions that require long answers. While occasional yes-no answers may help, be sure to stay on track with questions requiring more detailed answers. Do this by using **what**, **how**, **when**, **where,** and perhaps **why** leads:

- Tell me about your soil.
- Describe your soil for me.
- Is the soil part of your landscape or one that you brought in?
- How does your soil react when you water it?
- How do you care for your soil?
- Have you/when did you amend your soil?
- How often do you till your soil?
- What do you add to the soil?
- What worms or other living things do you see in the soil?

Be careful with “why” questions. They can sound accusatory and get in the way of gathering information.

Piggyback Questions

Remember to “piggyback” your new questions on top of the answers already obtained. Example – “Let’s talk about your soil in a little more detail. Is it a clayey or a sandy soil?” Avoid negative presuppositions. For example, ask “Have you amended your soil? What amendment did you use?” Do not accusingly ask, “You didn’t amend your soil with fresh manure, did you?” Other questions to consider are:

- Have you dug down into the soil?
- What is it like?
- Was it easy to dig?
- How deep did you dig down?

The following questions aim at assessing compaction and what may have been done to prevent it.

- Have you tried inserting a screwdriver into the soil? Did it go in easily or was it hard to insert?
- Do people frequently walk over that soil?
- Does any equipment or vehicles run over the soil?
- Does water enter easily or run off the soil?
- Is the soil mulched? What mulch was used?

Active Listening

Use “active listening” techniques or paraphrasing to restate what you have learned. By stating what is understood, both you and the client confirm a reference point to proceed in the conversation. An example is “So, you’re saying that your soil is a clay that is not mulched and not frequently walked on?”

This may lead to a clarifying statement such as “That is not what I’m saying. What I mean is …” This is okay because it can clarify important points in the communication.

Neutral Comments

Another way to keep the exchange moving is to use neutral comments. These comments acknowledge listening and prompt further information. Tone is important in using neutral comments. Sound interested but do not insert judgmental overtones into the comments. Examples of neutral comments are:

- You noticed a white substance in the soil.
- You didn’t find any earthworms.
- You used deicing salts on the walk.

Wait Time

Use “wait time.” Don’t be afraid of “dead air” in a conversation. It’s common to want to keep the conversation going by keeping the air filled with talk. Ask the client a question then pause for the answer. They may take some time to get their thoughts together, remember what happened, or consider how to get their words out before they respond. Don’t be tempted to fill in a question before they have a chance to answer the last one.

- Does your soil crumble easily when you press on the clods? *PAUSE.*
- How much compost did you add to the soil when you planted? *PAUSE.*

Listen For

Listening for information is an important skill to develop. When listening for information, you pick up clues to pursue with further questions. This approach has a higher probability of leading to solving a problem. It is very different than a ***"listen from"*** point of view that tries to fit information into a preconceived scenario. "Listen for" often pursues false leads, eliminates them, and then pursues other trails. This kind of detective work can be fun, and only practice will enable you to develop this skill.

Authors: Carl Wilson, CSU Extension, retired. Revised July 2016 by Mary Small, CSU Extension, retired. Reviewed April 2023 by Cassey Anderson, CSU Extension.

Reviewed April 2023

CMG GardenNotes #120-145

Botany

Trifolium pratense, Red Clover
Artwork by Melissa Schreiner © 2023

This Botany curriculum was developed by David Whiting, CSU Extension, retired; Joanne Jones, CSU Extension, retired; Linda McMulkin, CSU Extension, retired; Alison O'Connor, PhD, CSU Extension; and Laurel Potts, CSU Extension, retired. Cover art by Melissa Schreiner. Used with permission.

- Colorado Master Gardener GardenNotes are available online at https://cmg.extension.colostate.edu/.
- No endorsement is intended of products mentioned, nor is criticism implied of products not mentioned.

- Colorado State University, U.S. Department of Agriculture, and cooperating Colorado counties.

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CMG GardenNotes #120

Botany

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #121, *Horticulture Classification Terms.*
- #122, *Taxonomic Classification.*
- #131, *Plant Structures: Cells, Tissues, and Structures.*
- #132, *Plant Structures: Roots.*
- #133, *Plant Structures: Stems.*
- #134, *Plant Structures: Leaves.*
- #135, *Plant Structures: Flowers.*
- #136, *Plant Structures: Fruit.*
- #137, *Plant Structures: Seeds.*
- #141, *Plant Physiology: Photosynthesis, Transpiration, and Respiration.*
- #142, *Plant Growth Factors: Light.*
- #143, *Plant Growth Factors: Temperature.*
- #144, *Plant Growth Factors: Water.*
- #145, *Plant Growth Factors: Hormones.*

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.

Plant*talk* Colorado™

- http://planttalk.org.
- #2004, *Additional Information: Plant Societies*.
- #2008, *Commonly Used Plant Terms.*

Other

- International Plant Name Index at www.ipni.org.
- U.S. Department of Agriculture Plant Data Base at http://plants.usda.gov.
- *Botany for Gardeners, Fourth Edition: An Introduction to the Science of Plants*, Brian Capon. Timber Press, 2022. ISBN: 978-1643261430.
- *Gardener's Latin: A Lexicon*, Bill Neal. Algonquin Books, 2003. ISBN: 9781565123847.
- *The Science of Plants.* Tom Michaels. 2022 University of Minnesota Libraries https://open.umn.edu/opentextbooks/textbooks/1196.

- *Manual of Woody Landscape Plants,* Sixth edition, Michael A. Dirr. Stipes, 2009.
- *Flora of Colorado*, Jennifer Ackerfield. Second edition. BRIT press, 2022.
- *How Plants Work*, Linda Chalker-Scott. 2015.
- *Alice in the Land of Plants,* Yiannis Manetas. 2012.
- *The Why and How of Home Horticulture*, D.R. Bienz. Freeman, 1993. ISBN: 9780716723530.
- *Plant Form: An Illustrated Guide to Flowering Plant Morphology*, Adrian D. Bell, 2008, Timber Press.

Learning Objectives

At the end of this training, the student will be able to:
- Understand the importance of using correct terminology to enhance communications about plants.
- Practice skills needed in diagnosis by carefully examining plants and plant parts for plant identification.
- Correlate plant structure and growth processes with common plant disorders.

Review Questions

Note: Class time does not permit the instructor to cover all the topics. Please take time to read and review study materials. This unit covers many horticultural and botanical terms. The objective is to understand that terms are used to communicate and using terms correctly improves communications.

It is not the purpose of this training to memorize terms or definitions. When you come across a term that you do not understand, you can use the glossary in most botany or horticulture textbooks to look up the meaning.

Classifying Plants
1. Why is it important to understand the concepts of plant taxonomy and classification as a gardener?
2. What is meant by:
    - Warm season and cool season plants.
    - Tender and hardy plants.
    - Alpine, prairie, woodland, wetland, xeric and native plants.
    - Herbaceous and woody.
    - Trees, shrubs, and vines.
    - Deciduous, evergreen, and semi-evergreen.
    - Broadleaf, narrowleaf and needleleaf.
    - Annual, summer annual and winter annual.
    - Biennial.
    - Perennial, herbaceous perennial, spring ephemerals and woody perennials.
3. Why is it important to know the difference between monocots and dicots, especially when it comes to applying herbicides?
4. How can you identify monocots and dicots based on leaf venation, flower parts, and seed cotyledons?
5. Give the protocol for writing out scientific names.

Plant Structures

6. Describe the relationships of cells to tissues to structures to plants.
7. List the three primary functions of roots.

8. Define and identify the following root terms:
    - Meristematic zone.
    - Primary roots.
    - Lateral roots.
    - Root tip.
    - Epidermis.
    - Root hairs.
    - Tap root system.
    - Fibrous root system.
    - Adventitious roots.
9. List the three primary functions of stems.
10. Identify the following parts of a stem:
    - Nodes.
    - Internodes.
    - Terminal bud.
    - Lateral bud.
    - Terminal bud scar.
    - Leaf scar.
    - Bundle scar.
11. Describe how stem characteristics are used in plant identification.
12. Define the following stem terms:
    - Shoot.
    - Twig.
    - Branch.
    - Trunk.
    - Cane.
    - Bulb.
    - Corm.
    - Crown.
    - Stolon.
    - Rhizome.
    - Tuber.
13. List the two primary functions of leaves.
14. Define and identify the following leaf terms:
    - Leaf blade.
    - Leaf tip.
    - Leaf base.
    - Mid-vein or midrib.
    - Lateral veins.
    - Leaf stalk or petiole.
    - Stipules.
    - Bud.
    - Pinnate venation.
    - Palmate venation.
    - Parallel venation.
    - Simple leaf.
    - Pinnately compound.
    - Palmately compound.
    - Doubly (bipinnately) compound.
    - Alternate leaf arrangement.
    - Opposite leaf arrangement.
    - Whorled leaf arrangement.
15. What is the primary function of flowers?
16. Identify the following parts of a flower:
    - Sepals.
    - Calyx.
    - Petals.
    - Anthers.
    - Filament.
    - Stamen.
    - Stigma.
    - Style.
    - Ovary.
    - Ovules.
    - Pistil.
    - Floret.
17. Define the following flower and plant terms:
    - Complete flower.
    - Incomplete flower.
    - Perfect flower.
    - Monoecious plant.
    - Dioecious plant.
18. Describe how flowers are used in plant identification.
19. What is the primary function of fruit?
20. Identify the following parts of a seed:
    - Seed coat.
    - Endosperm.
    - Cotyledon.
    - Plumule.
    - Radicle.

Plant Growth

21. Define:
    - Photosynthesis.
    - Respiration.
    - Chloroplasts.
    - Chlorophyll.
    - Transpiration.
    - Stomate.
22. Define what is meant by:
    - Full sun.
    - Filtered shade.
23. Define photoperiod.
24. List three factors that influence plant hardiness.
25. What does a hardiness zone map indicate?
26. Define the following terms related to winter injury:
    - Sunscald.
    - Frost crack.
    - Winter drought.
27. How do temperate-zone plants know when to start growing in the spring?
28. List the roles of water in plant growth.
29. Explain how a plant balances shoot growth with root growth.
30. Explain how a plant grows toward the sun.

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CMG GardenNotes #121

Horticultural Classification Terms

Horticulture and Related Fields

Horticulture – The science and art of cultivating flowers, fruits, vegetables, turf, and ornamental plants in an orchard, garden, nursery, or greenhouse, on a large or small scale.

Horticulturist – A specialist in horticulture.

The terms **ornamental horticulture**, **landscape horticulture**, and **environmental horticulture** are commonly used to identify the sub-fields of horticulture dealing with designed landscape settings.

Agriculture – The theory and practice of growing crops.

Agronomy – A branch of agriculture dealing with field crop production and soil management.

Botany – A branch of biology dealing with plant life, (i.e., anatomy, taxonomy, genetics, physiology, and ecology). The science of applied botany deals with plants grown in uncultivated settings.

Forestry – The science of developing, caring for, or cultivating forests; the management of growing timber.

Urban forestry – A branch of forestry dealing specifically with the unique growth limitations and needs of trees in the landscape setting.

Horticultural Classifications of Plants

With hundreds of thousands of plant species and varieties on the planet, horticulturists look for practical ways to group them together. Plants are grouped by various common characteristics to help us communicate similar cultural requirements, garden uses, morphology, or taxonomy among other things. The following are examples of common classifications used in horticulture.

Classification by Use

1. **Edibles**
   A. Fruits*
      1. Tree fruits.
      2. Small fruits.
   B. Vegetables
      1. Warm-season vegetables.
      2. Cool-season vegetables.
   C. Herbs
      1. Culinary.
      2. Medicinal.
   D. Nuts

2. **Ornamentals/Landscape Plants**
   A. Woody plants
      1. Trees.
      2. Shrubs.
      3. Vines and ground covers.
   B. Herbaceous plants
      1. Flowers and foliage plants.
      2. Vines and ground covers (that do not develop woody stems).
   C. Grass/Turf

3. **Potted Plants, Houseplants, Gift Plants**
   A. Flowering Plants (grown primarily for flowers).
   B. Foliage plants (plants that may produce flowers, but which are grown for their foliar characteristics).

*Note: Do not confuse the multiple uses of the word ***fruit***. In reference to cookery (fruits and vegetables), “fruit” refers to crops primarily used in some European cuisines as a dessert (e.g. peaches, apples, strawberries, and raspberries) whereas “vegetables” refers to crops served as part of savory dishes (potatoes, carrots, spinach, etc.). In this frame of reference, tomatoes are vegetables. In taxonomic or anatomical classification, “fruit” refers to a seed-bearing structure – in this sense, tomatoes and squash are fruit. Potatoes are rhizomes (modified stems), carrots are roots, spinach is leaves, etc.

Classification by Climatic Requirements

Tropical plants originate in tropical climates with a year-round summer-like growing season without freezing temperatures (but possibly with wet and dry seasons). Examples include cacao, cashew and macadamia nuts, banana, mango, papaya, and pineapple.

Sub-tropical plants cannot tolerate severe winter temperatures but often need winter chilling to grow and produce correctly. Examples include citrus, dates, figs, and olives.

Temperate plants require a cold winter season as well as a summer growing season and are adapted to survive temperatures below freezing. Examples include apples, cherries, peaches, maples, cottonwoods, and aspen. In temperate-zones, tropical and sub-tropical plants can be grown as annuals and houseplants.

Cool Season plants thrive in cool temperatures (40°F to 70°F daytime temperatures) and are tolerant of light frosts. Examples include Kentucky bluegrass, peas, lettuce, and pansies.

Warm Season plants thrive in warm temperatures (65°F to 90°F daytime temperatures) and are intolerant of cool temperatures. Examples include corn, tomatoes, and squash.

Tender plants are intolerant of cool temperatures, frost, and cold winds. Examples include most summer annuals, including impatiens, squash, and tomatoes.

Hardy plants are tolerant of cool temperatures, light frost, and cold winds. Examples include spring-flowering bulbs, spring-flowering perennials, peas, lettuce, and cole crops.

Hardiness refers to a plant's tolerance to winter climatic conditions. Factors that influence hardiness include minimum temperature, recent temperature patterns, water supply, wind and sun exposure, genetic makeup, and carbohydrate reserves.

Cold hardiness zones are determined by the USDA and refer to the average annual minimum temperature for a geographic area, and thus the average minimum temperature that a plant can tolerate. Temperature is only one factor that influences a plant's winter hardiness.

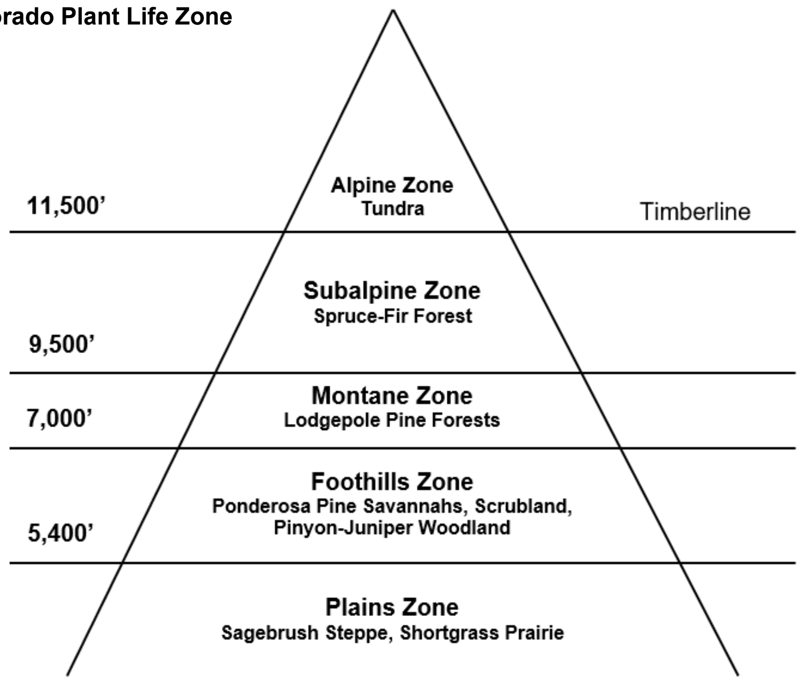
Classification by Elevation and Plant Life Zones

Plants can be classified by the plant communities in which they usually occur. Environmental characteristics determined by elevation create “zones” dominated by distinguishable plant communities. Examples of these communities include pinyon-juniper woodlands, sagebrush steppes, high plains grasslands, montane and subalpine forests, and the alpine tundra. Matching plants’ life zones to garden conditions can be a great way to pair the “right plant” with the “right place.” Plants grown outside of their life zones may require mitigations like extra water, more (or less) shade than they might tolerate in their natural habitat, special soil modifications, etc.

The elevation of life zones shifts downward as latitude increases. A climb of 1,000 feet is equal to a trip around 600 miles northward. Plant life zones will remain in the same relative position regardless of latitude, but the absolute elevation of each zone decreases as you move northward, for example the alpine tundra above 11,500 feet in Colorado is similar to the artic tundra near sea level on the north coast of Alaska and Canada. Higher elevations have increasingly shorter growing seasons due to colder temperatures. High elevations tend to have poorly developed soils, stronger light, persistent winds, and greater temperature fluctuations than lower elevations of the same region. Due to this harsh environment, plants of the alpine tundra tend to be compact in form. [**Figure 1**]

Figure 1 on next page.

Figure 1. Colorado Plant Life Zone



Classification by Ecological Adaptations

Related to life zones are ***ecological adaptations*** of plants. For example, characteristics of the Colorado high plains include low humidity, limited rainfall, and alkaline soils low in organic matter. Plants from environments with similar growing conditions will do well on the high plains, in general.

In higher mountain communities, the short frost-free season and low summer growing temperatures significantly change what plants can be grown well there compared to on the plains.

The following are a few examples of terms used to describe classifications based on ecological adaptation.

Alpine plants tolerate the short growing season, cold, and wind of higher mountain elevations. They are typically low-growing, small leaf perennials. Growing alpines at lower elevations takes special gardening techniques and care and has led to the development of Rock Alpine gardening as a horticultural movement.

Prairie plants are adapted to the open sun and winds of the plains. These plants are further classified into dry, mesic, and wet categories, or as tallgrass or shortgrass prairie plants. Many prairie plants, particularly tallgrass prairie plants, are very competitive in deep, nutrient-rich soil that you would find in the American Midwest.

Woodland plants are adapted to low light conditions either by shade avoidance (spring and winter growth and summer dormancy) or by shade tolerance. They tend to do best in soils rich in organic matter.

Wetland plants tolerate continually moist soil conditions of a bog or a pond. Some will tolerate drier soils, but most make poor choices for standard garden conditions. Some wetland species, like cattails, will spring up in overwatered, compacted soils in landscapes, and can serve as an indicator of irrigation issues.

Xeric plants tolerate dry conditions. They are often also tolerant of bright light and warm temperatures due to a variety of adaptations such as succulent, waxy, hairy, or small leaves, taproots, and succulent stems. Growing xeric plants in too wet conditions can result in poor plant performance.

Native and Adapted Plants for the Urban Environment

Native (indigenous) plants refer to plants growing in a given area during a defined time period. In The United States, the term often refers to plants growing in a region prior to the time of settlement by people of European descent. Many gardeners mistakenly consider *native* plants as *xeric* plants, and *xeric* plants as *native* plants. The two terms are **not** interchangeable – many native plants in our region are xeric, for example, but many others are not.

In gardening, the concept of native should not refer to political boundaries, such as state or country, but to an ecological habitat during a defined chronological period. For example, Colorado blue spruce and quaking aspen are native to the ecological habitat referred to as the montane zone. They are not native to the Colorado high plains, or elevations below 8,000 feet. Between 500 million and 300 million years ago, what is now Eastern Colorado was once an inland sea. Therefore, aquatic plants such as kelp would have been native at one time. Over time, the ecological habitat changed, changing the native plants along with it. Environmental change is an ongoing process, based both on global climatic events and on the activity of all organisms, including humankind.

Adapted plants are those that reliably grow well in a particular habitat without specific attention from humans in the form of winter protection, soil amendments, pest protection, water, etc. Adapted plants are considered to be ***low maintenance*** plants. In the context of gardening, **Adapted Plants** usually refers to non-native plants from similar ecological contexts. Some adapted plants have become noxious weeds.

The urban environment, for gardening purposes, needs to be recognized as a unique ecosystem, with challenges beyond what could be expected in the native natural environment. Characteristics of the urban environment include:

- Soil compaction.
- Reduced rooting areas.
- Increased surface runoff creates significant water quality problems.
- Higher temperatures and lower humidity.
- Air pollution.

Characteristics of an urban environment cultivated by humans (a garden) may include:

- Reduced wind.
- Increased availability of water due to irrigation.
- Increased organic matter and soil fertility.
- Different insect communities, both pests and beneficials.
- Increased soil stability.
- Slower temperature fluctuations.

The unique challenges of the urban environment and site-specific features should be considered when planning gardens with native or adapted plants.

Classification by Stem and Leaf Texture

- **Herbaceous** plants have non-woody stems.
- **Woody** plants have woody stems that usually live for several years, adding new growth each year.
  - **Deciduous** trees and shrubs shed all leaves at approximately the same time annually. Deciduous plants can be conifers (e.g. larch or bald cypress) or flowering plants (most shade trees), broadleaf or narrowleaf.
  - **Evergreen** trees and shrubs retain some leaves longer than one growing season so that leaves are present throughout the year. Seasonal drop of some of the oldest interior leaves are a natural part of the life cycle. Evergreens can be broadleaf or narrowleaf.
  - **Semi-evergreen** plants may retain their leaves year-round, depending on the winter temperature and moisture, losing them only in harsh winters.
- **Broadleaf** plants have a broad leaf blade, such as ash, maple, lilac, and beans.
- **Narrowleaf** plants have needle-like leaves such as pine and spruce, or awl-like leaves such as junipers.
- **Grass-like** plants or **graminoids** have narrow leaves, usually arising from the base of the plant. Grasses, rushes, and sedges are all graminoids.

Classification of Woody Plants by Growth Habit

Growth Habit refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread. [**Figure 2**]

- **Trees** typically have a single trunk and mature height over twelve feet.
- **Shrubs** typically have multiple branches from the ground and a mature height less than twelve feet.
- **Vines** have a climbing, clasping, or self-clinging growth habit.

Many landscape plants can be considered small trees or large shrubs. The terms tree or shrub is applied based on the general appearance of the plant – some say, "you walk under a tree, and around a shrub." Trees can be further classified by canopy shape.

A thorough understanding of growth habits is important to make knowledgeable decisions regarding plant placement, selection, pruning, and maintenance.

The species, cultivar, and/or marketing names of plants sometimes indicate a particular characteristic of growth habit – for example, *Pinus ponderosa* roughly translates to "big [heavy/significant] pine," and Mini-Man™ Viburnum is a dwarf variety.

Figure 2. Tree Forms

Columnar Oval Vase Weeping Pyramidal Round

Classification by Life Span

From a horticultural perspective, life span is a function of inherent plant characteristics, climate, and usage. Garden plants including tomatoes and geraniums that are grown as annuals in Colorado, are perennials in climates without freezing winter temperatures.

Annuals complete their life cycle (from seedling to setting seed) within a single growing season. However, the growing season may be from fall to summer, not just from spring to fall. These plants come back in subsequent growing seasons only from seeds.

> **Summer annuals** germinate from seed in the spring and complete flowering and seed production by fall, followed by plant death. Their growing season ranges from spring to fall. Examples include marigolds, squash, and crabgrass.
>
> **Winter annuals** germinate from seed in the fall, with flowering and seed development the following spring, followed by plant death in summer. Their growing season is from fall to summer. Examples include winter wheat, cheatgrass, redstem filaree (*Erodium cicutarium*) and annual bluegrass.

Biennials complete their life cycle within two growing seasons. Biennials germinate from seed during the first growing season and produce foliage and storage organs the first summer. Quite often, they maintain a rosette growth habit the first season, meaning that all the leaves are basal, or close to the base of the plant. They flower and develop seeds the second season, followed by death.

In the garden setting, we grow certain biennials as annuals - carrots, onions, and beets, for example, because we are more interested in the root than the bloom. Some biennial flowers, such as hollyhocks, may persist as short-lived perennials.

Perennials live through several growing seasons and can survive a period of dormancy between growing seasons. These plants regenerate from root systems or protected buds, in addition to seeds.

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Reviewed September 2022 by John Murgel, CSU Extension.

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CMG GardenNotes #122

Taxonomic Classification

Outline:

The most universal classification system of plants is plant taxonomy, or systematics. Taxonomy is the science of systematically naming and classifying organisms into groups that reflect their relatedness to other organisms. Plant systematics is an old science that uses the gross morphology (physical characteristics, [i.e., flower form, leaf shape, fruit form, etc.]) and, more recently, genetic information to understand their relationships and heritage. The science of classifying organisms to understand their relationships and evolutionary history is also known as *Phylogenetics*. Characteristics that distinguish organisms sometimes become a part of their name, though not always unambiguously. For example, *Quercus alba* means "white oak", and is so named because the underside of the leaf is white, and *Pinus contorta*, lodgepole pine, translates to "twisted pine", named for twisted seeds rather than its characteristically straight trunks.

Plant taxonomic classification changes with continuing research, so inconsistencies in nomenclature will be found among references. Knowing the currently accepted names is important, but do not get caught-up in which is "correct", as it can be a moving target. Rather focus on "are you communicating?"

An overview of plant taxonomy helps the gardener understand the basis of many cultural practices. For example, fire blight is a disease of the rose family; therefore, it is helpful to recognize members of the rose family to diagnose this disease.

Common Taxonomic Divisions

The scientific system of classification divides all living things into groups called **taxa** (singular, **taxon**). Taxa are arranged in hierarchy, ranging from Kingdom to Subspecies, with each taxonomic division "nested" into the group above. A phylogenetic Kingdom is usually the largest recognized taxonomic group. Every living thing can be classified into taxonomic groups according to this system.

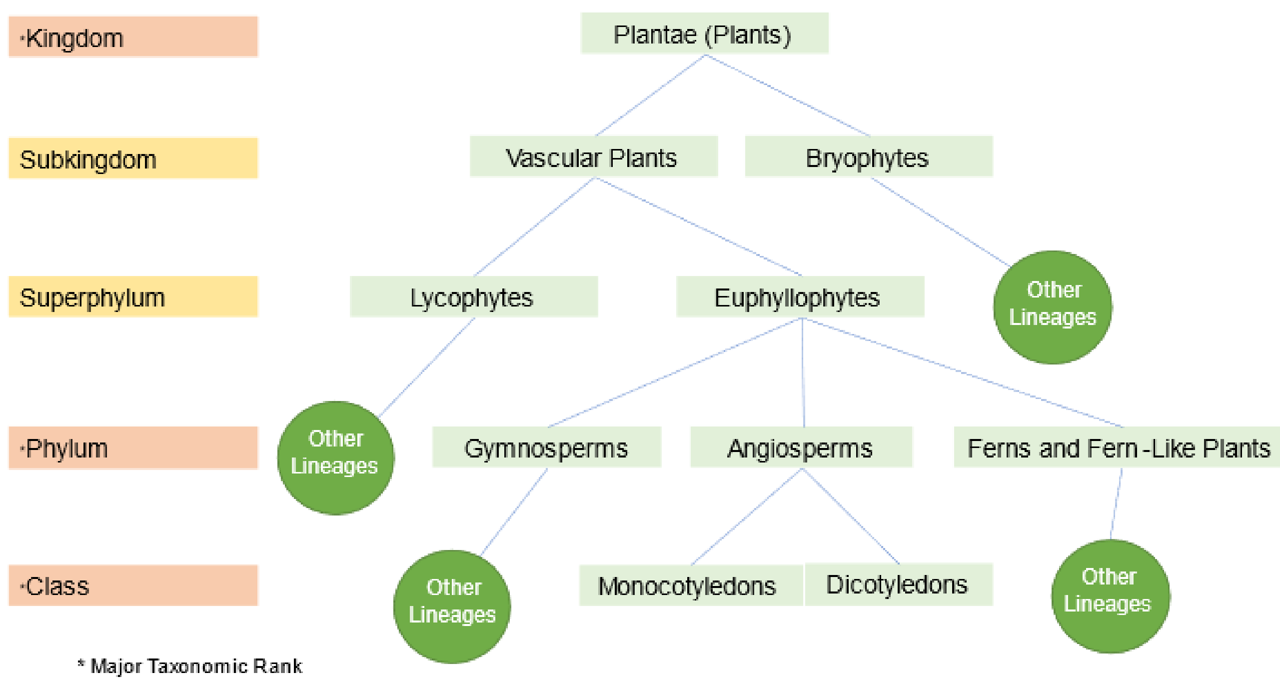
The seven major taxonomic groupings are, in order:

Kingdom
Phylum
Class
Order
Family
Genus
Species

Plants are in the kingdom of ***Plantae***. Other kingdoms include ***Fungi***, ***Protista*** (one-celled organisms including yeasts, bacteria, and protozoans), and ***Animalia*** (animals). [**Figure 1**]

The plant kingdom is divided between **bryophytes**, or **non-vascular plants**, (including true mosses and liverworts) and ***tracheophytes*** or **vascular plants** (plants with a vascular system that includes *tracheids*, a type of xylem cell).

Figure 1. The Upper Portion of the Plant "Family Tree"

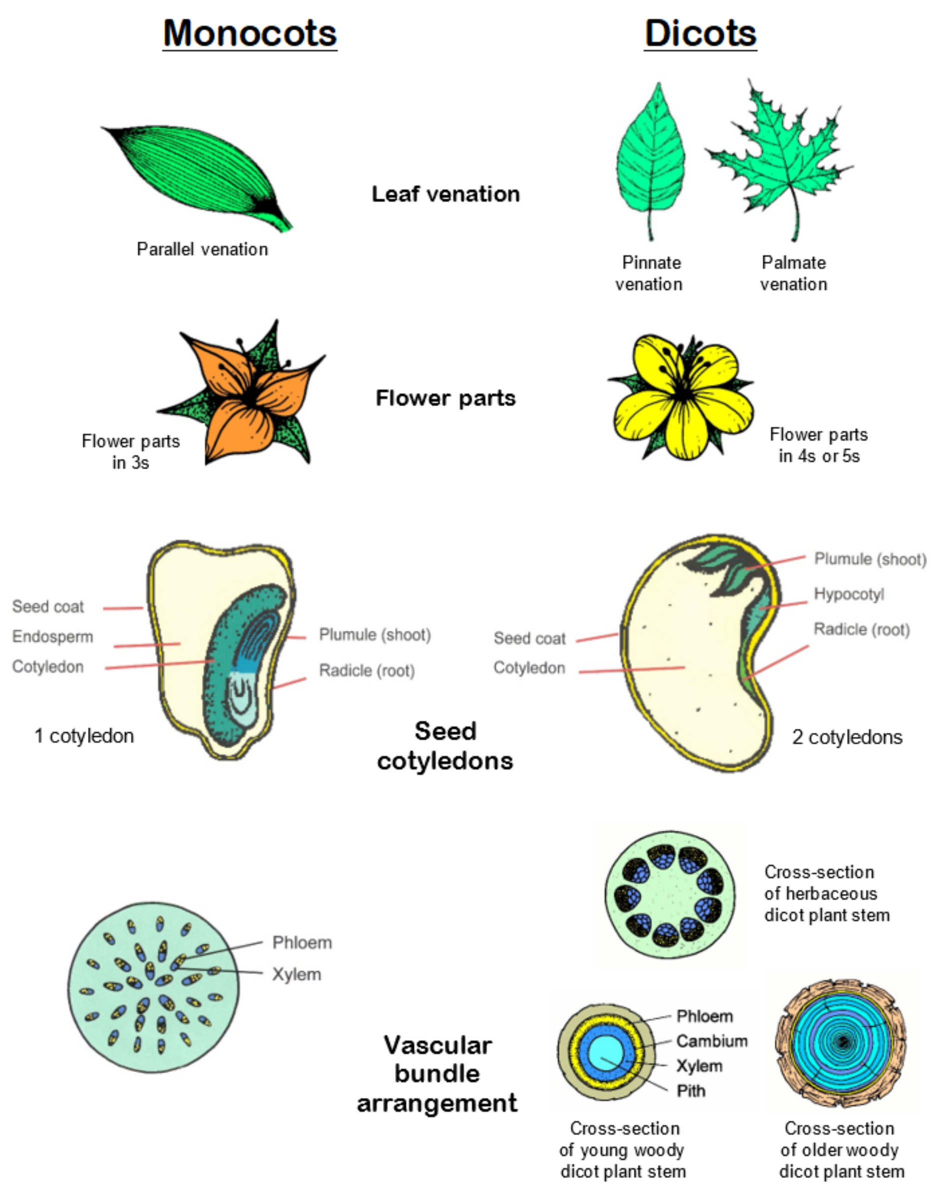


Vascular plants are further divided into two subgroups: lycophytes (plants with very simple vascular systems, like *Selaginella* and club-mosses) and *euphyllophytes* (plants with complex vascular systems and overtopping branches, like ferns, conifers, and flowering plants). One sub-group of the Euphyllophytes is the ***spermatophyta***, or **seed plants**, so named because they produce seeds rather than spores or free-swimming gametes. The seed plants include five phyla, Cycads, Gingkos, Conifers, and Gnetophytes (commonly referred to as a group as **Gymnospermae** or Gymnosperms) and flowering, **Magnoliaphyta** (Angiosperms). Plants from these groups make up most of the plants in the landscape (the most notable exception being ferns, which reproduce from spores rather than from seeds).

Gymnosperms do not produce flowers, but rather "naked seeds" (the translation of Gymnosperm) on or in specialized structures, such as pinecones. Cycads are common landscape plants in tropical and sub-tropical areas and may be grown as houseplants in Colorado. *Ginkgo biloba* is the only existing species in the Ginkgoales, but the fossil record includes many other members. Arborvitae, junipers, Douglas-fir, fir, pine, and spruce are examples of conifers (or literally, “cone-bearers”). The Gnetophytes are another small group, with only a few dozen species, the most well known in our area being *Ephedra*.

Angiosperms or phylum Magnoliaphyta, are flowering plants, and with nearly 260,000 existing species make up most of the diversity of plants. Angiosperms have more complicated vascular systems than other plant groups and a highly modified reproductive system compared to older lineages. Angiosperm seeds are enclosed in a fruit (i.e., not naked). The angiosperm phylum is divided into several classes: two important groups for landscape maintenance are ***monocotyledons*** (**monocots**) and ***dicotyledons*** (**dicots**). (Note that “dicots” are not themselves an individual taxonomic “class,” but rather the term refers to several variously related classes of flowering plants that are distinct from monocots). Distinguishing between monocots and dicots is a common practice in landscape management. For example, some of our common herbicides are selective against one group or another. Lawn weed sprays (such as 2,4-D and dicamba) kill dicots (broadleaf plants like dandelions) but not monocots (the grass). Other herbicides will kill monocots but not dicots, allowing the gardener to kill grass (a monocot) in the shrub or flowerbed (dicots). [**Figure 2**]

Figure 2. Monocots versus Dicots



Orders and Families

Plant Orders and Families are separated from one another by characteristics inherent in their reproductive structures (flowers, fruit, and seed). Many family members have obvious morphological similarities, but the resemblances can be less plain too. As with higher taxonomic groups, orders and families share common traits that reflect a shared heritage.

Family names end in '*aceae*'. Examples of common families include the following:

- ***Caprifoliaceae*** – Honeysuckle family, including elders, honeysuckle, snowberry, and viburnum.
- ***Fabaceae*** – Pea family, including Pagoda tree, locust and Siberian peashrub.
- ***Oleaceae*** – Olive family, including ash, forsythia, lilac, and privet.
- ***Rosaceae*** – Rose family, including apple, cotoneaster, crabapple, potentilla, peach, plum, mountain ash and 250 common landscape plants.

Genus and Species

The taxonomic divisions beneath the family level are genus and species. Plant species are named using a binomial system that was standardized by Carolus Linnaeus (1707-1778), a Swedish biologist who is known as the father of modern taxonomy thanks to his efforts. The binomial system assigns each living thing two names: a genus and specific epithet, which together make up the species name. The genus name comes first and is analogous to a person's last name (like Smith). The specific epithet names follow as a more specific identifier. It would be analogous to a person's first name (like John). Plant names are regulated internationally by the International Code of Botanical Nomenclature (ICBN), https://www.iapt-taxon.org/nomen/main.php. The goal of the ICBN is to provide only one, internationally recognized, correct name for each taxonomic group within a stable system of names (i.e., a "classification"), and is officially updated every six years by the International Botanical Congress.

Genus	Specific Epithet
Smith	John
Catalpa	*speciosa*

The common names of plants typically apply to a genus (plural ***genera***). For example, *Acer* is the genus of maples, *Fraxinus* of the ash, and *Juniperus* of the junipers. Many genus names have become 'generic' common names. For example: anemone, rhododendron, crocus, and viburnum, are all common names that are identical to the genus name. Genus names are always nouns in the singular.

The specific epithet classifies a member of a genus as a unique species. The specific epithet is always used in conjunction with the genus, never alone, and is an adjective, noun in apposition, or possessive noun that modifies the generic name. The specific epithet must grammatically agree with the genus (according to the rules of Latin).

When genus name and specific epithet are written, they are italicized. The genus name is always capitalized, but the specific epithet is not.

In writing, the abbreviation "sp." following the genus indicates a single unidentified species and "spp." indicates multiple species. For example, "Acer sp." would indicate an unidentified species of maple, and "Acer spp." refers to multiple species in the maple genus. The "sp." or "spp." is not italicized.

In technical papers, the person who first described the species, called the **Authority**, follows the specific epithet. For example, Japanese maple would be written *Acer palmatum* Thunberg or *Acer palmatum* T. The potato would be written *Solanum tuberosum* Linnaeus or *Solanum tuberosum* L.

Variety and Cultivar

The taxonomic divisions beyond the genus and species level include subspecies, variety, and form (forma).

Variety, form, or **subspecies** is a sub-grouping of species assigned to individuals displaying unique differences in natural populations. The differences are inheritable and reproduce true-to-type in each generation. For example, cauliflower and cabbage are varieties of the same species, *Brassica oleracea*, and our local native maple, *Acer saccharum* subsp. *grandidentatum* is a subspecies of sugar maple, *Acer saccharum*.

In technical writing, variety and subspecies names must be denoted with ‘var.’ or ‘ssp/subsp.’ when following a species name. The names themselves are italicized, while var. or ssp. is not. For example, the thornless variety of honeylocust would be written *Gleditsia triacanthos* var. *inermis*. The bigfruit evening primrose would be written *Oenothera macrocarpa* ssp. *incana*.

A cultivar (“cultivated variety”) is a man-made variety of plant that displays unique characteristics, typically of gardening importance. Some cultivars can be reproduced by seed; others need to be propagated vegetatively because they derive from a single plant. Vegetatively propagated cultivars are genetic clones. Cultivar names are not italicized, rather they are placed in ‘single quotes’. Often, a grower will introduce a trademarked marketing name for plants that is different from the recognized cultivar name - a marketing name has no taxonomic value. For example, October Glory Red Maple is *Acer rubrum* ‘October Glory’, whereas the real name of Autumn Blaze® Maple is *Acer* ‘Jeffersred’.

It is possible to have a cultivar of a variety. For example, *Cornus florida* var. *rubra* ‘Cherokee Chief’. Cultivars of native plants are sometimes called “Nativars”.

Examples of Taxonomic Classification chart on next page.

Examples of Taxonomic Classification:

Examples of Taxonomic Classification

- Vascular plants
  - Seedless
    - *Pteridophyta (Pterophyta)* – ferns
  - Seeded
    - *Gymnospermae* – **Gymnosperms** (naked seed plants)
      - *Cycadophyta* – Cycads
      - *Pinophyta (Coniferophyta)* – **Conifers** (cone bearing plants)
        - *Cupressaceae* (cypress family)
          - *Juniperus* spp. – **junipers**
            - *Juniperus horizontalis* (creeping Juniper)
              - *Juniperus horizontalis* 'Blue Chip' (blue chip juniper)
          - *Thuja* spp. – **arborvitae**
        - *Pinaceae* (pine family)
          - *Abies* spp. – **fir**
          - *Larix* spp. – **larch**
          - *Picea* spp. – **spruce**
            - *Picea pungens* – Colorado spruce
              - *Picea pungens* 'Bakeri' – Bakeri Colorado spruce
          - *Pinus* spp. – **pines**
            - *Pinus ponderosa* – ponderosa pine
          - *Pseudotsuga menziesii* – **Douglas-fir**
    - *Angiospermae* – **Angiosperms** (flowering plants) / ***Magnoliophyta (Anthophyta)***
      - *Aceraceae* – Maple family
        - *Acer* spp. – **maples**
          - *Acer platanoides* – Norway maple
            - *Acer platanoides* 'Crimson King' – Crimson King Norway maple
      - *Salicaceae* – Willow family
        - *Populus* spp. – **cottonwood, poplar, and aspen**
          - *Populus deltoides* – eastern cottonwood
            - *Populus deltoides* 'Siouxland' – Siouxland eastern cottonwood
          - *Populus tremuloides* – quaking aspen
      - *Rosaceae* – rose family
        - *Rosa* spp. – **roses**
          - *Rosa rugosa* – Rugosa rose
            - *Rosa rugosa* 'Hansa' – Hansa rugosa rose
        - *Cotoneaster* spp. – **cotoneasters**
          - *Cotoneaster apiculatus* – cranberry cotoneaster

Why Are Scientific Names "in Latin"?

When Linnaeus published *Species Plantarum* in 1753, he consistently used and established modern binomial classification. Because Latin was used in Western Europe at that time as the language of state and science, scientific names of plants are Latinized - that is, they take the form of Latin words, while they themselves are not necessarily Latin. (Even Linnaeus' own name is Latinized, from the Swedish Karl von Linne). Today, Linnaeus' system continues to provide consistent naming across the globe, allowing scientists from anywhere, speaking any language, to communicate with one another with confidence.

Pronouncing Scientific Names

Botanic names are universal **in spelling** (that is, each plant has a single genus and specific epithet, **spelled the same** worldwide). By using botanic names, plants can be positively identified from over 380,000 known plant species.

However, pronunciation of scientific names is not universal and will vary based on the local language. (You say 'toe-may-toe' and I say 'toe-mah-toe'.) Based on the native language and local dialect of the user, scientific names sound rather different in various countries.

Here are a few basic guidelines for American English:

- Botanic names, like Latin, are entirely phonetic. Silent letters are rare and occur only in names derived from languages other than Latin (e.g. Greek) or when a botanic name is based on a person's name. In general, what you see is what you say.
- Consonants are pronounced as in English. The letters 'c' and 'g' are normally hard in front of the vowels 'a', 'o' and 'u'. When in front of 'i' and 'e', the sound can be soft in American parlance (think "circle" and "gentle").
- The letters "ch" are usually pronounced like "k" because they are usually derived from the Greek letter χ ("chi") in botanic names.
- Vowels are usually long in an accent syllable. For example, *Acer* becomes AY-ser and *Pinus* become PIE-nus.
- Adjacent vowels may be marked with a dieresis or double dot, to indicate that they are to be pronounced separately. For example, the cycad genus *Dioön* is pronounced in three syllables: "dye-oh-on", not in two syllables: "dye-oon". The vowel pair "ae" is pronounced as a diphthong (i.e., not separately) as in "Julius Caesar". When in doubt, pronounce vowels separately.
- Examples:
  - *Quercus macrocarpa* (bur oak) – KWER-kus MAC-row-CAR-pah.
  - *Elaeagnus angustifolia* (Russian olive) – Ell-ee-AG-nus an-GUS-tih-FOL-ee-auh.
  - *Ptelea trifoliata* (hoptree/wafer ash) – TEA-lee-ah.
  - try-FOAL-ee-AH-tah (note the Greek-derived "pt").
  - *Kalanchoe pinnata* – KAL-an-COE-ee pin-NAH-ta (note the Greek-derived "ch" and separately pronounced vowels "oe").

Botanic Names Add Meaning

Botanic names often reflect something about the plant's description since the specific epithet is an adjective or noun modifying the genus name. For example:

- ***americana*** = of America – *Fraxinus americana* (white ash).
- **-ensis** = from a particular area (e.g. *texensis* for "from Texas") – *Clematis texensis* (scarlet leatherflower)
- ***baccata*** = berry bearing – *Taxus baccata* (common yew).
- ***micro*** = little, small – *Antennaria microphylla* (littleleaf pussytoes).
- ***officinalis*** = medicinal – *Rosmarinus officinalis* (rosemary).
- ***repens*** = creeping, crawling – *Berberis repens* (creeping Oregon grape).
- ***undulata*** = wavy – *Quercus undulata* (wavyleaf oak).
- ***variegatus*** = variegated – *Miscanthus sinensis* 'Variegatus' (variegated maiden grass).
- ***vulgaris*** = common – *Syringa vulgaris* (common purple lilac).
- ***alba*** = white – *Quercus alba* (white oak).
- ***niger*** = black – *Pinus nigra* (black pine).
- ***rubra*** = red – *Acer rubrum* (red maple), *Quercus rubra* (red oak).

- ***sanguineus*** = blood-red – *Geranium sanguineum*.

Common Names

In contrast to scientific names, common names are local in use rather than global. For example, *Liriodendron tulipifera* is known as the tulip tree in the northern USA and as yellow poplar in the south. *Carpinus caroliniana* goes by American hornbeam, blue beech, musclewood, water beech and ironwood. The European white lily, *Nymphaea alba*, has fifteen English common names, forty-four French common names, one-hundred-five German common names, and eighty-one Dutch common names. More problematic still, the same common name can often refer to more than one plant, for example, "bluebell" refers to several dozen plants across different genera and families. Common names can lead to confusion about taxonomy, ("poison oak" is not an oak at all), and huge numbers of plants do not have common names. **The use of scientific names is absolutely essential to ensure efficient, accurate communication about plants, particularly on a worldwide basis.**

References on Plant Taxonomy

Some suggested sources of scientific names and taxonomic information include the following:

- World Flora Online http://www.worldfloraonline.org/.
- Missouri Botanical Garden Angiosperm Phylogeny http://www.mobot.org/MOBOT/research/APweb/.
- USDA Plant Data Base at http://plants.usda.gov/.
- Published *Florae* of Geographic Areas, for example, *Flora of Colorado* by J. Ackerfield (Brit Press, 2015).

Authors: David Whiting, CSU Extension, retired; Alison O'Connor, CSU Extension; Joanne Jones CSU Extension, retired; Linda McMulkin, CSU Extension, retired; and Laurel Potts, CSU Extension, retired. Line drawings by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed October 2022 by John Murgel, CSU Extension.

Reviewed October 2022

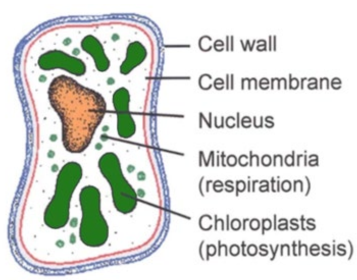
CMG GardenNotes #131

Plant Structures: Cells, Tissues, and Structures

Plant bodies are structurally and functionally specialized. This specialization is effected by differentiation among types of cells and tissues. Plant **cells** are grouped into **tissues** based on function (e.g., protecting the plant, conducting water, etc.). Cells and tissues comprise distinct **organs**, or externally recognizable plant parts.

Cells are individual building blocks for life processes and growth. Common cells contain genetic matter (**deoxyribonucleic acid**, or **DNA**) and metabolic and storage organelles. Cells are the site of **photosynthesis** (sugar production). Photosynthesis, the process of converting light energy into stored carbohydrates, is conducted in organelles called **chloroplasts**. [**Figure 1**]

Figure 1. Plant Cell



Tissues are groups of cells that are similar in function. Categorizing plant cells in this way is in some sense artificial because structural features in plants not only vary and intermix with one another, but because they are capable of changing into one another. Tissues are typically divided by functional properties that are related to position within the plant body. Plant tissues are organized into three systems, the **dermal**, **ground** (or fundamental) and **vascular** systems.

The dermal system separates the plant from the outside world, the ground system forms the bulk of the plant body and carries out essential metabolic functions, and the vascular system conducts water and nutrients through the plant.

Some Plant Cell and Tissue Types:

Epidermis is the continuous surface layer of cells that protects the plant body. The outside surface of the epidermis tissue is usually covered with a waxy substance called cutin, which reduces water loss and mechanically protects the plant. In addition to epidermal cells proper, stomatal guard cells, trichomes, root hairs, and secretory cells are all part of the epidermis.

Periderm is present in plants with secondary growth (wood) in stems and roots. When present, it replaces the epidermis and generates, among other things, bark.

Parenchyma cells form continuous tissues within the body of the plant. In stems and roots, for example, the parenchyma cells make up the cortex (storage tissues) and pith. In leaves, a layer of parenchyma cells called **mesophyll** under the epidermis is the primary site of photosynthesis. Parenchyma cells are active in wound healing and the production of secondary plant structures like adventitious roots.

Meristems are “immortal” cells that continuously divide to produce new cells at the growing points of plants.

Sclerenchyma tissue is made up of thick-walled support cells found throughout the plant, occurring both as continuous tissue, and as small, isolated groups.

Xylem is a structurally complex tissue that conducts water and nutrients throughout the plant, provides storage, and support. Several cell types are present in xylem. In woody plants, the xylem tissue becomes the wood.

Phloem tissue conducts food and metabolites from photosynthesis throughout the plant, including down to the roots, and like xylem, includes several different cell types.

Organs (structures) are externally recognizable plant parts (e.g., roots, stems, leaves). Flowers are typically viewed as an assemblage of organs (stamens, carpels, petal, and sepals).

Plants are made up of coordinated, highly specialized cells and tissues that form a single integrated organism.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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CMG GardenNotes #132

Plant Structures: Roots

Roots are the beginning of the vascular system pipeline that moves water and minerals from the soil up through the plant body.

To function, roots must have adequate levels of soil oxygen. Soil compaction or waterlogged soil situations, which reduce soil oxygen levels, will kill roots and lead to a shallow root system.

The structure and growth habits of roots have a pronounced effect on:

- Size and vigor of the plants.
- Adaptation to certain soils.
- Response to cultural practices.

Because they are out of sight, roots are often out of mind. They are widely overlooked as to their significance in plant health. The majority of all plant problems start with soil/root problems.

Functions of Roots

- Anchor and support plants.
- Absorb and conduct water and minerals.
- Store products of photosynthesis (carbohydrates, sugars, proteins).
  - Winter survival of perennials.
- Horticultural uses.
  - Food and feed.
  - Propagation.
  - Soil erosion control.

Structure

Primary (young) root in cross section. [**Figure 1**]

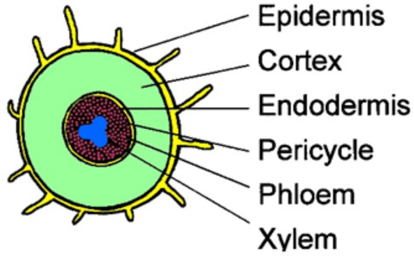

Figure 1. Cross section of a root.

Epidermis – The outer layer of cells.

Root hairs – Absorptive unicellular extensions of epidermal cells of a root. These tiny, hair-like structures function as the major site of water and mineral uptake. Root hairs are very delicate and subject to desiccation. Root hairs are easily destroyed in transplanting.
[**Figure 2**]

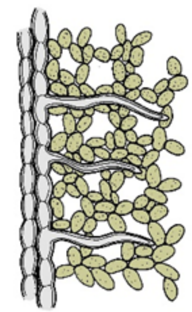

Figure 2. Root hairs are an extension of the epidermis.

Cortex – Primary tissues of a root bordered on the outside by the epidermis and on the inside by the endodermis. When roots begin thickening (secondary growth), the cortex and epidermis are gradually shed and replaced by the periderm.

Endodermis – A single layer of cells in a root that separates the cortex tissues from the pericycle. The endodermis includes the **Casparian Strip**, an impermeable layer that allows plants to control which substances can move from the cortex into the vascular system for transport to the rest of the plant.

Pericycle – A layer of parenchyma cells immediately inside the endodermis. Branch roots arise from the pericycle.

Vascular system

> **Phloem** tissue conducts products of photosynthesis from leaves throughout the plant including down to the roots.
>
> **Xylem** tissue conducts water and minerals from the roots up through the plant.

Root Meristems

[**Figure 3**]

Root Tip Meristem – Region of cell division that supports root elongation, found at the root tips just behind the root cap.

Root Cap – A thimble-shaped group of thick-walled cells at the root tip serves as a “hard hat” to push through soil. The root cap protects the tender meristem tissues.

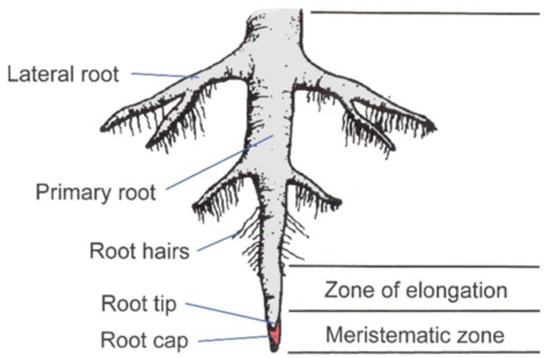

Figure 3. Lateral view of a root.

Vascular Cambium – The site of secondary root growth (root thickening). Vascular cambium develops in association with primary xylem and phloem and annually generates new vascular tissue in a ring shape, increasing the root girth and gradually crushing and sloughing off the pericycle, endodermis, cortex, and epidermis, replacing it with periderm.

Fibrous – Profusely branched roots that occupy a large volume of shallow soil around a plant's base (petunias, beans, peas). [**Figure 4**]

Taproot – Main, downward-growing root with limited branching, where soils permit (carrots, beets, radishes). [**Figure 4**]

Adventitious Roots – Generated in the ground system and arise at an “unexpected” place. For example, the buttress roots on corn and the short whitish bumps along a tomato stem are adventitious roots.

Aerial Roots – Arise from above-ground stem tissues. Aerial roots are common on ficus, philodendrons, pothos, and Christmas cactus.

Lateral Roots – The building blocks of the root system; branching roots that grow horizontally from the pericycle of the primary root.

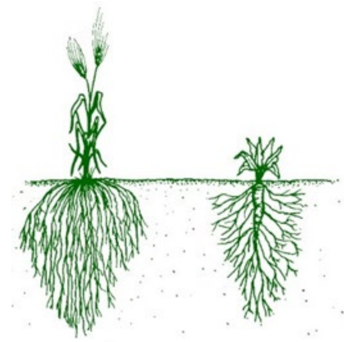

Figure 4. Root types.
Left: Fibrous root system of corn.
Right: Taproot system of carrot.

Sinker Roots – Make a sharp dive into deeper soils, wherever oxygen is available. Sinker roots are common on some tree species.

Storage or Tuberous Root – Enlarged roots that serve as storage organs (Canada thistle, morning glory, sweet potato, dahlia).

Depth and Spread

The depth and spread of roots are dependent on the inherent growth characteristics of the plant and the soil’s texture and structure. Roots require adequate levels of soil oxygen, so growth habit will be determined by where oxygen is available in addition to inherent plant characteristics. [**Figure 5**]

In compacted soils, roots will be shallow, remaining near the surface where oxygen is available.

In droughty soils, the root system will often spread farther, mining a larger soil area for moisture and minerals.

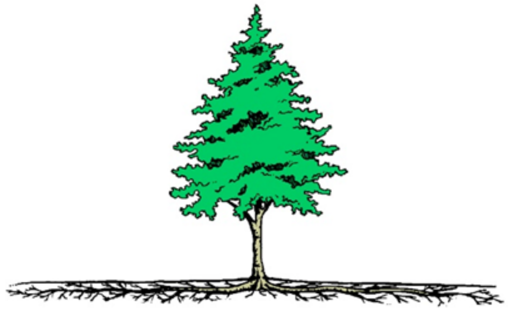

Figure 5. Typical rooting pattern of trees. Shallow and spreading.

It is difficult to predict root spread and depth. Under favorable growing conditions, the typical rooting of a tree includes:

- 90-95% of roots in the top thirty-six inches.
- 50% of roots in the top twelve inches.
- Extends two to three times tree's height or canopy (dripline) spread.

In compacted clayey soils, the typical root spread of trees includes:

- 90-95% of roots in the top twelve inches or less.
- 50% of roots in the top four inches.
- Potentially extends five or more times the tree's height or canopy (dripline) spread.

Some plants are genetically programmed to have very deep, spreading root systems (i.e., they are more tolerant of low soil oxygen levels). This growth habit is an environmental adaptation. Examples include bindweed and prairie grasses.

Soil type is a key factor in water penetration and root uptake. Where soil allows, the primary water extraction depth extends to:

- Flowers – eighteen to twenty-four inches.
- Turf – twenty-four inches.
- Vegetables – twenty-four inches.
- Shade trees – twenty-four to sixty inches.

Root Associations

Mycorrhizae are beneficial soil fungi that form mutualistic (mutually beneficial) associations with plants via roots. While the role of mycorrhizae is not fully understood, they function to expand the root's contact with the soil profile, enhancing water, and nutrient uptake. The same mycorrhizal partner can be associated with multiple trees, connecting multiple individuals. For additional information, refer to CMG GardenNotes #212, The Living Soil.

Rhizobium is a beneficial soil bacterium that forms a mutualistic relationship with plants, primarily those in the bean/pea family. These bacteria make atmospheric nitrogen available to plants. Rhizobium typically forms nodules on the roots of plants. These may be mistaken for insect injury or deformity. When alfalfa, a member of the bean/pea family, is left to mature then tilled into a field, it is considered "green manure" because the plant is rich in nitrogen due to the Rhizobium in the roots.

Natural Root Grafts are formed between roots of different trees, usually of the same species. Roots that come into contact with one another fuse at root hairs and can subsequently grow together by secondary growth, establishing a vascular connection between individuals. Large numbers of plants can become connected in this way; providing a mechanism for not only resources but pathogens and poisons to be shared widely.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #133

Plant Structures: Stems

Stems are the part of a plant that bears leaves and flowers, and they are the continuation of the vascular system pipeline that starts in the roots. Stems can grow in *length* at the tips and in *girth* in older stems that have developed a vascular cambium.

Functions

- Framework for leaves, flowers, and seeds.
- Continuation of vascular system carrying water and minerals from the soil, and sugars manufactured in leaves throughout the plant.
- Green stems also manufacture food.
- Food storage.
- Horticultural uses.
  - Aesthetic (winter interest in the landscape, appealing bark, etc.).
  - Feed and food.
  - Fuel.
  - Plant identification.
  - Propagation (cuttings and layering).
  - Wildlife habitat.
  - Wood industry and construction.

Stems in Common Parlance

Shoot – Young, typically pliable stem.

Twig – Slender woody stems growing from a branch or trunk.

Branch – A woody stem growing from a trunk or bough. Branches are usually considered to be larger than twigs but smaller than boughs.

Bough – Larger or main limbs of a tree, though sometimes applied to smaller branches.

Trunk – Main support stem(s) of woody plants.

Water Sprouts – Adventitious shoots arising on a branch vertically, generally growing very rapidly. Because they are adventitious, they are poorly attached to the main limb. Also called **epicormic shoots**.

Suckers – Adventitious shoots arising from the roots, generally rapidly growing.

Canes – Stems with relatively large pith and that usually live (or are allowed to grow) for only one to two years (roses, grapes, blackberries, and raspberries).

Structure

Internal Features

Shoot Apical Meristem – "Immortal" cells at the tips of stems that generate new cells for differentiation and growth in stem length.

Epidermis – Outer layer of wax-coated cells that provides protection and covering.

Cortex – Primary structural and storage tissues of a stem.

Vascular Tissues

Vascular Bundle – grouped phloem, xylem, and associated cells in primary stems. Vascular bundles give rise to the Vascular Cambium in plants that are capable of secondary growth (stem thickening).

Vascular Cambium – the layer of meristematic (dividing) tissues that forms in some plants to generate **secondary growth** (growth in girth). The cambium divides to form phloem tissues toward the outside of the stem and xylem tissues toward the inside. Cell division of the cambium tissues adds width to the stem. [**Figure 1**]

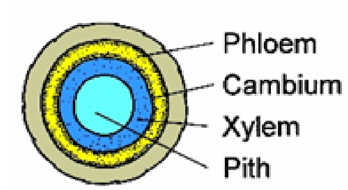


Figure 1. Cross section of stem in secondary growth.

Secondary Phloem (inner bark) – In plants with secondary growth (woody plants), the phloem is located to the outside of the vascular cambium and just beneath the bark. If the stem is damaged or girdled so as to disrupt or block the phloem, it can enlarge just above the blockage due to the sugars moving down from the leaves for distribution throughout the plant. Tissues below the blockage slowly starve. Roots die back, eventually leading to death of the plant.

Secondary Xylem (wood) – distributes water and minerals from the roots up through the plant. Typically only the xylem tissue nearest the vascular cambium (the youngest xylem) functions for water transmission; older xylem provides structural support.

Pith – the soft center of dicot plant stems, consisting of parenchyma cells. In some plants the pith breaks down forming a hollow stem. [**Figure 2**]

Woody stems are used in tree and shrub identification. Features to look at include the cross-section shape of the pith (rounded, star-shaped, or triangulate) and whether the pith is solid, hollow, or chambered.

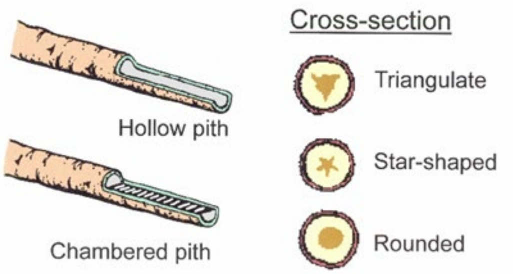


Figure 2. Stem pith is used in plant identification. It may be solid, hollow, or chambered. In a cross section, the pith may be rounded, triangulate, or star-shaped.

Tree Rings

In trees and shrubs, xylem growth makes the “annual rings” used to tell a tree’s age (phloem, being to the outside the vascular cambium, is continually sloughed off and renewed and does not accumulate in rings). Water and mineral movement occur in the more recent years of xylem rings, that is, those closest to the outside of the tree. Because water is critical in supporting cell growth and expansion, drought reduces both the width of the annual rings and the size of xylem vessels in the rings, and thus the potential for water and nutrient movement. Multi-year droughts, with their corresponding reduction in xylem size, have long-term impacts on plant growth potential. [**Figure 3**]

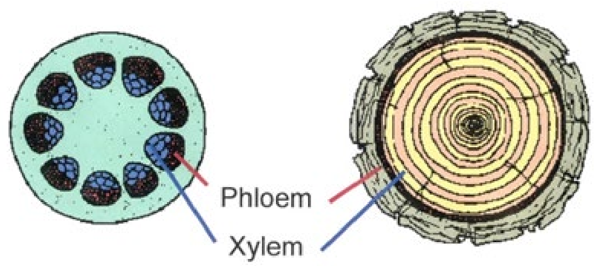


Figure 3. Cross section of dicot stems in primary growth (left) and secondary growth (right).

External Features

Bud – A stem's primary growing point. Buds can be either leaf buds (vegetative) or flower buds (reproductive). These buds can be remarkably similar in appearance, but flower buds tend to be plumper than leaf buds.

Terminal bud – Bud at the tip of a stem. In many plants, auxin (a plant hormone) released from the terminal bud suppresses development of lateral buds, thereby focusing the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. [**Figure 4**]

Lateral Buds – They grow from the leaf axils on the side of a stem.

Leaf Scar – Mark left on stem where leaf was attached. Often used in woody plant identification.

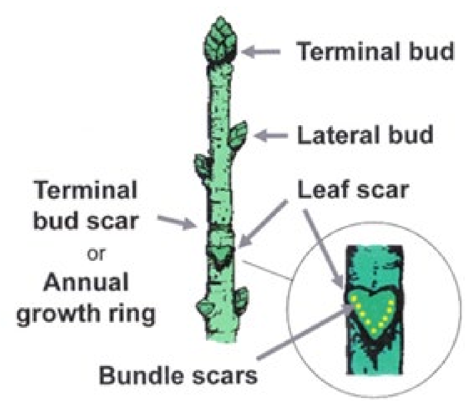


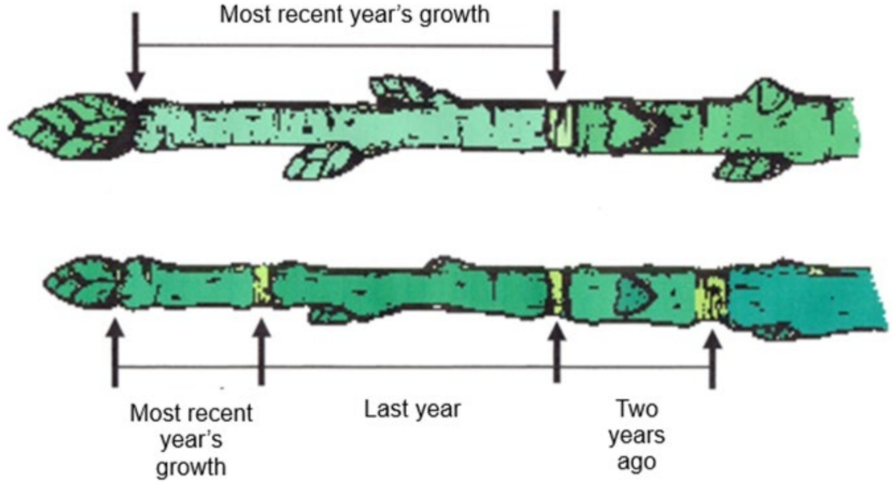
Figure 4. External features of a stem.

Bundle Scar – Marks left in the leaf scar from the vascular tissue attachment. Used in woody plant identification.

Lenticel – Pores that allow for gas exchange.

Terminal Bud Scale Scars or **Annual Growth Rings** – Marks left on stem from the terminal bud scales in previous years. Terminal bud scale scars can be used to measure annual growth. Therefore, they are important in assessing plant vigor. [**Figure 5**]

Figure 5. Terminal Bud Scars and Annual Growth Increments



Node – Segment of stem where leaves and lateral buds are attached. [**Figure 6**] Note: Roots do not have nodes.

Internode – Section of a stem between two nodes.

Bark – Protective outer tissue that develops with age. Used in woody plant identification.

Close examination of stems can tell you a great deal about a plant pertinent to its identification and health.

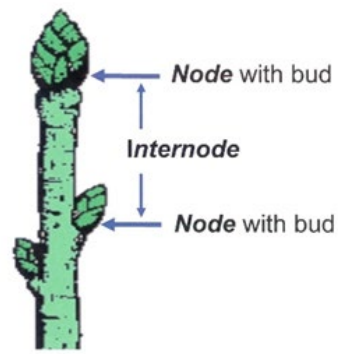


Figure 6. Node and Internode

Modified Stems

Corm – Short, thickened, underground monocot stem. [**Figure 7**]

Figure 7. Corm

Crown – Compressed stem having leaves and flowers growing above and roots beneath (strawberry plant, dandelion, African violet). [**Figure 8**]

Figure 8. Crown

Rhizome – Horizontal, underground stem, typically forms roots and plantlets at tips or nodes (iris, bentgrass, cannas). [**Figure 9**]

Figure 9. Rhizome

Spur – Very compressed (shortened), fruiting twig found on some apples, pears, cherries, and ginkgo. [**Figure 10**]

Figure 10. Spur

Stolon (or runner) – Horizontal, above-ground stems often forming roots and/or plantlets at their tips or nodes (strawberry runners, spider plants). [**Figure 11**]

Figure 11. Stolon

Thorn – A stem modified for plant defense. Thorns maintain cell types and morphology of stems, whereas prickles are superficial outgrowths of the epidermis. Hawthorns have thorns, roses have prickles.

Twining stems – Modified stems used for climbing. Some twist clockwise (hops, honeysuckle); others twist counterclockwise (pole beans, Dutchman's pipe).

Tuber – A solid thickened portion or outgrowth of an underground stem containing stored food (e.g., potato, the eyes of the potato are axillary buds). [**Figure 12**]

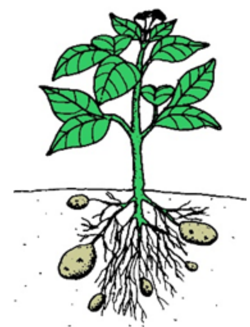


Figure 12. Tuber

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CMG GardenNotes #134

Plant Structures: Leaves

Outline:

Leaves, produced on stems, are the principle structure where photosynthesis takes place.

Functions

- Capture light for photosynthesis (the manufacture of sugars).
- Transpiration from the leaves moves water and nutrients up from the roots.
- Water, gas exchange for photosynthesis and respiration, and temperature are regulated through small openings on the leaf, known as **stomata**.
- Horticultural uses:
  - Aesthetic qualities.
  - Feed and food.
  - Mulch and compost.
  - Plant identification.
  - Propagation from cuttings.
  - Summer cooling. (Evaporative cooling accounts for 70-80% of the shading impact of a tree.)
  - Wildlife habitat.
  - Wind, dust, and noise reduction.

External Structure Features

[**Figure 1**]

Leaf Blade – Flattened part of the leaf.

Petiole – Leaf stalk.

Stipules – Appendages at the base of the leaf, which may be leaf-like, spines, or reduced/absent.

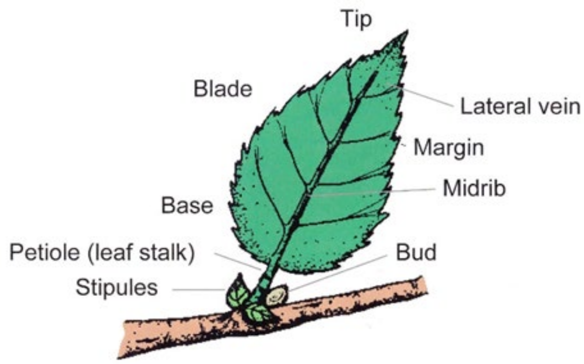


Figure 1.
External features of a leaf.

For plant identification purposes, the shape of the leaf margin, leaf tip, and leaf base are key features to note. Remember, a leaf begins at the lateral or auxiliary bud.

Leaf Arrangement on Stems [**Figure 2**]

Alternate – Arranged in staggered fashion along stem (willow).

Opposite – Pair of leaves arranged across from each other on stem (maple).

Whorled – Arranged in a ring (catalpa).

Rosette – Leaves arranged tightly at the plant crown (dandelion).

Figure 2.
Leaf arrangement on stem.

Leaf Types [**Figure 3**]

Simple – Leaf blade is one continuous unit (cherry, maple, and elm).

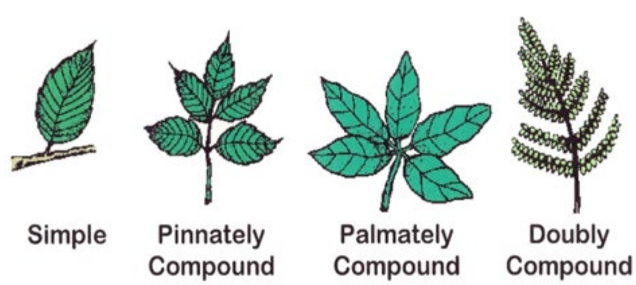
Compound – Several **leaflets** arise from the same petiole.

Palmately Compound – Leaflets radiate from one central point, like fingers from a palm. (Ohio buckeye and horse chestnut).

Pinnately Compound – Leaflets arranged on both sides of a common rachis (leaf petiole), like a feather (mountain ash).

Bi-pinnately (Doubly) Compound – Leaflets are themselves compound, with smaller leaflets on a secondary rachis.

Figure 3.
Leaf Types



Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

Overall Leaf Shape

Leaf shape is a primary tool in plant identification. Descriptions often go into minute detail about leaf shapes and margins. **Figure 4** illustrates common overall leaf shapes.

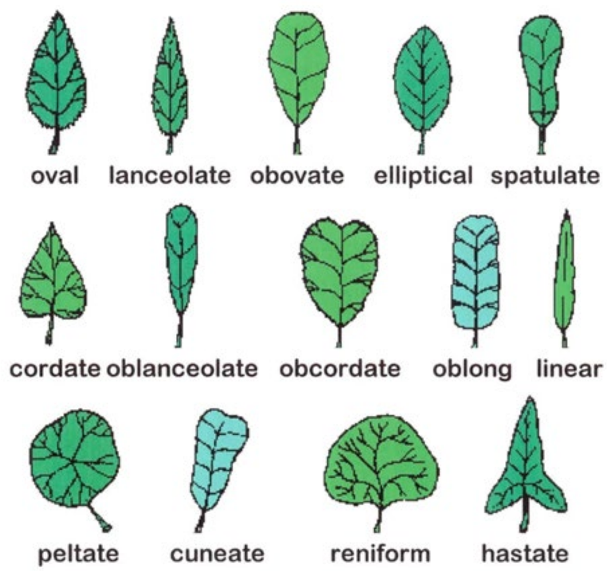


Figure 4. Leaf Shapes

Leaf Shape Descriptions

Cordate – Heart-shaped.

Cuneate – Leaves with small width at base, widening near the top (think wedge).

Elliptical – Leaves widest in the middle, tapering on both ends.

Hastate – Arrowhead shaped leaves.

Lanceolate – Leaf is three times or longer than width and broadest below the middle.

Linear – Leaves narrow, four times longer than width and have the same width.

Obcordate – Reverse appearance of cordate leaves. (The heart shape is upside down).

Oblanceolate – Leaf is three times longer than wide and broadest above the middle.

Oblong – Leaf is two to three times as long as it is wide and has parallel sides.

Obovate – Leaf is broadest above the middle and about two times as long as the width.

Ovate – Leaf is broadest below the middle and about two times as long as the width, also called oval (egg shaped).

Peltate – Leaves rounded with petiole attached under the leaf base.

Reniform – Leaves wider than they are high.

Spatulate – Generally narrow leaves widening to a rounded shape at the tip.

Shape of Leaf or Leaflet Apex

The shape of the leaf apex (tip) and base is another tool in plant identification. **Figures 4** and **5** illustrate common tip and base styles.

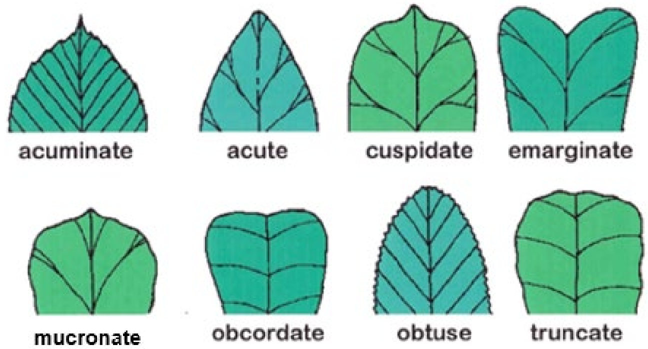


Figure 5. Common leaf tips shapes.

Leaf Apex Descriptions

Acuminate – Leaf margins forming a terminal angle of less than 45 degrees.

Acute – Leaf margins forming a terminal angle of 45 to 90 degrees.

Cuspidate – Tip is sharp; looks like two curves meeting at the tip.

Emarginate – Tip is slightly indented.

Mucronate – Tip ends in a small sharp point that is actually continuation of leaf midrib.

Obcordate – Upside down heart shape.

Obtuse – Leaf tip is blunt with an angle greater than 90 degrees.

Truncate – Leaf tip appears to be squared off, as though cut, or truncated.

Shape of Leaf Base [**Figure 6**]

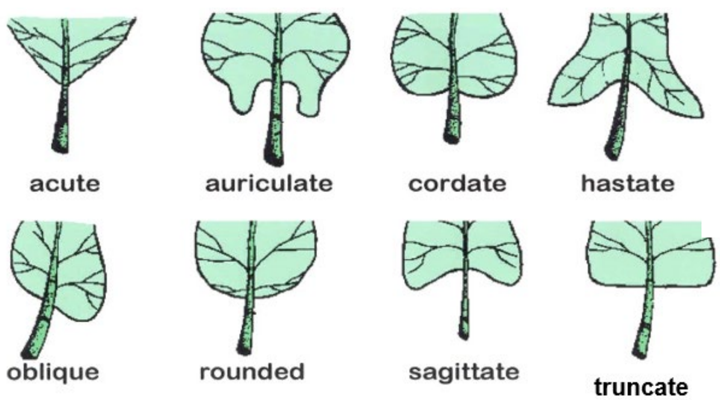


Figure 6. Common leaf base shapes.

Leaf Base Descriptions

Acute – Base is pointed toward the stem, with leaf edges forming an angle of less than 90 degrees to one another.

Auriculate – Base has ear-shaped appendages near the petiole.

Cordate – Base is heart-shaped.

Hastate – Base has pointed, flaring lobes, making a triangular leaf that resembles a spearhead.

Oblique – Base has one side lower than the other.

Rounded – Circular with no point.

Sagittate – Lower lobes of leaf are folded or pointed down, like an arrowhead.

Truncate – Leaf base is roughly squared, perpendicular to the petiole.

Leaf Margins

The leaf margin is another tool in plant identification. **Figure 7** illustrates common margin types.

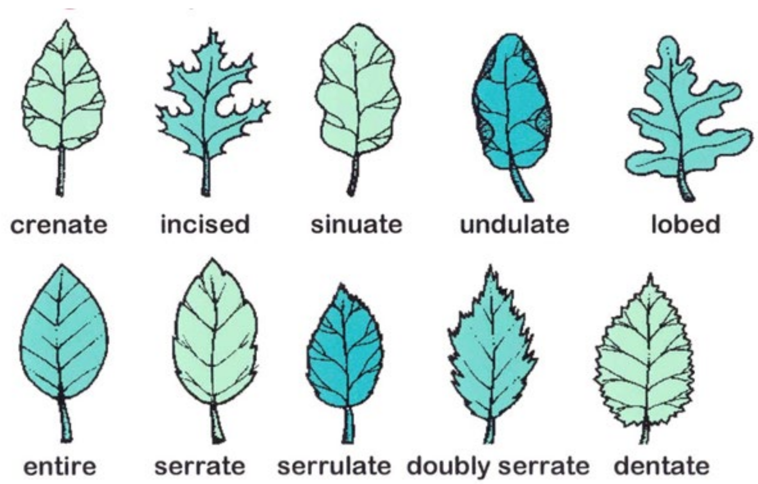


Figure 7.
Common leaf margins.

Leaf Margin Descriptions

Crenate – Leaf edge has blunt, rounded teeth.

Dentate – Leaf has triangular or tooth-like edges.

Doubly Serrate – Edges with saw like teeth that have even smaller teeth within the larger ones.

Entire – Leaf edge is smooth.

Incised – Leaf margins have deep, irregular teeth.

Lobed – Leaf edges are deep and rounded.

Serrate – Leaf edges are sharp and saw-like (think serrated knife).

Serrulate – Leaf edges with smaller, more evenly spaced serrations than a serrated leaf.

Sinuate – Margins are slightly wavy.

Undulate – Very wavy margins.

Leaf Venation

Monocots

Parallel Venation – Veins run in parallel lines (common in monocots, e.g., grasses, lilies, tulips). [**Figure 8**]

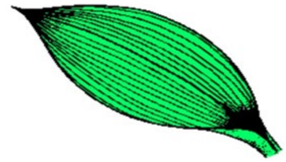


Figure 8.
Parallel veined monocot leaf.

Dicots [**Figure 9**]

Pinnate Venation – Veins extend from a midrib toward the edge, resembling a feather. (elm, peach, apple, cherry).

Palmate Venation – Veins radiate from a central point in a fan-shape from the petiole, like fingers on a palm (maple, grapes).

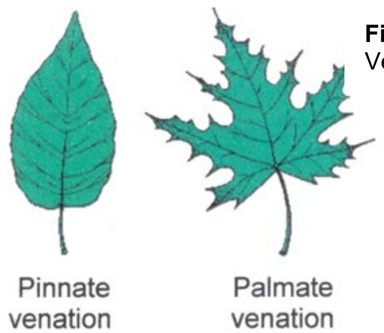


Figure 9.
Venation of dicot leaves.

Modified Leaves

Adhesive Disc – Modified leaf used as an attachment mechanism. Sometimes referred to as a holdfast (Boston ivy).

Bract – Specialized, often highly colored leaf below flower that often serves to lure pollinators (poinsettia, dogwood).

Tendril – Modified leaf, stipule, or other plant part used for climbing or as an attachment mechanism (Virginia creeper, peas, grapes). Distinguished from twining stems by the absence of leaves along their length (since they are themselves leaves).

Internal Structural Features

The leaf blade is composed of several layers. [**Figure 10**]

Epidermis – Outer layer of cells

Cuticle – Waxy protective outer layer of epidermis that prevents water loss from leaves, green stems, and fruits. The amount of cutin or wax increases with light intensity.

Leaf Hairs/Trichomes – Uni- or multicellular projections that can provide physical defense or excrete chemical compounds.

Stomates (**Stomata**) – Natural openings in leaves and herbaceous stems that allow for gas exchange (water vapor, carbon dioxide and oxygen) and plant cooling. Most stomates are found on the underside of leaves.

Guard Cells – Specialized kidney-shaped cells that open and close the stomata.

Vascular bundle – Xylem and phloem tissues comprising the leaf veins.

Mesophyll – Cells within the leaf directly involved with photosynthesis, storage, and other metabolic processes. Mesophyll organization is variable within the leaves of different plant species.

Palisade Layer – Closely ranked cells directly beneath the epidermis, very photosynthetically active. Not all plants have a well differentiated palisade layer.

Spongy Mesophyll – Loosely organized ground tissue (mostly parenchyma cells) that are involved with photosynthesis, water and nutrient exchange, and metabolism.

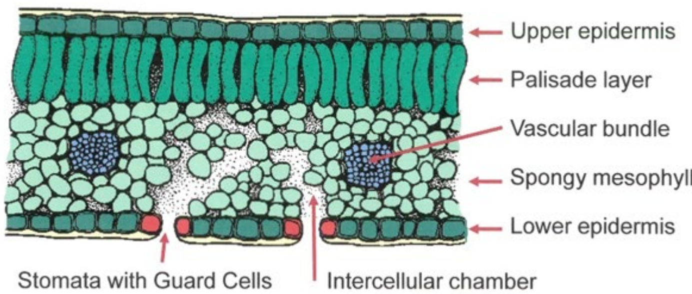


Figure 10.
Cross sectional view of a leaf.

Figures 4, 5, and 7, drawn after by D. Whiting, inspired from the book Manual of Woody Landscape Plants, Michael A. Dirr. Stipes Pub LLC, fifth edition,1998. ISBN: 0-87563-795-7.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised October 2017 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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CMG GardenNotes #135

Plant Structures: Flowers

Flowers are the reproductive structures of a flowering plant. Flowers are the primary structures used in identifying plant families.

Function

Reproduction.

Horticultural uses:

- Aesthetic qualities.
- Cut flowers and potted blooming plants.
- Edible flowers and herbs.
- Plant identification.

Structure

Pistil – Collective term for female floral parts. [**Figure 1**]

Stigma – Receives pollen, typically flattened and sticky.

Style – Connective tissues between stigma and ovary, elevates stigma to be within reach of pollination.

Ovary – Contains and protects developing ovules which are underutilized, immature seeds. Ovarian tissue develops into fruits. Ovaries can be separated into ***carpels***, divisions, or sections that each contain ovules. Ovaries can be superior (attached to the receptacle above the point where other floral parts are attached), or inferior (attached to the receptacle below the point where other floral parts are attached).

Stamen – Male floral organ. [**Figure 1**]

Anther – Pollen-producing organ.

Filament – Stalk supporting anther.

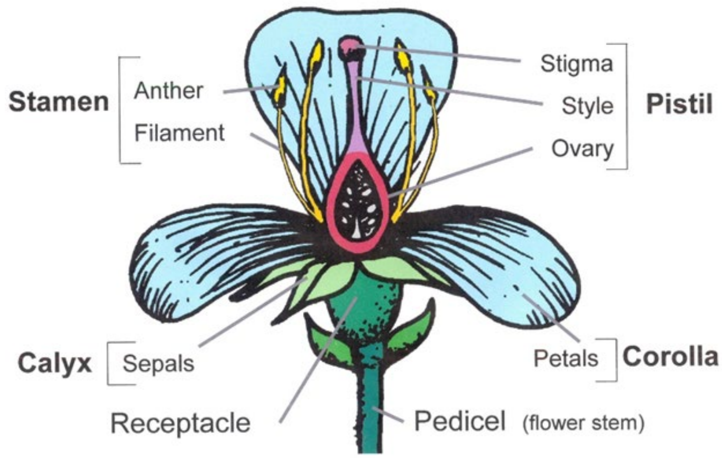
Petals – Usually colorful display organs of the flower, collectively called the ***corolla***. [**Figure 1**]

Sepals – Protective leaf-like enclosures for the flower buds, usually green, collectively called ***calyx***. Sometimes highly colored like the petal as in iris. [**Figure 1**]

Receptacle – Base of the flower where the parts of the flower are attached. [**Figure 1**]

Pedicel – Flower stalk of an individual flower in an inflorescence. [**Figure 1**]

Figure 1. Parts of a Flower



Terms Defining Flower Types

Complete – Flower containing sepals, petals, stamens, and pistil.

Incomplete – Flower lacking sepals, petals, stamens, and/or pistils.

Perfect – Flowers containing male and female parts.

Imperfect – Flowers that lack either male or female parts.

Pistillate (**Gynoecious**) – Flowers containing only female parts.

Staminate (**Androecious**) – Flowers containing only male parts.

Radially Symmetrical – Able to be cut into a mirror image along many axes (e.g., daisy, lily, rose).

Zygomorphically Symmetrical – Flowers symmetrical along a single plane only; divisible into a mirror image in only one way (e.g., orchids, penstemon, snapdragon).

Terms Defining Plant Types

Monoecious – (from the Greek for "one house") Plants with separate male flowers and female flowers on the same plant.

Dioecious – (from the Greek for "two houses") Plants with male flowers and female flowers on separate plants, functionally resulting in "male" and "female" plants.

Inflorescence (Flower Arrangement on a Stem)

Catkin – A unisexual inflorescence, with flowers arranged along a central stalk; forming a roughly cylindrical and generally dangling structure which falls off in a single piece (e.g., willow, birch, alder, ash).

Composite or Head – A daisy-type "flower" composed of several ray florets (usually sterile with an attractive colored petal) around the edge and fertile disc florets in the center of the flat head (e.g., sunflower and aster). Some inflorescences may be composed entirely of ray florets, entirely of disc florets, or of various combinations of the two (e.g., chrysanthemum, rudbeckia, dandelion). [**Figure 2**]

Corymb – A modified raceme, with flowers attached by stemlets (pedicels) arranged along the main stem proportionally so that outer, older flowers are level with inner, giving the display a flat top (e.g., yarrow, crabapple). [**Figure 2**]

Cyme – Clustered inflorescence with the single flower along the central stem opening first and bloom continuing in branches outwards, with subsequent flowers borne at the tips of lateral branches. May be flat-topped or helicoid (e.g., elderberry, borage). [**Figure 2**]

Panicle – An indeterminate inflorescence with repeated loose branching, creating "airy" clusters of flowers (e.g., oats, panicum grass, pagoda tree, begonia). [**Figure 2**]

Raceme – A loose spike, with flowers attached to a single main stem (peduncle) by stemlets (pedicels) of roughly equal length and with the terminal flower blooming last (e.g., snapdragon, lupine). [**Figure 2**]

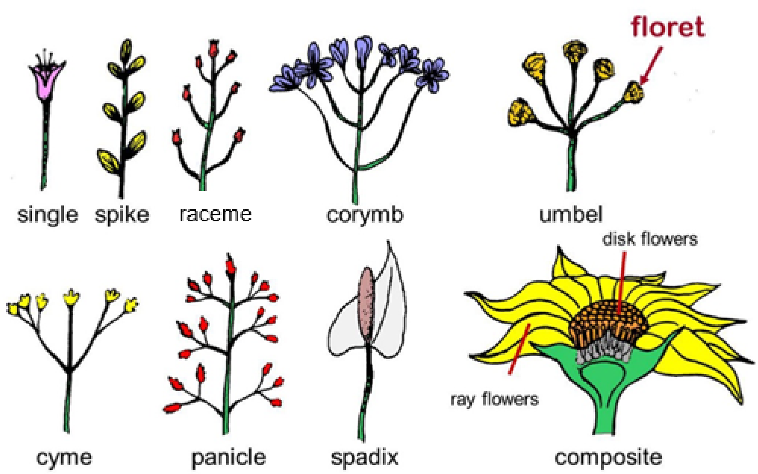
Solitary or Single – One flower per stem (e.g., tulip, crocus). [**Figure 2**]

Spadix – A thick, fleshy spike, often surrounded by a ***spathe*** (ornamental bract) (e.g., calla, caladium). [**Figure 2**]

Spike – Flowers attached quite closely to main stem, without or with very short stemlets, with bottom florets opening first (e.g., gladiolus, ajuga, and gayfeather). [**Figure 2**]

Umbel – Flowers attached to main stem at one central point, forming a flat or rounded top. Outer flowers open first (e.g., dill, Queen Anne's lace). [**Figure 2**]

Figure 2. Inflorescences



Pollination and Nectar Guides

To produce fruit and seed and ensure their survival, plants need to be pollinated. Some flowers are wind pollinated (anemophilous), but most are not. They must attract an animal to assist with the process of moving pollen from the anthers to the stigma. Nectar, an energy rich fluid produced by flowers, along with protein rich pollen, is the prize.

Figure 3. Nectar guides on penstemon (lines on the flower).

When pollinators collect nectar, the hairs on their bodies brush against the pollen and hold it tightly. As the pollinator moves to other flowers of the same species, the pollen can brush off onto the stigma and thus, pollination occurs.

To help bees and other pollinators find their way to their nectar, many plants have "nectar guides" on their flower petals.

These may or may not be visible to humans. Often, they are not, as many are only visible in the ultraviolet range. Fortunately, most insect pollinators can see in this light range and quickly find their way to the nectar. It is an example of mutualism, which ensures efficient pollination for the plant and fast nectar and pollen collection for the insects.

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CMG GardenNotes #136

Plant Structures: Fruit

Fruit develops from the maturing ovary following pollination and fertilization. Fruits can be either fleshy or dry. They contain one or more seeds.

Function

- Seed protection and distribution.
- Horticulture uses:
    - Feed, food, and oils.
    - Aesthetic qualities.
    - Plant identification.

Structure

Fruit consists of tissue derived from the plant pistil; the carpels house the developing seeds, and the ovary wall, or **pericarp**, develops into structures to help protect and/or distribute the seeds. Most fruits have seeds enclosed within the ovary, see **Figure 1**, (apples, peaches, oranges, squash, and cucumbers); but some plants have fruits with seeds that are situated on the periphery of the pericarp (strawberry). The peel of an orange, the pea pod, the sunflower shell, and the skin flesh and pit of a peach are all derived from the pericarp.

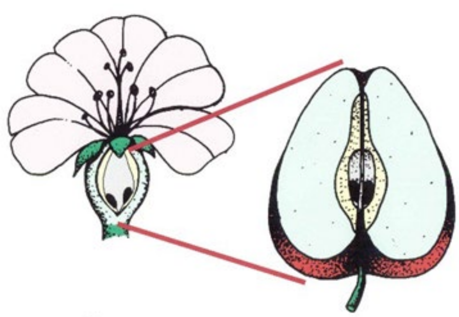

Figure 1. In apples, the ovary wall becomes the fleshy part of the fruit. Notice the small fruit structure in the blossom.

Fruit Types

Dehiscent Fruit – Fruit splits open at maturity, releasing (usually multiple) seeds (beans, flax, penstemon).

Indehiscent Fruit – Fruit formed from an ovary in which usually only one seed develops, and within which the seed remains during distribution (sunflowers, grasses).

Fleshy Fruit – Fruit developed from unicarpellate (one-seeded) or multicarpellate (many-seeded) ovaries. The ovary wall develops rapidly proliferating cells that take on diverse roles in the resulting fruit.

Hesperidium – Citrus fruit, with a rind and easily divisible segments.

Pome – A fleshy enlarged fruit derived from non-ovarian "accessory tissue" (like the receptacle) surrounding a leathery or papery core (the true "fruit"). Typical of the rose family, including apples, pears, and rosehips. [**Figure 2**]

Berry – A pulpy fruit with many seeds scattered throughout (tomato, blueberry).

Pepo – A type of berry usually with a hard outer rind, specifically characteristic of the family Cucurbitaceae (zucchini, pumpkin, cucumber).

Drupe – A fleshy fruit with a single seed originating from a single carpel, the pit (peaches, plums). [**Figure 3**]

Drupelet – A single-seeded fruit making up part of a larger composite fruit, as in blackberries and raspberries.

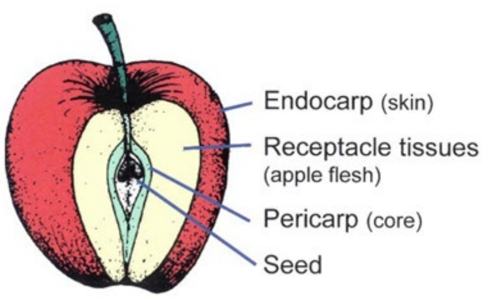

Figure 2. Pome fruit (apple).

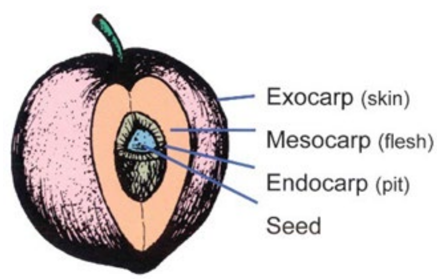

Figure 3. Stone fruit (peach).

Fruit Growth Terms

Pollination – Transfer of pollen from the anthers of the male flower to the stigma of the female flower.

Fertilization – Union of the sperm from the pollen grain with the egg cell in the female flower.

Abscission – The natural separation of the fruit from the plant.

Drop – Early abscission when not fertilized, when too much fruit sets on a tree, or caused by environmental factors.

Climacteric Fruit – Fruit that will continue to ripen if removed from a plant, for example, peaches, apples, bananas, pumpkins.

Seed Dispersal in Conifers

Conifers technically do not have fruit (remember that “gymnosperm” refers to the “naked seeds” of these plants). They do have analogous structures, though, in cones. Cones can be dry (pinecones) or fleshy (juniper berries). [**Figure 4**]

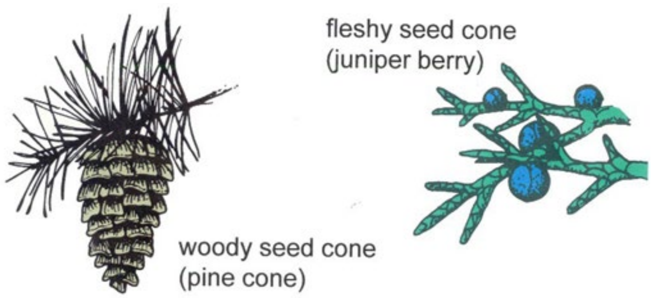

Figure 4. Fruit of conifers.
Left: Woody seed cone (pinecone).
Right: Fleshy seed cone (juniper berry).

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CMG GardenNotes #137

Plant Structures: Seeds

A seed contains the plant embryo, nutrient tissue, and a protective cover. Most seeds contain a built-in food supply called endosperm, which is the result of a separate fertilization event within the ovule (the process of creating an embryo with its endosperm is known as *double fertilization*). The endosperm contains high amounts of carbohydrates/starch, along with proteins and lipids.

Function

- Propagation.
- Horticultural uses.
    - Feed.
    - Food, beverages (coffee, cocoa, beer), medicine, fiber (cotton) and industrial oils and biofuels.

Structure and Emergence

The seed of angiosperms develops as a consequence of double fertilization – development of both embryo and endosperm is required for successful seed growth. Seeds provide protection and resources for developing embryos, making them more versatile than spores for the continuation of plant species. The nutrients are primarily contained initially in endosperm; though during seed maturation the embryo itself can absorb and store the nutrients in its seed leaves, the cotyledons, before the seed becomes dormant. Still other seeds, notably those of orchids, contain very little nutritive tissue.

Externally, seeds can be differentiated and characterized by their shape, size, surface texture, placement of the *hilum* (attachment point to the mother plant, akin to a belly button), and the presence or absence of structures such as *arils* or *elaiosomes*, appendages that aid in seed dispersal.

Internally, seeds are often divided into groups based on the position of the embryo within. Growth and development of all seeds follow a standard sequence and proceed in stages including cell differentiation of the various structures, growth of the endosperm, and finally, development and growth of the embryo in preparation for germination. During germination, the embryo mobilizes its stored food reserves to quickly develop and expand the photosynthetic apparatus that will allow it to feed itself as a young plant.

After maturation and before germination, most seeds enter dormancy, a state of very low metabolic activity that allows the embryo to survive until conditions are right for germination. Some seeds can survive only a short time before needing to germinate, others, particularly of plants from stressful and unpredictable habitats, can wait decades before sprouting. Plants use many different mechanisms (and combinations of mechanisms) to prevent seeds from germinating at unpropitious times, summarized in **Table 1**.

Exogenous Factors ("Imposed" on the Embryo From the Outside)		
Type	**Mechanism**	**Broken By**
Physical	Seed coat impermeable to water.	Opening of specialized structure or scarification.
Chemical	Germination inhibitors contained in the seed coat.	Leaching with water.
Mechanical	Woody or hard structures physically impede embryo growth.	Warm and/or cold stratification.
Endogenous Factors (Inherent in the Embryo Itself)		
Physiological	"Physiological Inhibiting Mechanism" (PIM) – Biochemical restriction.	Warm and/or cold stratification.
Morphological	Underdeveloped embryo.	Appropriate conditions for embryo growth.
Morphophysiological	PIM directly influencing embryo development.	Warm and/or cold stratification.

(After from Nikolaeva, M.G. (1977) Factors controlling the seed dormancy pattern. pp. 51–74 in Khan, A.A. (Ed.) The physiology and biochemistry of seed dormancy and germination. Amsterdam, North-Holland.)

Seed Growth and Development Terms

Cotyledon – Also known as the seed leaves, these are the first leaves that develop within the seed and allow the seedling to feed itself immediately following germination while it grows "true leaves."

Dormancy – State of suspended growth to survive adverse conditions.

Germination – Sprouting of seed following exposure to correct environmental conditions for the species.

Hypocotyl – From the Greek, "below the cotyledon," this is the embryonic plant stem.

Radicle – Embryonic plant root, often pushing through the seed coat at the beginning of germination.

Seed Coat – Hardened exterior protective layer of seeds, often involved in enforcing dormancy.

Stratification – Exposing seeds to variable temperatures in order to promote germination and growth. Cold, moist stratification is most common for plants of temperate habitats. Etymological note: "stratification" refers to the placement of the seeds in layers of growing medium in order to provide the needed germination conditions.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Revised May 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #141

Plant Physiology: Photosynthesis, Transpiration, and Respiration

The three major functions that are basic to plant growth and development are:

- **Photosynthesis** – The process of using chlorophyll to capture light energy and convert it to energy stored in sugars. Photosynthesis uses light energy, carbon dioxide (CO2), and water (H2O) to generate glucose with a byproduct of oxygen.
- **Transpiration** – The loss of water vapor through the stomates of leaves.
- **Respiration** – The process of metabolizing (burning) sugars to yield energy for growth, reproduction, and other life processes. Respiration uses glucose and oxygen to generate kinetic energy, with a byproduct of carbon dioxide and water.

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In photosynthesis, plants use carbon dioxide from air and water in the soil with the sun's energy to generate photosynthates (sugar) releasing oxygen as a byproduct. [**Figure 1**]

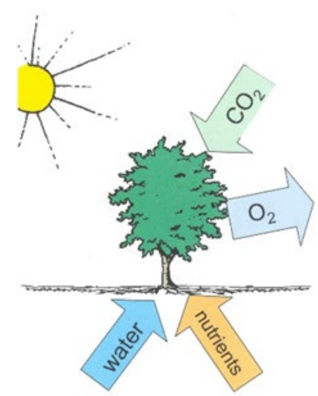


Figure 1. Photosynthesis

Photosynthesis literally means to put together with light. It occurs only in the **chloroplasts**, organelles contained in the cells of leaves and green stems. The chemical equation for photosynthesis is

carbon dioxide + water + light energy = glucose + oxygen

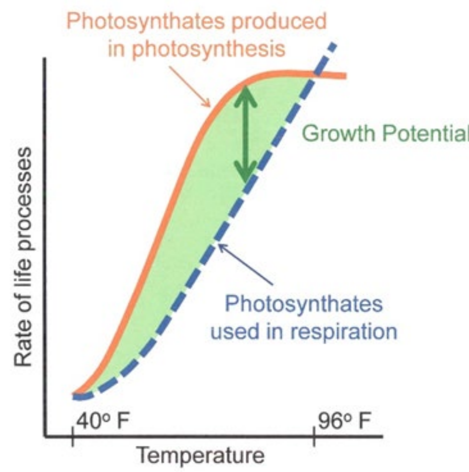
$$6CO_2 + 6H_2O + \text{light energy} = C_6H_{12}O_6 + 6O_2$$

This process is directly dependent on the supply of water, light, and carbon dioxide. Limiting any one of the factors on the left side of the equation (carbon dioxide, water, or light) can limit photosynthesis regardless of the availability of the other factors. An implication of drought or severe landscape irrigation restrictions result in reduction of photosynthesis and thus a decrease in plant vigor and growth.

In a tightly closed greenhouse, there may be very little fresh air infiltration and carbon dioxide levels can become limiting during the day while photosynthesis is actively occurring, thus limiting plant growth. Large commercial greenhouses may provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is temperature dependent. In general, warmer temperatures increase the rates of photosynthesis, but only up to a point. At high temperatures, enzymes used in photosynthesis become less efficient. Furthermore, respiration increases with temperature as well. For example, when temperatures rise above 96 degrees Fahrenheit in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop. Most other plants react similarly. [**Figure 2**]

Figure 2. In the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96°F, the rate of photosynthesis levels off, while the rate of respiration continues to rise.



Transpiration

Water in the roots is pulled through the plant by **transpiration** (loss of water vapor through the stomates of the leaves). Transpiration uses about 90% of the water that enters the plant. The other 10% is used as an ingredient in photosynthesis and cell growth.

Transpiration serves three essential roles:

- **Movement of dissolved nutrients and minerals** up from the roots (via xylem) and sugars (products of photosynthesis) throughout the plant (via phloem). Water serves as both the solvent and the avenue of transport.
- **Cooling**. 80% of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and humans.
- **Turgor Pressure**. Water maintains the turgor pressure in cells much like air inflates a balloon, giving form to the non-woody plant parts. Turgidity is important so the plant can remain stiff, upright, and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells that surround the stomates, regulates water loss, and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also mediated by osmotic pressure and capillary action.

Osmotic pressure is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal.

A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug's body crosses the membrane that is its skin. The slug dehydrates and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Fertilizer burn and dog urine spots in a lawn are examples of salt problems. In moderately salty soil, the plant can draw water into its roots less efficiently than from soils not affected by salts. In severe cases, the salt level is higher outside the plant than within it, and water is drawn from the plant.

Capillary action relies on the property of water that causes it to form droplets (hydrogen bonding). Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity and are more effective in small diameter tubes ("capillaries"), in which water can move opposite gravity to considerable height.

Respiration

In **respiration**, plants (and animals) convert sugars (photosynthates) back into energy for growth and other life processes. The chemical equation for respiration shows that the photosynthates are oxidized, releasing energy, carbon dioxide, and water. Notice that the equation for respiration is the opposite of that for photosynthesis.

$$\text{glucose} + \text{oxygen} = \text{energy} + \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 = \text{energy} + 6CO_2 + 6H_2O$$

Chemically speaking, the process is similar to the **oxidation** that occurs as wood is burned, producing heat. When compounds are oxidized, the process is often referred to as "burning." For example, athletes burn energy (sugars) as they exercise; the harder they exercise, the more sugars they burn so they need more oxygen. This is why at full speed they are breathing very fast. Athletes take in oxygen through their lungs.

Plants take up oxygen through the stomates in their leaves and through their roots. Like animals and microorganisms, plants respire to generate the energy they need to live, thus requiring both oxygen and carbon dioxide in order to survive. This is why waterlogged or compacted soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil, oxygen is not available.

Comparison of Photosynthesis and Respiration

Photosynthesis	←→	Respiration
Produces sugars from energy.		Burns sugars for energy.
Energy is stored.		Energy is released.
Occurs only in cells with chloroplasts.		Occurs in all living cells.
Oxygen is produced.		Oxygen is used.
Water is used.		Water is produced.
Carbon dioxide is used.		Carbon dioxide is produced.
Requires light.		Occurs in dark and light.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Revised June 2016 by Patti O’Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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CMG GardenNotes #142

Plant Growth Factors: Light

The quality, intensity, and duration of light directly impacts plant growth.

Light Quality

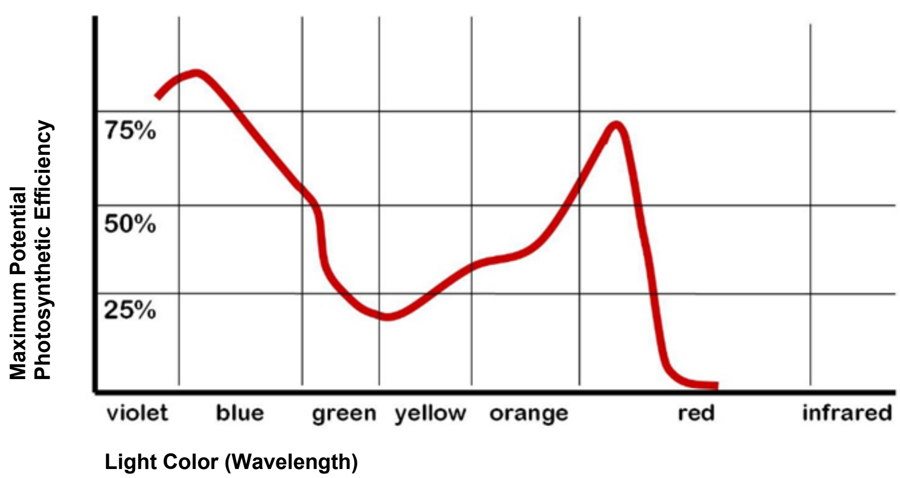
Light quality refers to the particular colors or wavelengths of light reaching the plant's surface. Visible light ("white" light) can be separated into the spectrum of colors familiar in the rainbow; each color of light is associated with particular wavelengths. [**Figure 1**]

Red and blue light have the greatest impact on plant growth – the particular energy of these wavelengths is what chlorophyll is able to capture best. Green light is least effective (plants appear green because the other wavelengths are more absorbed/used by the plants, leaving green to bounce back to our eyes).

Light quality is a major consideration for indoor growing.

LED lights are the most common lights available for indoor growing. For general use, bulbs that generate light in the 400-700nm wavelength range (blue to red) are effective for plant growth. Specialist and commercial growers can enhance the photosynthetically active spectra, but this is rarely needed in homes.

Figure 1. Relative efficiency of various light colors in photosynthesis.

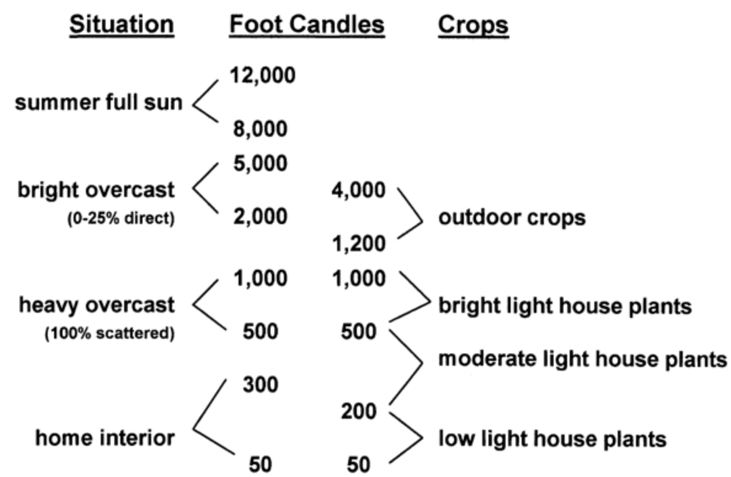


Light Intensity

The more sunlight a plant receives, to a degree, the higher the photosynthetic rate will be. However, leaves of plants growing in low light readily sunburn when moved to a bright location. Over time, as the plant acclimates, it will become more sun tolerant.

As illustrated in **Figure 2**, light levels in most homes are below that required for all but low light house plants. Except for rather bright sunny rooms, most house plants can only be grown directly in front of bright windows. Inexpensive light meters are available in many garden supply stores to help the indoor gardener evaluate light levels (though importantly, do not distinguish among wavelengths, so cannot guarantee satisfactory plant growth).

Figure 2. Light Intensity for Various Situations
Light intensity is measured in *lux* or *foot-candles*.



Landscape plants vary in their adaptation to light intensity. Many gardening texts divide plants into sun, partial sun, and shade. However, the experienced gardener understands the various degrees of sun and shade:

Full sun – Direct sun for at least eight hours a day, including from 9 a.m. to 4 p.m.

Full sun with reflected heat – Where plants receive reflected heat from a building or other structure, temperatures can be extremely hot. This situation significantly limits the choice of plants for the site.

Morning shade with afternoon sun – This southwest and west reflected heat can be extremely hot and limiting to plant growth.

Morning sun with afternoon shade – This is an ideal site for many plants. The afternoon shade protects plants from extreme heat.

Filtered shade – Dappled shade filtered through trees can be bright shade to dark shade depending on the tree's canopy. The constantly moving shade pattern protects under-story plants from heat. In darker dappled shade, only the more shade-tolerant plants will thrive.

Open shade – Plants may be in the situation where they have open sky above, but direct sunlight is blocked during the day by buildings, fences, and other structures. Only more shade-tolerant plants will thrive here.

Closed shade – The situation where plants are under a canopy blocking sunlight, like under a deck or covered patio, is most limiting. Only the most shade-tolerant plants will survive this situation.

In hot climates, temperature is often a limiting factor related to shade. Some plants, like impatiens and begonias, may require shade as an escape from heat. These plants will tolerate full sun in cooler summer climates.

Light penetration is a primary influence on correct pruning. [**Figure 3**]. For example, dwarf apple trees are pruned to a Christmas tree shape. This gives better light penetration for the best quality fruit. Mature fruit trees are thinned each spring for better light penetration. A hedge should be pruned with a wider base and narrow top. Otherwise the bottom thins out due to the shade from above. A common mistake in pruning flowering shrubs is to shear off the top. The resulting regrowth gives a thick upper canopy that shades out the bottom foliage.

Figure 3. Light penetration is a primary influence in pruning.
Left: Dwarf apple trees pruned to a Christmas tree shape allow better light penetration for best quality fruit.
Right: Regrowth on flowering shrubs that are sheared on top creates/promotes heavy upper canopy growth. This shades out the bottom creating an unattractive “naked” base.

Light Duration

Light duration refers to the amount of time that a plant is exposed to sunlight. Travelers to Alaska often marvel at the giant vegetables and flowers that grow under the long days of the arctic sun even with cool temperatures.

Even so, plants are generally intolerant of continuous light for twenty-four hours. Many important physiological processes occur at night, including repair of photosynthetic mechanisms.

Photoperiod

The flowering response of many plants is controlled by the **photoperiod** (the length of the light period in twenty-four hours). Photoperiod response can be divided into three types. [**Figure 4**]

Short-day plants flower in response to long periods of night darkness. Examples include poinsettias, Christmas cactus, chrysanthemums, and single-crop strawberries.

Long-day plants flower in response to shorter periods of night darkness than daylight. Examples include asters, California poppies, and spinach.

Day-neutral plants flower without regard to the length of the night, but typically flower earlier and more profusely under long daylight regimes. Day neutral strawberries provide summer long harvesting (except during heat extremes).

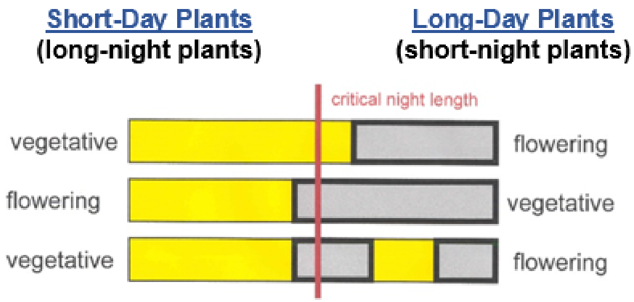


Figure 4. Photoperiod and flowering.
Left side: Short day plants flower with uninterrupted long nights.
Right side: Long-day plants flower with short nights or interrupted long nights.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson, David Whiting, and USDA. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

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CMG GardenNotes #143

Plant Growth Factors: Temperature

Temperature Considerations

Temperature factors that figure into plant growth potentials include the following:

- Maximum daily temperature.
- Minimum daily temperature.
- Difference between day and night temperatures.
- Average daytime temperature.
- Average nighttime temperature.

Microclimates

Microclimates are small areas where environmental conditions may be different than the general surrounding area. The microclimate of a garden plays a primary role in actual garden temperatures. In mountain communities, changes in elevation, air drainage, exposure, and thermal heat mass (surrounding rocks) will make some gardens significantly warmer or cooler than the temperatures recorded for the area. In mountain communities, it is important to know where the local weather station is located so gardeners can factor in the difference in their specific location to forecast temperatures more accurately.

Examples of factors to consider include the following:

Elevation – A 300-foot rise in elevation accounts for approximately 1°F drop in temperature.

Drainage – At night, cool air drains to low spots. Valley floors may be more than 10°F cooler than surrounding gardens on hillsides above the valley floor. That is why fruit orchards are typically located on higher ground rather than on the valley floor. [**Figure 1**]

Figure 1. This garden on a hillside above Steamboat Springs, Colorado (a mountain community with a short frost-free season) has good drainage giving it a growing season that is several weeks longer than down in town.

Exposure – Southern exposures absorb more solar radiation than northern exposures. In mountain communities, northern exposures will have shorter growing seasons. In mountain communities, gardeners often place warm season plants, like tomatoes, on the south side of buildings to capture more heat. [**Figure 2**]

Based on local topography, buildings, fences, and plantings, garden areas may be protected from or exposed to cold and drying winds.

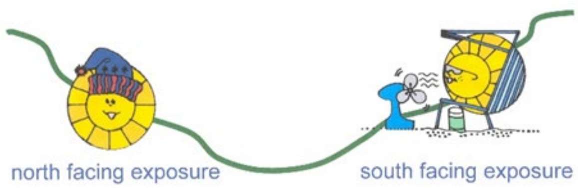

Figure 2. Temperatures and growing season vary greatly based on exposure. A north facing exposure will typically be cooler and moist. A south facing exposure will typically be hot and dry.

Thermal Heat Mass (Surrounding Rocks) – In many Colorado communities, the surrounding rock formations can form heat sinks creating wonderful gardening spots for local gardeners. Nestled in among the mountains, some gardeners have growing seasons several weeks longer than neighbors only a half mile away.

In cooler locations, rock mulch may give some frost protection and increase temperatures (particularly spring and fall soil temperatures) for enhanced plant growth. In lower elevations and latitudes, rock mulch can significantly increase summer temperatures and water requirements of landscape plants. [**Figure 3**]

In Phoenix, Arizona, the urban heat island effect created by impermeable surfaces and rock mulch has significantly raised day and night temperatures.

Figure 3. The sidewalks and stone walls of this intercity plaza creates a heat pocket with a frost-free period three months longer than the surrounding neighborhood.

Influence of Heat on Crop Growth

Temperature affects the growth and productivity of plants. The effect on individual plants depends on physiology, for example vegetables being a warm season or cool season crop dictate their performance at hot or cold temperatures.

Photosynthesis – Within limits, rates of photosynthesis and respiration both rise with increasing temperatures. As temperatures reach the upper growing limits for a plant, the rate of food used by respiration may exceed the rate at which food is manufactured by photosynthesis. Furthermore, photosynthesis becomes less efficient at higher temperatures. Some plants (many grasses and succulents, for example) have specialized photosynthetic pathways in order to allow them to grow at higher temperatures.

Temperature Influence on Germination

Seeds of cool season crops germinate at 40 degrees to 90 degrees. Warm season crop seeds germinate at 50°F to 105°F. In the spring, cool soil temperatures can be a limiting factor for plant growth. In mid-summer, hot soil temperatures may prohibit seed germination.

Examples of temperature influence on flowering:

Tomatoes

- Pollen does not develop if night temperatures are below 55°F.
- Blossoms drop when daytime temperatures are consistently above 85°F or nighttime temperatures are consistently above 70°F.
- Tomatoes grown in cool climates will have softer fruit with bland flavors.

Spinach (a cool season, short day crop) flowers in warm weather with long days.
Christmas cacti and poinsettias flower in response to cool temperatures and short days.

Examples of temperature influence on crop quality:

- High temperatures increase respiration rates, reducing sugar content of produce. Fruits and vegetables grown in heat will be less sweet.
- In heat, crop yields reduce while water demand goes up.
- In hot weather, flower colors fade and flowers have a shorter life.

Table 1 illustrates temperature differences in warm season and cool season crops.

Table 1. Temperature Comparison of Cool Season and Warm Season Crops

Temperature for:	Cool Season: broccoli, cabbage, carrots, etc.	Warm Season: tomatoes, peppers, squash, melons, etc.
Germination	40°F to 90°F, 65°- 85°F optimum range.	50°F to 105°F, 70°- 95° F optimum range.
Growth	**Daytime** • 65°F to 80°F preferred. • 40°F minimum. **Nighttime** • >32°F, tender transplants • > mid-20s°F, established plants.	**Daytime** • 75°- 85°F optimum. • 55°F minimum. • A week below 55°F will stunt plant, reducing yields. **Nighttime** • >52°F.
Flowering	Temperature extremes lead to bolting and buttoning.	• Nighttime <55°F, non-viable pollen (use blossom set hormones) • Daytime >95°F early in day; blossoms abort.
Soil	**Cool** • Use organic mulch to keep soil cool. • Since seeds germinate best in warm soils, use transplants for spring planting, and direct seeding for mid-summer plantings (fall harvest).	**Warm** • Use black plastic or rock mulch to warm soil, increasing yields and earliness of crop.

Influence of Cold Temperatures

Plant Hardiness Zone Maps indicate the **average annual minimum temperature** expected for geographic areas. While this is a factor in plant selection, it is only one of many factors influencing plant hardiness.

In 2012, the U.S. Department of Agriculture released a new USDA Hardiness Zone Map. It can be found at https://planthardiness.ars.usda.gov/. It documents a climate zone creep, that is, zones moving northwards in recent years. Zones are based on a 10°F difference in **average annual minimum temperature.**

Average Annual Minimum Temperature
Zone 4, -20° F to –30° F.
Zone 5, -10° F to –20° F.
Zone 6, 0° F to –10° F.
Zone 7, 0° F to –10° F.

Much of the Colorado Front Range area falls into Zone 5, with higher mountain areas in Zone 4. Warmer locations in the Denver Metro area, the upper Arkansas valley, and southeast Colorado fall into Zone 6. Warmer areas of western and southwestern Colorado are in Zone 7.

Plant Hardiness

Hardiness refers to a plant’s tolerance to cold temperatures. Low temperature is only one of many factors influencing plant hardiness. Other hardiness factors include:

- Photoperiod.
- Genetics (source of plant material).
- Acclimation.
- Recent temperature pattern.
- Rapid temperature changes.
- Moisture.
- Wind exposure.
- Sun exposure.
- Carbohydrate reserve.

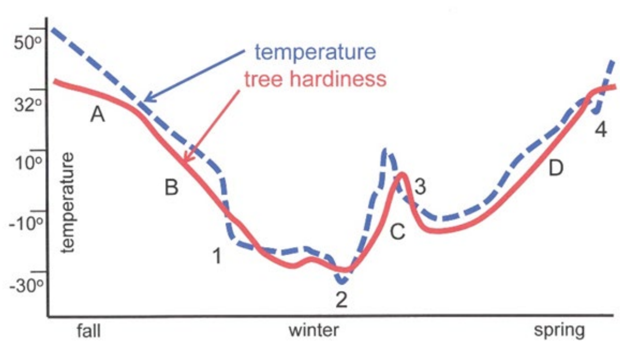

Figure 4. Influence of temperature change on winter hardiness of trees.

Figure 4. The solid line represents a tree's hardiness. Regions A-D represent various stages of hardiness through the winter season. The dotted line represents temperature. When the dotted (temperature) line drops below the solid (hardiness) line, damage occurs. Points 1-4 represent damage situations.

A. Increased cold hardiness induced by shorter daylength of fall.
B. Increased cold hardiness induced by lowering temperatures.

C. Dehardening due to abnormally warm mid-winter temperatures.
D. Normal spring dehardening as temperatures warm.

1. Injury due to rapid drop in temperatures with inadequate fall hardening.
2. Injury at temperatures lower than hardening capability.
3. Injury due to rise and fall of midwinter temperatures.
4. Injury due to spring frosts.

Examples of Winter Injury

Bud Kill and Dieback – From spring and fall frosts.

Root Temperature Injury – Roots have limited tolerance to sub-freezing temperatures. Roots receive limited protection from soil, mulch, and snow. Under extreme cold, roots may be killed by the lack of snow cover or mulch. Street trees are at high risk for root kill in extreme, long-term cold.

Soil Heaving – Pushes out plants, breaking roots. Protect with snow cover or mulch.

Trunk Injury – Drought predisposes trunks to winter injury.

Sunscald – Caused by heating of bark on sunny winter days followed by a rapid temperature drop, rupturing membranes as cells freeze. Winter drought predisposes tree trunks to sunscald. [**Figure 5**]

Frost Shake – Separation of wood along one or more growth rings, typically between phloem (inner bark) and xylem (wood), caused by sudden rise in bark temperature.

Frost Crack – Vertical split on tree trunk caused by rapid drop in bark temperature. [**Figure 6**]

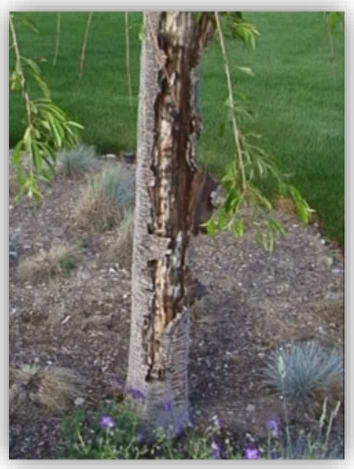

Figure 5. Southwest bark injury is common on trees that are drought stressed or that have thin, smooth bark.

Figure 6. Vertical frost crack is common on trees when the temperature drops rapidly. In Colorado it is common to go from a nice spring day back to cold with a 40 to 60 degree temperature drop in an hour!

Winter Injury on Evergreens

Winter drought – Water transpires from needles and cannot be replaced from frozen soils. It is more severe on growing tips and on the windy side of trees. [**Figure 7**]

Sunscald – Winter sun warms the needles, followed by rapid temperature drop rupturing cell membranes. It occurs typically on the southwest side, side of reflected heat, or with sudden shade.

Photo-Oxidization of Chlorophyll – Foliage bleaches during cold sunny days. Needles may green-up again in spring.

Tissue Kill – Tissues killed when temperatures drop below hardiness levels.

Figure 7. Winter drought, sunscald, and photo-oxidization of chlorophyll are common on arborvitae. It's a poor plant choice for this windy site with little winter moisture.

Rest Period

An accumulation of cool units controls the flowering period of temperate-zone woody plants. The winter rest period (hours above freezing and below 45°F) required to break bud dormancy includes:

- Apples at 250-1700 hours.
- Apricots at 350-900 hours.
- Cherry, sour, at 600-1400 hours.
- Cherry, sweet, at 500-1300 hours.
- Peaches at 800-1200 hours.
- Pears at 200-1500 hours.
- Plums, European, at 900-1700 hours.
- Plums, Japanese, at 300-1200 hours.

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CMG GardenNotes #144

Plant Growth Factors: Water

In Colorado, both water availability and water quality can be limiting factors for plant growth. Quality issues are generally related to excessive sodium or other soluble salts.

Available water limits the potential for many crops and garden plants in many areas of the West. In western cities, the cost of the infrastructure to supply water, overallocation of limited water resources, and increasing population drive the need for water conservation.

Water management is a topic of other Colorado Master Gardener training classes. For additional information refer to CMG GardenNotes:
#260, *Irrigation Management References and Study Questions*.
#261, *Colorado's Water Situation*.
#262, *Water Movement Through the Landscape*.
#263, *Understanding Irrigation Management Factors*.
#264, *Irrigation Equipment*.
#265, *Methods to Schedule Home Lawn Irrigation*.
#266, *Converting Inches to Minutes*.
#267, *Watering Efficiently*.
#268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Check-Up*.
#410, *Water-Wise Landscape Design References and Study Questions*.
#411, *Water-Wise Landscape Design: Steps*.
#412, *Water-Wise Landscape Design: Selecting Turf Options*.
#413, *Water-Wise Landscape Design: Principles of Landscape Design*.

Role of Water

Table 1. Role of Water in Plant Growth	
Role of Water in Plants	**Impact of Water Shortage**
• Required component of photosynthesis and transpiration.	• Reduced plant growth and vigor.
• Turgor pressure (pressure to inflate cells and hold plant erect).	• Wilting.
• Solvent to move minerals from the soil up to the plant. ○ NO_3^-, NH_4^+, $H_2PO_4^-$, HPO_4^{-2}, K^+, Ca^{+2}, Mg^{+2}, SO_4^{-2}, $H_2BO_3^-$, Cl^-, Co^{+2}, Cu^{+2}, Fe^{+2}, Fe^{+3}, Mn^{+2}, MoO_4^{-2}, and Zn^{+2}	• Reduced plant growth and vigor. • Nutrient deficiencies.
• Solvent to move products of photosynthesis throughout the plant, including down to the root system.	• Reduced health of roots which leads (over time) to reduced health of plant.
• Regulation of stomatal opening and closure, thus regulating transpiration and photosynthesis.	• Reduced plant growth and vigor. • Reduced cooling effect = warmer micro-climate temperatures and warmer plant tissue temperatures.
• Source of pressure to move roots through the soil.	• Reduced root growth = reduced plant growth and vigor.
• Medium for biochemical reactions.	• Reduced plant growth and vigor.

One of the most common visible symptoms of long-term drought stress is leaf scorch. Street trees are especially vulnerable to leaf scorch in the hot parts of the year. **Leaf scorch** is characterized by:

- Marginal browning (necrosis).
- Often from the top down, on southwest side, or from the side with root injury or root restrictions.

Contributing factors to leaf scorch:

- Dry or overly wet soils.
- Compacted soils.
- Limited root spread.
- Root injury.
- Structural damage to xylem tissues.
- Trunk and branch injury.
- Excessive wind and heat (hot microclimates).
- Excessive canopy growth (from heavy fertilization).

Common Causes of Water Stress

Drought

- Decreased growth.
- Small, off-colored leaves.
- Decline from top down.
- Early fall color.
- Reduced xylem growth = long-term growth reduction.
- Stress may show up five or more years later.

Waterlogged Soils

- Root activity slows or shuts down, and plants show symptoms of drought.
- Decline in root growth slows plant growth processes.
- Leaves may wilt from lack of water uptake.
- Root rots are common in some species, plants vary in their ability to tolerate “wet feet.”
- Lower, interior leaves may yellow first.

Bacterial and Fungal Infections

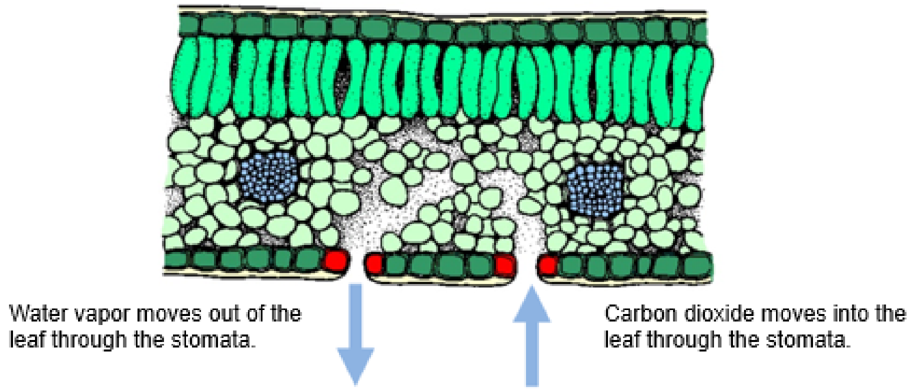
- Bacteria or fungi infect and proliferate in xylem tissue.
- Obstructed vascular system results in symptoms of drought stress.

Relative Humidity

You have already learned about osmosis and water movement. Another way to think of this is that water moves from areas of high relative humidity to areas of lower relative humidity. Inside a leaf, the relative humidity between cells approaches 100%. When the stomata open, water vapors inside the leaf rush out, forming a “bubble” of higher humidity around the stomata on the outside of the leaf.

The difference in relative humidity around the stomata and adjacent air regulates transpiration rates and pulls water up through the xylem tissues. Transpiration peaks under hot dry and/or windy conditions. When the supply of water from the roots is inadequate, the stomata close, photosynthesis shuts down, and plants can wilt. [**Figure 1**]

Figure 1. Leaf Cross Section



Colorado's typically low relative humidity means that, in general, plants not adapted to dry air are always experiencing or at the brink of experiencing stress. This is one of the reasons that it can be challenging to grow many classic garden plants without significant investment in supplemental watering and wind protection.

Authors: David Whiting, CSU Extension, retired; Michael Roll, former CSU Extension employee; and Larry Vickerman, former CSU Extension employee. Artwork by Scott Johnson and David Whiting. Used with permission. Revised July 2016 by Patti O'Neal, CSU Extension, retired; Roberta Tolan, CSU Extension, retired; and Mary Small, CSU Extension, retired. Reviewed March 2023 by John Murgel, CSU Extension and Sherie Shaffer, CSU Extension.

Reviewed March 2023

CMG GardenNotes #145

Plant Growth Factors: Plant Hormones

Plant Hormones and Plant Growth Regulators

Another factor in plant growth is the influence of plant hormones. **Hormones** are chemicals produced by plants that regulate their growth processes.

Plant growth regulators are chemicals applied to regulate plant growth; they are synthetic plant hormones. In plant propagation, cuttings are dipped in a rooting hormone to stimulate root development. In greenhouse production, many potted flowering plants (like poinsettias and Easter lilies) may be treated with plant growth regulators to keep them short. Seedless grapes are treated with plant growth regulators to increase the size of the fruit. In certain situations, turf may be treated to slow growth and mitigate the need for mowing. Some plant growth regulators are expensive, labor-intensive, and have little application in home gardening. Others are commonly used, including many herbicides.

Plant Hormones

Different hormones affect different plant processes. Understanding how hormones work allows horticulturists to manipulate plants for specific purposes.

Auxins produced in the terminal buds suppress the growth of side buds. This focuses the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. Auxins also stimulate root growth and affect cell elongation (tropism), apical dominance, and fruit drop or retention. [**Figure 1**]

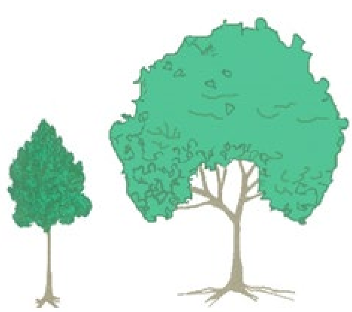


Figure 1. Auxins produced in the rapidly growing terminal buds suppress growth of side buds, giving a young tree a more upright form. As growth rates slow with age, reduction in apical dominance gives the maturing tree a more rounded crown.

Gibberellins affect:

- The rate of cell division.
- Flowering.
- Increase in size of leaves and fruits.
- Seed and bud dormancy.
- Induction of growth at lower temperatures (used to green up lawns two to three weeks earlier).

Cytokinins promote cell division, and influence cell differentiation and aging of leaves.

Abscisic acid inhibits the effects of other hormones to reduce growth during times of plant stress and plays a role in the development of stress tolerance and seed maturation. Despite its name, it plays a limited role in leaf abscission.

Ethylene is another hormone associated with maturation and/or stress. It plays an important role in promoting fruit ripening and leaf drop.

Hormone Influence on Pruning

Understanding hormones is key to proper pruning. **Auxin** produced in the terminal buds suppresses growth of side buds and stimulates root growth. **Gibberellins** produced in the root growing tips stimulate shoot growth. Pruning a newly planted tree removes the auxin-generating tissues, slowing root regeneration. [**Figure 2**]

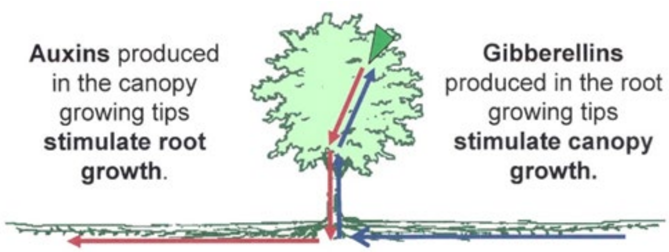


Figure 2. Trees balance canopy growth with root growth by concentrations of auxins and gibberellins.

Heading cuts remove a branch tip to eliminate the apical dominance maintained by auxins from the terminal bud. This allows side shoots to develop, and the branch becomes bushier. On the other hand, **thinning cuts** remove a side branch back to the branch union (crotch). This type of cut opens the plant to more light and does not have the same structural effect as removing growing tips from leaders; for this reason, most pruning should be limited to thinning cuts. [**Figure 3**]

Figure 3. Left: A heading cut releases apical dominance and the branch becomes denser as the lateral buds begin to grow. **Right:** A thinning cut removes a branch back at a branch union (crotch), opening the plant for better light penetration. Thinning cuts promote an open growth habit by redirecting sugars to the terminal shoots.

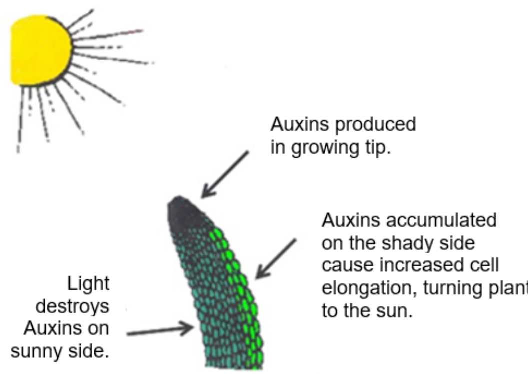
For details on pruning, refer to Fact Sheet 7.003, Training and Pruning Fruit Trees as well as CMG GardenNotes #610-617 on The Science of Pruning.

Tropisms

Auxins also play a key role in some **tropisms** (controlling the direction of plant growth). [**Figures 4** and **5**]

Figure 4. **Geotropism**
Under the influence of gravity, auxins accumulate in the lower side of a horizontal stem, causing cells to enlarge faster, turning the stem upright.

Figure 5. Phototropism
Auxin concentrations on the shaded side stimulates cell elongation, turning the stem to the sun.



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MASTER GARDENER
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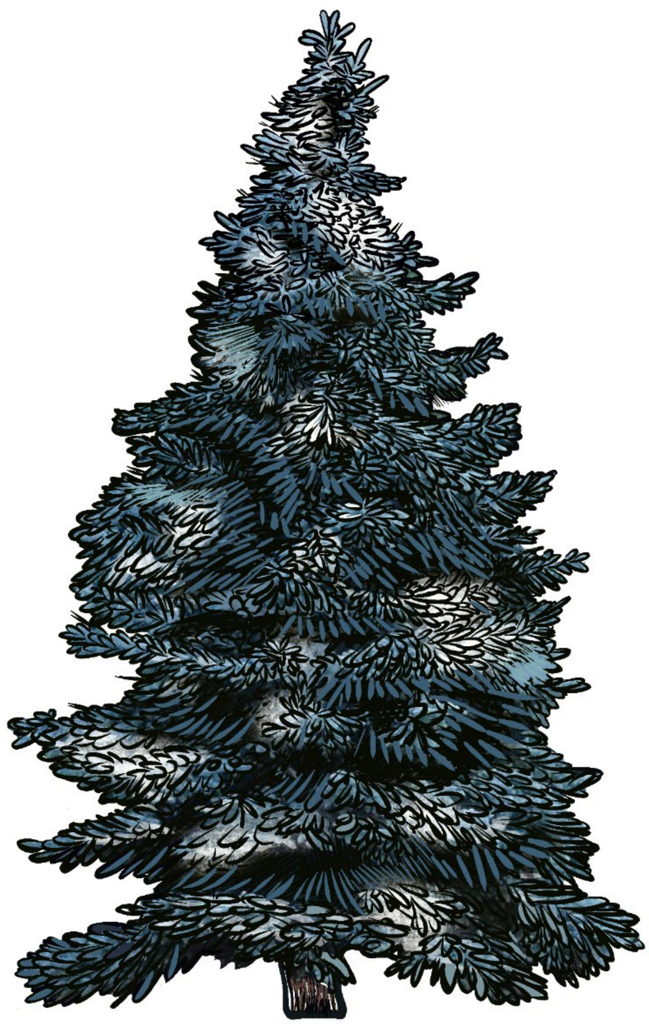
CMG GardenNotes #170-173

Identifying Trees and Shrubs



Picea pungens, Colorado Blue Spruce
Artwork by Melissa Schreiner © 2023

This Identifying Trees and Shrubs curriculum was developed by Alison O'Connor, PhD, CSU Extension; David Whiting, CSU Extension, retired; and Linda McMulkin, CSU Extension, retired. Cover art by Melissa Schreiner. Used with permission.

- Colorado Master Gardener GardenNotes are available online at https://cmg.extension.colostate.edu/.
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Updated 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #170

Identifying Trees and Shrubs

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #171, *Identifying Trees and Shrubs*.
- #172, *Identifying Conifers*.
- #173, *Identifying Broadleaf Flowering Trees and Shrubs.*
- #177, *Key to Identifying Common Landscape Trees of Colorado*.

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #7.415, *Deciduous Shrubs*.
- #7.419, *Large Deciduous Trees*
- #7.427, *Columnar and Fastigiate Trees for CO Landscapes*.

Other

- Colorado State University Online Herbarium at https://herbarium.colostate.edu/.
- USDA Plant Data Base at https://plants.usda.gov/home.
- International Plant Name Index at https://www.ipni.org/.
- Royal Botanic Gardens, Kew Resource Page at https://www.kew.org/science/collections-and-resources/data-and-digital.
- *Flora of Colorado*, Jennifer Ackerfield. Brit Press, Second edition, 2022. ISBN: 1889878898.
- *Plant Identification Terminology: An Illustrated Glossary*, Second Edition. James and Melina Harris. Spring Lake Publishing, 2001. ISBN: 978-0964022164.
- *Identification Key for Woody Plants of the Pikes Peak Region.* Colorado State University Extension, El Paso County.
- *Manual of Woody Landscape Plants, Sixth Edition*, Michael A. Dirr. Stipes, 2009.
- *Trees and Shrubs of Colorado*, Second edition, Jack L. Carter. 2006.
- *Trees of Colorado Field Guide*, Stan Tekiela, Adventure Publications. Second Edition. 2022.
- *Winter Guide to Central Rocky Mountain Shrubs*, Colorado Department of Natural Resources, Division of Wildlife. 1976.

MASTER GARDENER
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CMG GardenNotes #171

Identifying Trees and Shrubs

I. Introduction

Plant identification is a skill that takes time and patience to develop. There is a myriad of rewards for developing this skill including:

- Serving your community as an informed plant expert.
- Confidently communicating with clients about plant ID-related questions.
- Enhanced ability to utilize plant diagnostics materials (most are based on plant identification).
- Obtaining the personal satisfaction of knowing the names of plants in gardens, landscaping, and in natural areas.

The steps to plant identification involve observation, questioning, and research, similar to the process learned in diagnosing tree disorders found in CMG GardenNotes #112, *Systemic Plant Evaluation*.

Colorado Master Gardeners are often asked to identify plants either over the phone, with photos, or with a single leaf or plant part. Asking informed questions about the plant may provide the details needed for successful identification, but more than likely you will need to see a sample. Good samples include the stem with leaves attached (including the bud), and flowers or fruit whenever possible.

For details on the taxonomic system, including use of scientific names, refer to CMG GardenNotes #122, *Taxonomic Classification*.

II. Plant Identification Tools

The most important skill used in successful plant identification is the ability to observe and define the characteristics of an individual plant. Examine the plant and note the overall appearance, and the structure, shape, and texture of stems, leaves, buds, flowers, and fruit, as well as any available roots. Use visual clues as well as the texture and scent of the plant. However, use caution, as some plants or plant parts are known to be irritating or toxic. One thing to keep in mind when observing plant characteristics is that even on the same plant, there is variation in each of the leaves, stems, flowers, etc. Your chances of a correct identification increase when you look at the characters as an average from the whole plant, not just from one or two leaves.

Simple tools such as a hand lens, ruler, and a sharp blade (knife, scalpel or pruning shears) are helpful for examining plant parts. For more detailed work, a dissecting microscope is useful, especially for observing the details of small hairs or floral parts.

If you cannot identify a plant on the spot, you can collect samples (with permission only) for future identification or simply maintaining a visual collection of your own! Samples can be stored short-term in resealable plastic bags in the refrigerator for one to two weeks. Long-term storage involves pressing the sample between layers of newspaper in a plant press or between flat, heavy objects (stacks of books work well). When the specimen is completely dried, it can be mounted on special herbarium paper.

There are many references available for plant identification, both print and electronic. While photo books are easy to use, they often only contain the most common of species (otherwise photo books would be large, heavy, and very expensive). Website search features often require that the user already know something about the family or the name of the plant, but they are especially useful in confirming identification or to obtain additional information regarding characteristics. There are also various phone apps that can be downloaded – while these can be helpful, it is always a good practice to cross-reference before making a final identification.

a. Plant Identification Keys

Plant Identification keys are designed to systematically compare plant structures until the identification of a plant species is reached. Authors of plant keys use the most up-to-date and scientific references to design a series of choices based on differing plant characteristics. In most cases, keys attempt to use easily distinguishable characteristics. However, when groups are more similar (i.e., determining between species or subspecies), the characters used in sorting out groups will require closer inspection and greater attention to detail. It is important to remember that keys are written by someone who may see plants in a different way from you and me; keys can be somewhat subjective.

i. Dichotomous Keys

The term “dichotomous” comes from the Greek word dikhotomos, which means “to cut in two.” The premise of a dichotomous key is to give two choices, and only two choices, at each step. The step is called a couplet and will compare variations in similar plant characteristics, such as

1a. Leaves narrow, less than ½ inch………...go to 2.
1b. Leaves wider than ½ inch………………...go to 7.

Read both statements in the couplet and choose the statement that best describes the plant being examined. Each statement is followed by a number, which indicates the next couplet you will read. If the leaf width is less than ½ inch, move down to the couplet labeled 2a and 2b. If the leaf width is more than ½ inch, skip couplets 2 through 6 and resume the process at 7a and 7b. Remember: try to look at the average appearance of the plant as a whole, to answer questions about individual characteristics.

When you reach a couplet that gives you a plant name instead of a number, you have reached your identification. Check with your online and print resources to confirm that your identification is correct!

ii. Outline Keys

In outline keys, the options you compare are at each indentation level. More often these options are not adjacent in line order. For example, from the key below the first choice would be either I (needles single) or II (needles in clusters). If the needles were single, the next choice would be a (needles flat) or b (needles square).

I. Needles single
   a. Needles flat in cross-section and flexible.
      i. Leaf scar oval, bud tips pointed – ***Pseudotsuga* (Douglas fir)**.
      ii. Leaf scar round, bud tips roundish – ***Abies* (fir)**.
   b. Needles square in cross-section and stiff – ***Picea* (spruce)**.
II. Needles in clusters of 2 or more – ***Pinus* (pine)**.

There are many key formats that give you more than just two options to evaluate each subsequent level. Select the characteristics that best describe the plant as a whole.

III. Terminology

The terminology of plant identification can be intimidating to a beginner, as well as the experienced plant taxonomist. There are specific terms for the tiniest of traits. For example, in *Plant Identification Terminology: An Illustrated Glossary,* James Harris lists thirty-five terms that describe the hairs on the surfaces of stems and leaves. Because there are so many specific terms, most plant taxonomists have specific glossaries with line or picture drawings.

Most keys and photo references also often contain a glossary with definitions of the botanical terms used in that publication. With practice, commonly used words become familiar; however, there are some terms that are used infrequently. There is no need to memorize all botanical terms! Use your resources and look them up as needed. When you are first learning to use botanical terms, it is often helpful to draw a picture of the structures or paraphrase the definitions in your own words.

IV. The Plant Identification Process

Plant identification is a process that begins with observing the plant as a whole, followed by systematically evaluating the details of the plant parts. When observing the whole plant, take some notes and draw some pictures of the larger features. Attention to detail is important in plant identification, but at the beginning of the process, try not to get overwhelmed with those details. There are an unlimited number of features on each plant, but you will only require some of them to identify the plant. The necessary details can be determined as you work through the key. Follow these first steps to get you started in your plant identification process. These will provide you with the larger features that will narrow down your possibilities before diving into more detailed observations.

a. Step 1: Collect Basic Information Regarding the Plant

i. Determine if the Tree/Shrub is a Conifer or a Broadleaf Flowering Plant

Conifers are woody trees and shrubs generally with **needle-like or scale-like foliage**, and usually evergreen. Seeds are produced in cones, which are generally woody, (like a pinecone) but sometimes fleshy and berry-like (juniper fruit). See **Figure 1**. Examples include arborvitae, Douglas-fir, fir, junipers, larch, pine, spruce, and yews.

- Conifers are *Gymnosperms* (along with *Ginkgo biloba* and cycads), which are a group of plants that do not flower, but instead produce seed in a 'cone' structure made of modified leaves called scales. The term 'Gymnosperm' literally means "naked seed" and refers to the exposure of the female reproductive structure during pollination (instead of wrapped in an ovary as in flowering plants) rather than the actual seed being uncovered.

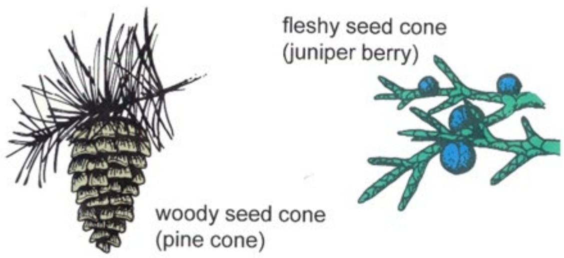

Figure 1.
Woody and fleshy cones of conifers.

- **Broadleaf flowering plants** are *Angiosperms*, which is a highly diverse group of plants that produce flowers and seeds enclosed in fruits. Flowers range from tiny and inconspicuous to large and showy. This group includes woody trees, shrubs, and vines, and is often referred to as broadleaf plants due to the large, flattened leaf blade. See **Figure 2**.

Figure 2.
Large, flattened leaf blade common of Angiosperms.

ii. *Determine if the Plant is Deciduous or Evergreen*

- **Deciduous** plants shed leaves in the fall. Most broadleaf flowering plants in Colorado are deciduous, along with a few conifers such as some *Larix* (Larch).
- **Semi-evergreen** plants may retain some leaves, depending on winter temperatures and moisture.
- **Evergreen** plants retain leaves for multiple seasons. Leaves (needles) will be present throughout the year. Most conifers are evergreen, along with some broadleaf plants such as Berberis *Mahonia* (Oregon grape).

iii. *Determine the Growth Habit of the Plant*

Growth habit refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread.

- **Trees** typically have a single trunk and mature height over twelve feet. Note that there are multi-stem trees or clump trees sold in the nursery trade.
- **Shrubs** typically have multiple branches from the ground and a mature height less than twelve feet.
- **Vines** have a climbing, clasping, or self-clinging growth habit.

Note: Many landscape plants could be considered small trees **or** large shrubs. The term "tree" or "shrub" would be applied based on the general appearance of the plant. The species, cultivar, or variety name sometimes indicates plant characteristic, including form.

b. Step 2 – Consult a Key to Lead You Through the Identification Process

Each region of the county has a variety of keys written for trees in that region. Examples of keys for the Colorado region include the following:

- CMG GardenNotes #172, *Identifying Conifers.*
- *Flora of Colorado,* Jennifer Ackerfield. Brit Press. 2015.
- *Trees and Shrubs of Colorado*, Jack L. Carter. Second edition, 2006.

Authors: Linda McMulkin, CSU Extension, retired; David Whiting, CSU Extension, retired; Alison O'Connor, CSU Extension. Line drawings by Scott Johnson and David Whiting. Used with permission. Revised October 2017 by Alison O'Connor, CSU Extension. Reviewed October 2022 by Alison O'Connor, CSU Extension.

Reviewed October 2022

CMG GardenNotes #172

Identifying Conifers:

Arborvitae, Douglas Fir, Fir, Juniper, Pine, Spruce, and Yew

I. Characteristics of Conifers

a. Leaves

Most conifers (cone bearing plants) have characteristic leaf shape and arrangement that allow them to be quickly identified to the genus level.

- The *Pinaceae* family contains members such as pine, spruce, fir, and Douglas fir. This family has the classic needle-shaped leaves you think of when you think of Conifers (i.e., pine needles). The genera of the *Pinaceae* family are further sorted by how the needles are clustered on the stem. [**Figure 1**]

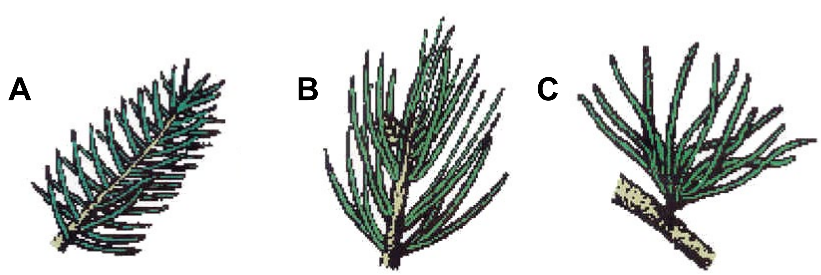

Figure 1: A) Single needles characteristic of the genera *Picea* and *Pseudotsuga*. B) Bundled needles characteristic of the genus *Pinus*. C) Clustered needles characteristic of the genus *Larix.*

- The *Cupressaceae* family includes members such as juniper and arborvitae. This family has leaves that are more scale-like or awl-like. [**Figure 2A** and **2B**]

- The *Taxaceae* family is the Yew family. The leaves of these Conifers are flat and arranged along the stem in a manner that resembles a feather. [see **Figure 2C**]

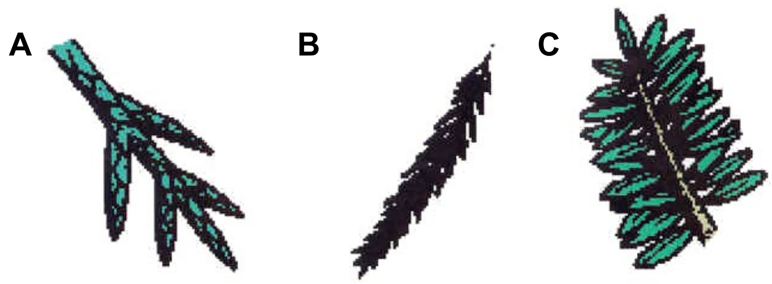

Figure 2: A) Scale-like leaves characteristic of *Juniperus* and *Thuja*. B) Awl-shaped leaves characteristic of *Juniperus*. C) Linear, feather-like leaves characteristic of *Taxus*.

b. **Seed Production**

Conifers are **Gymnosperms** (along with *Ginkgo biloba* and cycads), which are a group of plants that do not flower, but instead produce seed in a 'cone' structure made of modified leaves called scales. The term 'Gymnosperm' literally means "naked seed" and refers to the exposure of the female reproductive structure during pollination (instead of wrapped in an ovary as in flowering plants) rather than the actual seed being uncovered.

Members of the *Pinaceae* family and arborvitae are **monoecious** plants. These plants have separate male and female cones on the same plant (the term "monoecious" is Greek for 'one house'). Male cones produce pollen and are normally short lived. Female cones are generally larger and longer-lived, remaining on the tree until the seeds are mature and distributed. Junipers and Yews are **dioecious** plants, which have separate male and female plants ("dioecious" is Greek for 'two houses').

Cones of pines, spruce, and fir are made up of leathery or woody scales, which open to distribute the seed when the seed is mature. The cones of junipers have fused scales around the seed, resulting in a more berry-like appearance. [**Figure 3**]

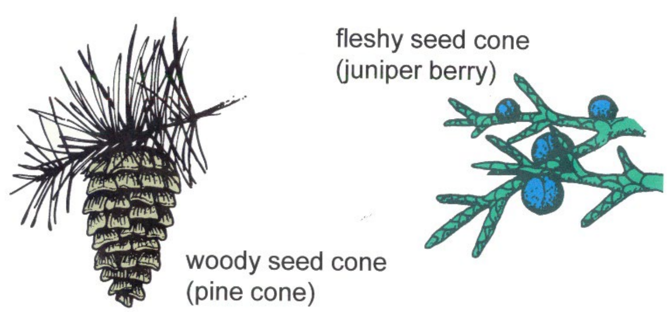

Figure 3: Woody cones of the *Pinaceae* family and fleshy cones of the *Juniperus* genus.

II. Key to Conifers

a. **Leaves scale-like or awl-like.** Fruit is a berry-like cone with scales fused together – *Cupressaceae* family (Junipers and Arborvitae).

i. Leaves scale-like or awl-like, often closely pressed to the branches. Foliage arranged around the branch, rather than flattened. Cones are berry-like with scales pressed close together – ***Juniperus* (Junipers)**.

ii. Leaves small, scale-like, hugging the stem. Foliage in flattened plate-like display. Cones are berry-like with thick scales – ***Thuja* (Arborvitae)** – visit the ***Key to Thuja*** on page 5.

b. Leaves needle-like. *Pinaceae* family (pine, spruce, fir, and Douglas fir).

i. Needles single.

1. Needles flat in cross-section and flexible.

a. Leaf scar oval, bud tips pointed. Cones have three-prong lobed tongue-like "bract" that extend out beyond the scales – ***Pseudotsuga menziesii* (Douglas Fir)**.

b. Leaf scar round, bud tips roundish. Cones grow upright on the branch, usually disintegrating before falling to the ground – ***Abies* (Fir) –** visit the ***Key to Abies*** on page 3.

2. Needles square in cross-section and stiff. Older twigs studded with the persistent stumps of fallen needles – ***Picea* (Spruce)** – visit the ***Key to Picea*** on page 3.

ii. Needles sheathed at the base in bundles of two to five. Cone scales thick and woody with swollen tips – ***Pinus* (Pine)** – visit the ***Key to Pinus*** on page 4.

iii. Short needles in tufts of ten or more. May be deciduous – ***Larix* (Larch)**.

c. Leaves flat, linear-shaped in a feather-like arrangement. Shrubs with dark green leathery leaves. Red, berry-like fruit – *Taxus* (Yew).

III. Key to *Abies* (Fir)

a. Young stems not hairy. Needles usually longer than one inch (but can be misleading). Cones grayish green, 2½ to 5 inches long. Bracts of the cone scales with a short, triangular tip – ***Abies concolor* (White Fir)**.

b. Young stems hairy. Needles usually shorter than one inch. Cones dark brown/purple, 2 to 4 inches long. Bracts of the cones scale are long with sublated tip. Native to higher elevations – ***Abies lasiocarpa* or *Abies bifolia* (Subalpine Fir)**.

IV. Key to *Picea* (Spruce)

a. Needles very stiff, sharp, ¾ to 1½ inch long, often bluish, pointing outwards from stem. Stems not hairy. Cones 2½ to four inches long. Cone scales papery, furrowed, pointed/ragged. Bark black to dark grey furrowed. Native, generally below nine thousand feet elevation – ***Picea pungens* (Colorado Spruce)**.

b. **Needles somewhat blunt, not as stiff, or sharp, pointed toward end of twig**. Young stems somewhat hairy. Cones less than 2½ inches long. Cone scales rounded. Bark smooth, with purplish brown to russet red scales on mature trees. Native. – ***Picea engelmannii* (Engelmann Spruce)**.

c. **Needles ¼ to ½ inches long**. Each branch very short (2-4 inches long). Landscape shrub. – ***Picea glauca* 'Conica' (Dwarf Alberta Spruce)**.

V. Key to *Pinus* (Pine)

a. Two needles per bundle.

i. Needles ½-1 ½ inches long, curved, medium green with white lines, some resin droplets. Cones small, rough, without prickles on scale. Seeds large (pine nuts). Shrubby tree. Native to the plateaus and mesas – ***Pinus edulis* (Pinon Pine)**.

ii. Needles 1-2 inches long, finely toothed, slightly twisted, curved, dark green, persisting five plus years. Branches out abruptly from trunk base, central leader not obvious, more shrub-like – ***Pinus mugo* (Mugo Pine)**.

iii. Needles 1-3 inches long, yellowish green, slightly twisted. Cones small, less than 2 inches long, hard, one-sided with prickled tips on scales. Branches slender, slightly flexible. Bark scaly, not becoming platy. Native in dense forest stands in higher elevations – ***Pinus contorta* (Lodgepole Pine)**.

iv. Needles 1½-3 inches long, twisted, persistent two to four years. Cones 1½ inches long, scattered throughout the tree, without prickles on the scales. Older bark orange – ***Pinus sylvestris* (Scotch Pine, Scots Pine)**.

v. Needles 3-6 inches long, stiff, dark green, dense on the branch, persisting four plus years. Cones 2-3 inches long with small prickles on scales. Buds whitish. Older bark dark gray furrowed – ***Pinus nigra* (Austrian Pine)**.

b. Two and three needles per bundle, 3-10 inches long, medium green, crowded at end of branches on older trees, persisting three years. Cones 3-5 inches long, armed with sharp prickles on scales. Bark furrowed, eventually breaking into reddish plates. Native from outer foothills to subalpine regions – ***Pinus ponderosa* (Ponderosa Pine)**.

c. Five needles per bundle – **White Pines** group.

i. White resin dots scattered on dark green needles, 1-1½ inches (25-38 mm) long. Cone scales long, sharp prickles. Native to higher elevations – ***Pinus aristata* (Bristlecone Pine)**.

ii. Needles 1-3 inches long, rigid, dark green, often clustered near branch ends, margins smooth, pointing forward, persist for five to six years. Cones 4-8 inches long on short stalk, with no prickles on scales. Branches very flexible. Bark silvery white to light gray. Small tree with irregular trunk and branching pattern. Native to higher elevation and high plains, often on open sites – ***Pinus flexilis* (Limber Pine)**.

iii. Needles 2-5 inches long, blue green, very soft, thin, margin toothed, persistent two years. The branches are green-brown. Cones 3-8 inches long with 1-inch-long stalk. Cone scales thin, don't bend back – ***Pinus strobus* (Eastern White Pine)**.

iv. Needles with a few small teeth near tip, not as soft as Eastern White Pine. Branchlets yellow-brown or red brown. Cones are short-stalked. Cone scales bend back. Tall tree with straight, unbranched trunks. Native to San Juan Mountains, Sangre de Cristo, and Rampart ranges – **Pinus strobiformis (Southwestern White Pine)**.

VI. Key to *Thuja* (Arborvitae)

a. Foliage in vertical plate-like displays – ***Thuja orientalis* (Oriental Arborvitae)**.

b. Foliage in horizontal plate-like displays **–** ***Thuja occidentalis* (American or Eastern Arborvitae)**.

Authors: David Whiting, CSU Extension, retired; Linda McMulkin, CSU Extension, retired; Joanne Jones, CSU Extension, retired; Alison O'Connor, CSU Extension; and Laurel Potts, CSU Extension, retired. Artwork by Scott Johnson and David Whiting. Used with permission. Revised October 2017. Reviewed October 2022 by Alison O'Connor, CSU Extension.

Reviewed October 2022

MASTER GARDENER
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CMG GardenNotes #173

Identifying Broadleaf Flowering Trees and Shrubs

Identification of broadleaf trees and shrubs is a skill mastered with practice and knowledge of the plant families. Most trees and shrubs can be readily identified to family and genus with a basic knowledge of the plant's characteristics and the use of a key. There are always a few exceptions with plants that do not look like their relatives. Identification to specific epithet requires more skill and a closer look at plant characteristics. Identification to variety and cultivar can be very difficult, as the defining characteristics may not be clearly observable from plant samples. Identify the plant to the level you are comfortable and to what the task requires.

Keys can be arranged in a variety of ways, but most start by separating Gymnosperms from Angiosperms then start with broad, easily identifiable characteristics to narrow the plant to family level. Usually, the more specific and smaller plant characteristics will be used to narrow the plant down to genus and specific epithet. The following sections will cover the most common characteristics you will encounter in a plant key. Some of these characteristics you will come across with every plant you key, and you should be comfortable using these terms.

Leaf Characteristics

a. Leaf Arrangement [**Figure 1**]

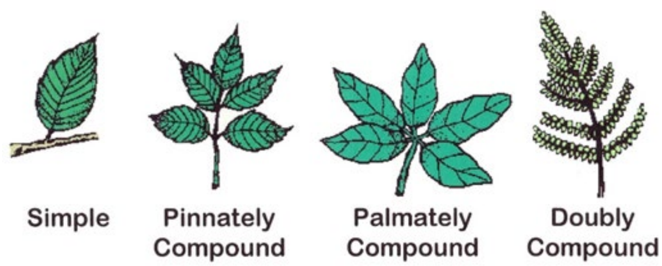
- **Alternate** – Arranged in staggered fashion along stem, i.e., willow.
- **Opposite** – Pair of leaves arranged across from each other on stem, i.e., maple.
- **Whorled** – Arranged in a ring around the stem, i.e., catalpa.

Figure 1. Leaf Arrangement on the Stem

b. Leaf Form [**Figure 2**]

- **Simple** – Leaf blade is one continuous unit, i.e., cherry, maple, and elm.
- **Compound** – Several leaflets arranged on one petiole.
- **Pinnately compound** – Leaflets arranged on both sides of a rachis are an extension of the petiole, like a feather, i.e., honeylocust.
- **Palmately compound** – Leaflets radiate from one central point at the tip of the petiole, i.e., Ohio buckeye and horse chestnut.
- **Doubly pinnately** (or bipinnately) compound – leaflets are arranged on a branch off the rachis, i.e., Kentucky coffee tree.

Figure 2. Variety of Leaf Forms

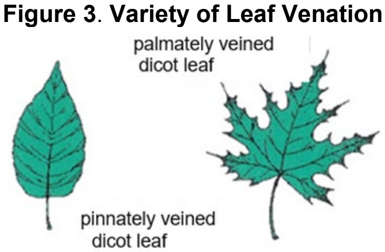


Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

c. Leaf Venation [**Figure 3**]

- **Pinnately** veined leaves have a central vein down the center with smaller veins branching off and extending to the leaf margin, i.e., elm, peach, and linden.
- **Palmately** veined leaves radiate smaller veins out in a fan-shaped pattern from a central point at the petiole leaf stem, i.e., maple, mulberry, and poplar.

Figure 3. **Variety of Leaf Venation**



d. Leaf Shape [see **Figures 4-7**]

Leaf shape is a primary tool in plant identification. Descriptions often go into fine detail about general leaf shape, and the shape of the leaf apex and base. There is no hard and fast dividing line where one type suddenly becomes another type; rather it is a judgment call. When using keys, look at several leaves from the plant, select the average shape, and be flexible in your description. The authors of these plant identification keys are aware of the variation within plants and will often write several options into the key. The following figures show the common overall shapes, leaf apexes and bases, and leaf margins.

Figure 4. Variety of Overall Leaf Shapes

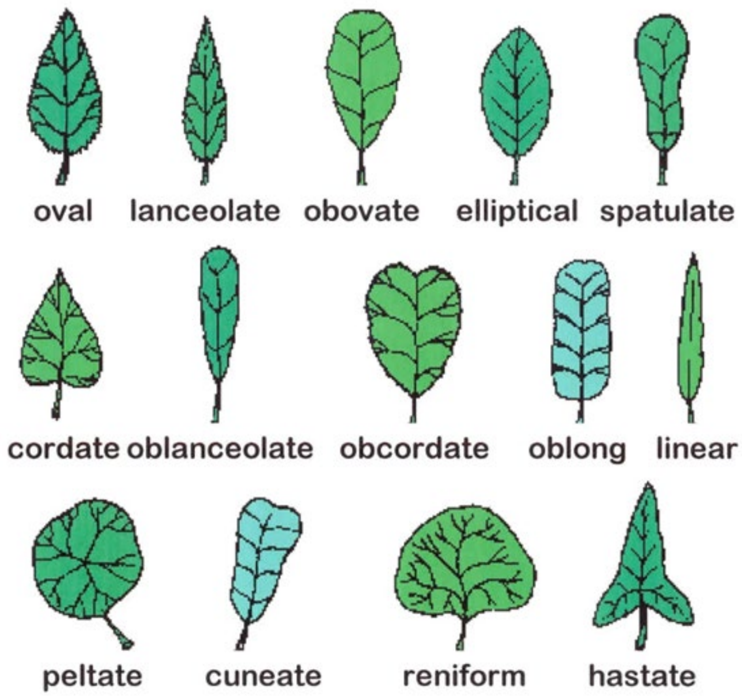


Figure 5. Variety of Leaf Apex Shapes

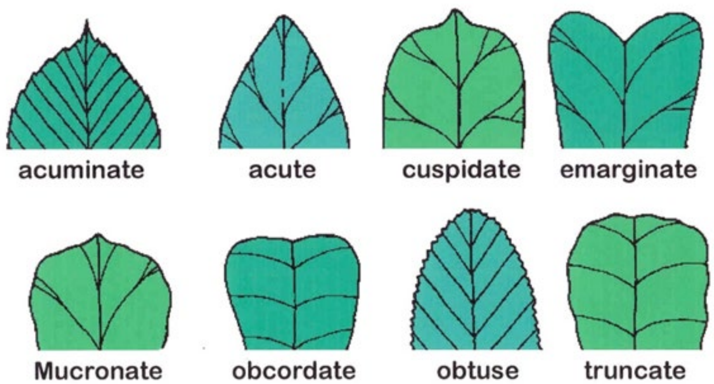


Figure 6. Variety of Leaf Base Shapes

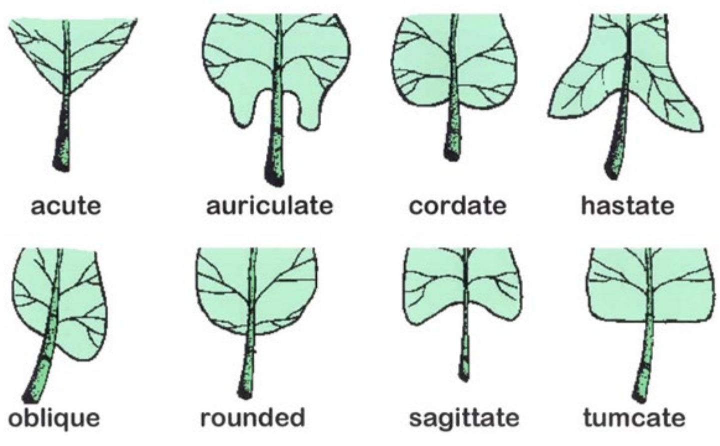
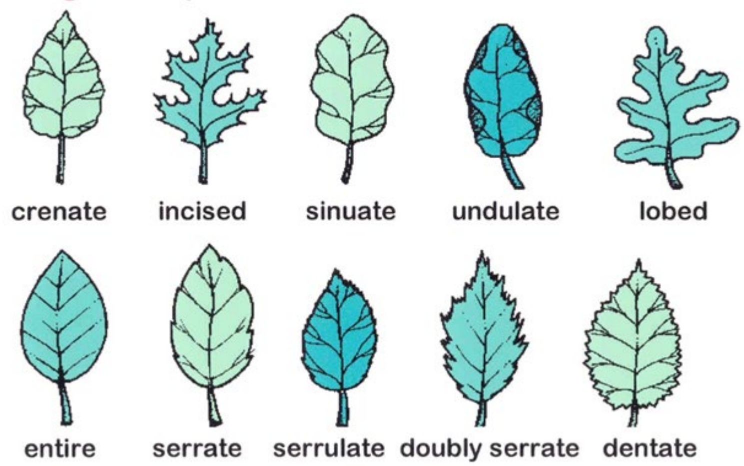


Figure 7. Variety of Leaf Margins

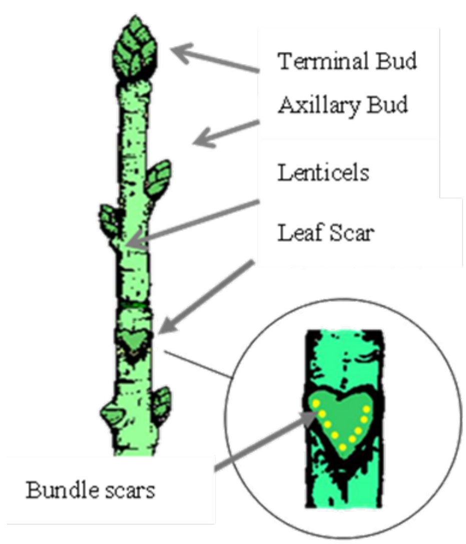


e. **Leaf Surface Texture**
   Look at all the leaf surfaces, above and below. Note the location, color, density and length of scales and hairs. These terms are commonly encountered when describing leaf surface texture.
   - **Ciliate** – Orderly, widely spaces hairs along the edge (margin), also called fringed.
   - **Glandular** – Hairs bearing glands.
   - **Glutinous** – Sticky to the touch.
   - **Scabrous** – Hairs very short.
   - **Stellate** – Star shaped hair (needs magnification).
   - **Velutinous** – Dense hairs of equal height, like velvet.

Stem Characteristics

Stems contain several features important to identifying plants. Cut into the stem to see the pith. Look at the epidermis, buds, arrangement of the nodes and any surface coating or texture. For winter identification of woody plants, look at the pattern of the scales on the terminal and axillary buds and the shape of the leaf scars.

Figure 8. External Stem Features



a. **External Stem Features** [see **Figure 8**]
   - **Terminal bud** – This bud is where growth that lengthens the stem happens. The young, dividing cells are protected by terminal bud scales.
   - **Axillary bud** – These buds, also called lateral buds, when actively dividing, will become a new branch. They are smaller versions of the terminal bud and can also be protected by scales.
   - **Leaf scar** – The mark left on a stem where leaf was attached. The shape of the leaf scar is often used in woody plant identification.
   - **Bundle scar** – Marks left in the leaf scar from the vascular tissue attachment. The shape of the bundle scar is often used in woody plant identification.
   - **Lenticels** – Woody twigs have these pores in the bark to allow for gas exchange. These look like little dots along the stem.

b. Axillary Bud Type [Figure 9]

The type of axillary bud (the way the scales are arranged over the bud) is another feature used in plant identification.

Figure 9: Axillary Bud Types

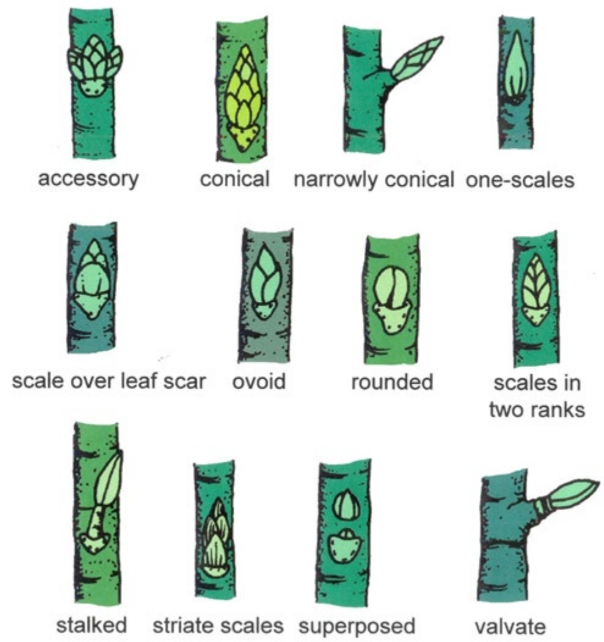


Figure 9. Illustrations of some bud types.

c. Stem Surface Texture

The surface of woody twigs may have a texture that can be used to distinguish one plant from another. Terms used to describe the surfaces of stems can also apply to leaves.

- **Farinose** – Covered with a mealy, powdery substance.
- **Glabrous** – Smooth.
- **Glaucous** – Having a bloom or whitish covering, often waxy.
- **Hirsute** – Covered with coarse, stiff hairs, rough enough to break the skin.
- **Pubescent** – Covered with hairs.
- **Scurfy** – Covered with small scales.
- **Tomentose –** Covered with short, matted or tangled, soft, wooly hairs.

d. Internal Stem Features

Pith is the tissue found at the center of stems and roots. Pith characteristics may provide identification clues. A diagonal cut across the stem reveals if the center of the stem is hollow or if the pith is solid or chambered. A straight cut across the stem reveals the shape of the pith (rounded, star, or triangle). [**Figure 10**]

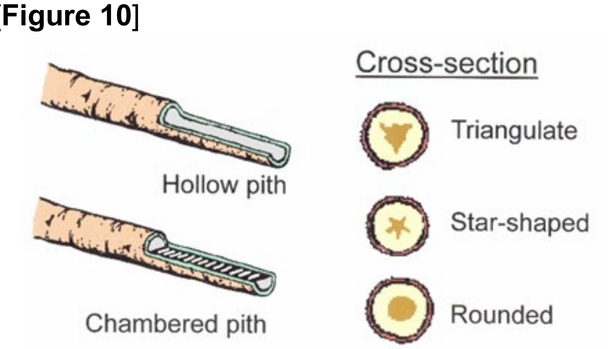


Figure 10.
Internal stem features used in plant identification.

Fruit Characteristics

Generally, the identification of trees and shrubs is done without fruit, as the fruit is only around for a short season. However, when fruit is present, it can be a tool in plant identification. For example, legumes are characteristic of the Pea family (*Fabaceae*). The following is an outline key defining the different fruit types you may see on trees and shrubs.

A note on floral terms here, the **carpel** is the innermost section of a flower and contains the female reproductive structures of the plant. One or more carpels make up the pistil. The pistil can have one ovary (chamber), or several ovaries fused together. Single flowers can also have multiple pistils. The pistil is the part of the flower that the fruit is derived from, so these differences in fruit types come from differences in the arrangement of the pistil. A good place to practice your fruit identification is at the grocery store.

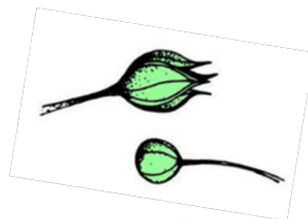
Key of Fruit Types

a. **Simple fruit** – Fruit formed from one pistil.

1. **Dry fruit**

***Dehiscent* fruits** – These fruits split open when mature to release seeds.

- **Capsule** – Many seeded fruits formed from more than one united carpel.



- **Follicle** – Composed of one carpel but splits open at maturity along one suture exposing seeds.

- **Legume** (Pod) – Composed of one carpel that splits open along two sutures (like a pea pod). Characteristics of most members of the *Fabaceae* family.

***Indehiscent* fruits** – These fruits do not split open when mature; the seed stays intact inside.

- **Achene** – One seeded fruit with seed attached at only one place to the pericarp. Pericarp is very close-fitted and does not split open, at least along regular established lines.

- **Samara** – One or two seeded with a membranous wing.

- **Nut** – A bony, hard, one-seeded fruit.

- **Nutlet** – A tiny nut.

b. **Fleshy fruits**

- **Berry** – The entire fruit is fleshy like grapes or currents.

- **Drupe** – The fruit is clearly differentiated into three layers, the outside layer is the epidermis, the middle layer is fleshy, and the inside layer forms a stony “pit” around the seed like a peach or plum.

- **Pome** – The pericarp is surrounded by the floral cup (hypanthium), which becomes the fleshy edible part of the fruit like an apple.

3. **Aggregate fruits** – Develop from a single flower that contains many separate pistils. The fruits from the individual pistils are arranged on one receptacle.

   Examples:
   - ***Fragaria*** (strawberry) – Aggregate of achenes.
   - ***Liriodendron*** (tuliptree) – Aggregate of samaras.
   - ***Maclura*** (Osage-orange) – Aggregate of drupes.
   - ***Magnolia*** (magnolia) – Aggregate of follicles.
   - ***Rubus*** (raspberry) – Aggregate of drupes.

4. **Multiple fruits** – Consists of several flowers which are more or less united into one mass.

   Example:
   - ***Morus*** (Mulberry) and pineapples.

Identification Keys to Landscape Trees

The following is a helpful list of plant identification keys you can use in your broadleaf shrubs and trees identification:

- CMG GardenNotes #172, *Identifying Conifers*: *Arborvitae, Douglas Fir, Fir, Juniper, Pine, Spruce, and Yew.*
- *Flora of Colorado*, Jennifer Ackerfield. Brit Press 2015.
- *Trees and Shrubs of Colorado*, Jack L. Carter. Second edition, 2006.
- *Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses,* Michael A. Dirr, 6th Edition, 1998.

Authors: David Whiting, CSU Extension, retired; Linda McMulkin, CSU Extension, retired; Joanne Jones, CSU Extension, retired; Alison O’Connor, CSU Extension. Line drawings by Scott Johnson and David Whiting. Used with permission.
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Reviewed October 2022

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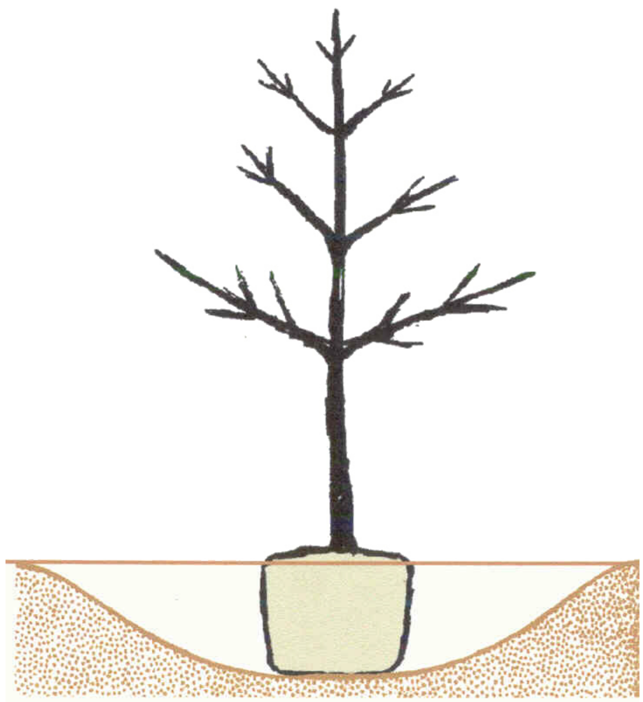

The Science of Planting Trees
Right Plant, Right Place

Colorado Master Gardener[SM]

References / Reading

Colorado State University Extension

Books

- ***Principles and Practice of Planting Trees and Shrubs*** by Gary W. Watson and E.B. Himelick. International Society of Arboriculture. 1997. ISBN:1-881956-18-0
- ***Woody Landscape Plants for the High Plains*** by D.H. Fairchild and J.E. Klett. Colorado State University Cooperative Extension Bulletin LTLB93-1. 1993. To order call the CSU Cooperative Extension Resource Center toll-free at 877-692-9358.
- ***Manual of Woody Landscape Plants*** by Michael A. Dirr. Stipes Publishing. 2009. ISBN-10: 1588748685.

Web

- **Dr. Ed Gilman's Tree Planting Site at University of Florida:** http://hort.ifas.ufl.edu/woody/planting.shtml
- ***Front Range Tree Recommendation List*** at http://www.ext.colostate.edu/pubs/garden/treereclist.pdf

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Tree planting curriculum developed by David Whiting (CSU Extension, retired), with Joann Jones (CSU Extension, retired), Alison O'Connor (CSU Extension), and Carol O'Meara (CSU Extension).

Revised October 2014

Learning Objectives

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

- For a given home landscape situation, discuss *Right Plant, Right Place* considerations for tree placement.
- For a given home landscape situation, discuss *Right Plant, Right Place* considerations for tree selection.
- Plant a tree for rapid root establishment.
- Describe post planting tree care.

Review Questions

Right Plant, Right Place

1 What is the average life of a newly planted landscape tree? Why is it so short?

2. What five categories of plant care play in the success of tree plantings?

3. Describe functions of trees in landscape design.

4. Define a specimen tree, group planting, and mass planting.

5. For energy conservation, where should trees be placed to maximize summer shading and to maximize winter heating?

6. What percent of the sun's radiation will a tree block on a clear summer day?

7. What percent of the cooling effect of trees comes from evapotranspiration? How do drought and irrigation restrictions influence this cooling?

8. In order, list the four priorities for summer shading.

9. For energy conservation, what is the goal in urban forestry as to tree canopy cover?

10. For noise abatement, where should trees and shrubs be placed?

11. List benefits of shade trees.

12. What is the meaning behind "right plant, right place?" List examples of criteria to consider in selecting a tree species for a site.

13. Explain the criteria for above-ground space and below-ground rooting space in tree selection.

14. What happens when the root system cannot escape the root vault area?

15. Give examples of soil- and water-related considerations in tree selection.

16. Give examples of maintenance-related considerations in tree selection.

17. List factors that play into a tree's hardiness. What does a hardiness zone map tell about hardiness? Explain how hardiness changes through the winter in relation to weather.

18. Explain how the microclimate around a home influences plant selection.

19. Give examples of other criteria in tree selection.

20. Explain the rule of thumb for what it takes to move a tree with a 2-, 3-, and 4-foot wide root ball.

21. Where do you find standards (regulations) for plant-size-to-root-size relationships for various types of nursery stock?

22. What are the advantages of selecting a small-caliper tree? A larger-caliper tree? Which will be the largest size five years after planting?

23. Types of stock: Define the following terms and list advantages and limitations of each as indicated on the lecture slides.

    a. Container-grown
    b. In- ground, fabric grow bag
    c. Field-grown – B&B
    d. Field-grown – Balled and Potted
    e. Bare-root

24. To avoid purchasing problems, list key points in the selection and inspection of nursery plants.

25. List key points in pre-plant handling of nursery stock to minimize post-planting stress.

The Science of Planting Trees

26. What is the most limiting factor on a tree's root growth potential?

27. Compared to a field-grown, B&B tree or container-grown tree, what percent of the fine absorbing roots will be found in the nursery stock root ball?

28. What is meant by the "science of planting trees"?

29. What is the proper depth of a tree in the root ball? How can you tell if it is planted at the correct depth? What should be done by the planter if the tree is planted too deep in the root ball?

30. What is the proper depth of the root ball in the planting hole? Why should the tree sit on undisturbed soil? What should be done if the planting hole is accidentally dug too deep?

31. Explain the benefits of the saucer-shaped hole three times wider than the root ball. Explain the concerns about it filling with water.

32. If the planting hole is dug with an auger, how can it be readily modified so the tree has the benefits of a saucer-shaped hole?

33. Be able to diagram and label the routine planting specifications, including depth of tree in the root ball, depth of root ball in planting hole and planting hole depth and width.

34. How are the recommended planting criteria modified for the following planting situations?

    a. Wet soil
    b. Compacted/clayish soil
    c. Planting on slopes

35. For container-grown nursery stock, discuss considerations in removing the container and setting tree in place.

36. For field-grown, B&B nursery stock, discuss considerations in setting tree in place and removing the wrappings.

    a. For B&B materials, why is the wrapping material removed after setting the tree in place and packing soil around the bottom?
    b. What about the packing materials on the bottom? Explain why it does not interfere with root growth.
    c. What packing materials should be removed from the sides? How far down?
    d. Do wire baskets interfere with root growth?
    e. Will burlap decay fast enough to not interfere with root growth?
    f. How fast do synthetic burlap, fabric grow bags, nylon twine, and wire baskets decay?

37. What should the planter do if the root ball has circling roots? What should the planter do if the root ball has roots sticking way out from the root ball?

38. Explain the statement that unamended backfill soil is not the same as unmodified backfill soil. Discuss the issue of amending the backfill. What criteria should be used to determine what criteria are appropriate for a given site?

39. List the four types of above-ground staking. Describe criteria for each.

40. Describe techniques used in below-ground stabilization.

41. Describe criteria for mulching around a newly planted tree.

    a. How deep should the mulch be applied?
    b. What about mulch up against the trunk?
    c. What is the problem with "mulch volcanoes"?

42. Describe steps in planting bare-root nursery stock.

Care after planting

43. Describe the plan for watering newly planted trees based on size. How much should be applied? How often? For how long?

44. How should a tree in the establishment phase be fertilized?

45. What is the rule of thumb on how long the establishment phase lasts?

CMG GardenNotes #631

Tree Placement: Right Plant, Right Place

Outline:

This publication outlines considerations for tree placement in the home landscape. The average life of a tree in the landscape is only eight years due to poor design and planting techniques. Homeowners and landscape designers often place trees in situations where trees have little chance to establish and thrive. Successful tree planting and establishment need attention in these five areas:

- Functional design
- Plant selection
- Pre-plant handling
- Planting techniques
- Post-planting care

Tree Placement in Landscape Design

In landscape design, placement of trees needs careful consideration to function and design elements. Trees are typically the major plant structure in a landscape. Trees give architectural form and organization to space.

In landscape design, trees should not be randomly placed around the property. Rather, place trees as specimens, group plantings, or mass plantings.

Specimen trees – The individual tree becomes the landscape feature. It is set off from other trees and plant materials by unique spacing, form, color, and/or texture. Specimen trees are often, but not always, a focal point in the design.

Group plantings – In group plantings, the trees as a unit become the landscape feature. Groupings are often, but not always, the same species. In group plantings, do not mix contrasting forms.

Mass plantings – In mass plantings, individual trees lose identity and appear as one larger unit in the design. A group planting may grow into a mass planting as trees mature.

Trees serve several key roles in landscape design. They often **define space**. Their spreading branches create a canopy that forms a ceiling for an outdoor room. Because we spend a lot of time indoors, people are more comfortable with this outdoor **ceiling effect**. [Figure 1]

Figure 1. Trees create a comfortable outdoor living space with their "ceiling effect."

Trees are used to **frame and mask views**. Vertical views are effectively framed with trees on both sides. The yard should flow into the view. Avoid specimen plants that draw attention away from the view. [Figure 2]

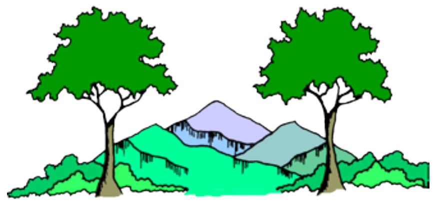


Figure 2. In framing a view, allow the yard to flow into the view.

When framing a house, consider trees in front and to the sides as well as trees that can be viewed over the roofline. For framing, use the point of reference from which most people would view the house rather than straight on. [Figure 3]

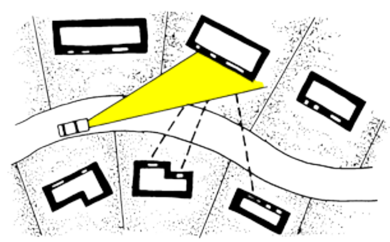


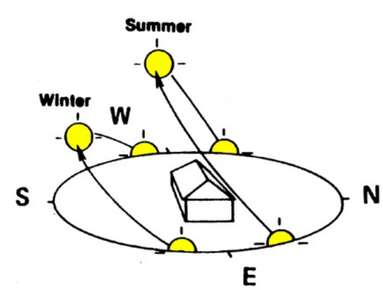
Figure 3. When framing a house, consider how others would look at the home rather than straight on.

Trees and Energy Conservation

Tree placement can play a significant role in energy conservation. Winter sun entering south-facing windows can effectively heat many homes. Summer shade on south- and west-facing windows provides summer cooling.

In evaluating shading and heating patterns, be aware that shade patterns change with the season and with the latitude. [Figure 4]

Figure 4. The shade pattern changes with the season and with latitude.



Maximizing Winter Solar Heating

Homes with south-facing windows have a great potential to capture winter solar heat.

In the winter, deciduous tree branches intercept 20-55% of the sun's radiation. For winter energy conservation, avoid placing trees where they would shade the windows in the winter, and open drapes to allow the sun's energy into the home. Winter shade patterns are large, approximately 2½ times the mature height of the tree at Colorado latitudes. [Figure 5]

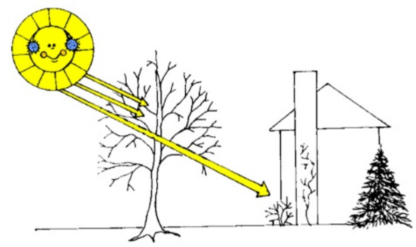


Figure 5. For homes with south-facing windows, tree placement can compromise winter heating potential.

Maximizing Summer Cooling

In the summer, trees block 70-90% of the sun's radiation on a clear summer day. When properly placed, trees can reduce air conditioning demands by 10-30%. Along the Colorado high plains and mountain communities, where temperatures typically cool in the evening, shading a home may adequately moderate temperatures without the expense of air conditioning. [Figure 6]

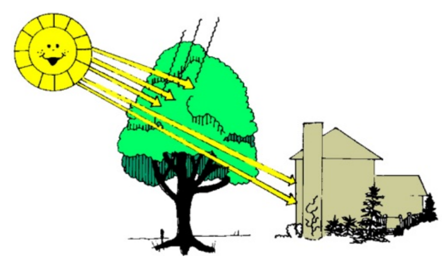


Figure 6. Carefully placed trees can reduce home cooling costs by 10-30%.

Evapotranspiration accounts for 70-80% of the cooling benefit. Under dry conditions (including water restrictions that prohibit landscape irrigation) evapotranspiration shuts down, photosynthesis stops (trees live off carbohydrate reserves), and the cooling effect is reduced. Community temperatures may rise significantly when landscape irrigation restrictions prohibit outdoor watering.

Shading the House

In shading the house, there is a 2-3 hour lag time on sun heat hitting the house and the house becoming extremely hot. Shading priorities at Colorado latitudes include the following:

1. Shade windows on south and west
2. Shade south walls
3. Shade west walls
4. Shade air-conditioning units

Shading Pavement

As illustrated in Figure 7, a paved area stores approximately 50% of the sun's energy. In comparison, a grass area only stores 5% of the energy and uses 50% for evapotranspiration, resulting in a cooling effect. This cooling effect is only operational when the grass has water for active growth.

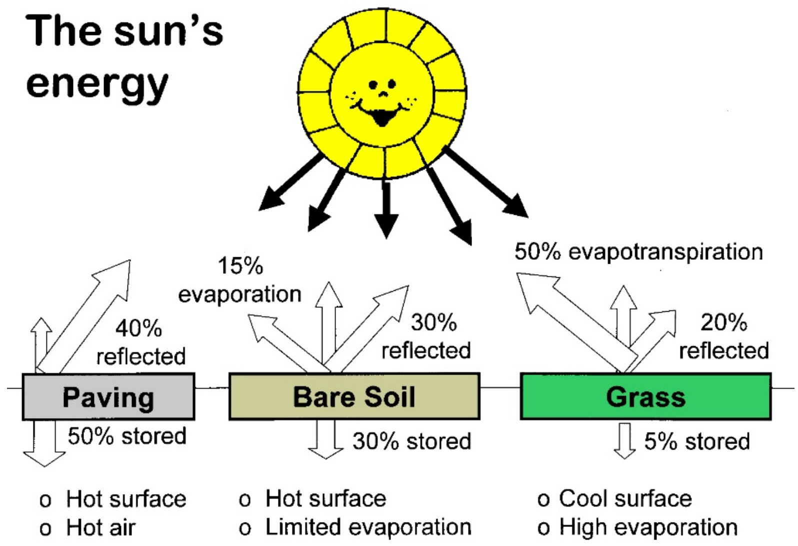


Figure 7. The sun's energy

Another important cooling technique is to shade pavement and other heat-storing materials like the patio and driveway. Also, minimizing paved surfaces helps keep the living area cool. [Figure 8]

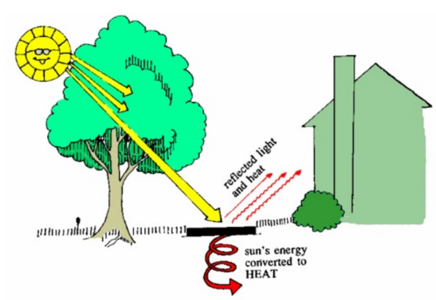


Figure 8. For cooling, shade heat-storing areas and minimize heat-storing surfaces.

Trees and other plant materials may also be used to shield the living space from stored and reflected heat. [Figure 9]

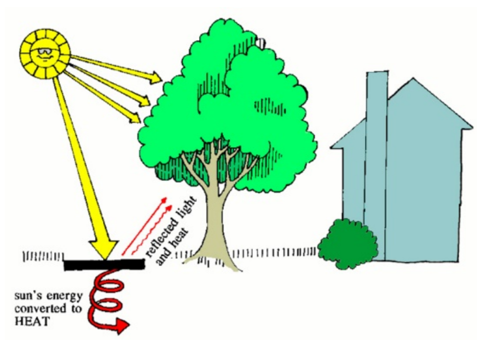


Figure 9. Use trees to cool the air between the heat-storing surface and living space.

Shading Streets

Older communities with tree-lined streets are noted for the pleasing, inviting surroundings that street trees create. Shaded streets are 10°F to 40°F cooler.

However, street trees are often predisposed to poor growth and limited life spans due to poor soil conditions. Tree roots can generally spread under a sidewalk into open lawn areas beyond. Root spread under a street is dependent on the soil properties created during road construction.

When the planting strip between the street and sidewalk is less than eight feet wide, tree health, vigor, and life span will be reduced. In most communities, planting strip width is set by the city ordinance in effect at the time of development.

An effective alternative for tree-lined streets is to plant trees in the lawn eight feet in from the street. This may give trees a better soil environment for root growth, resulting in improved tree vigor, growth, and longevity. In this situation, trees are also less likely to be hit by cars or damaged from road repairs. Eliminating the narrow planting area between the street and sidewalk is also an important water conservation technique as the "mow strip" is difficult to irrigate efficiently.

Noise Abatement with Trees and Shrubs

Tree and shrub hedgerows (planting belts) effectively abate noise pollution. To be most effective, place the hedgerow close to the noise source away from the living area. The hedgerow should be twice as long as the distance from the noise source to the living space. To be effective, the hedgerow needs to be dense. A few trees and shrubs here and there do little to abate noise. [Figure 10]

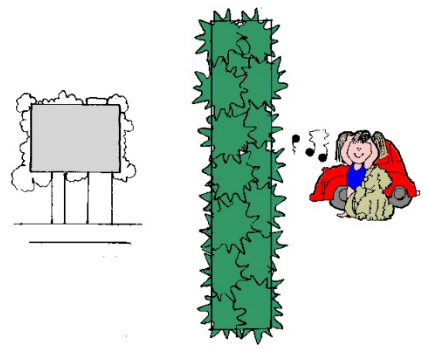


Figure 10. For effective noise abatement, place plant belt next to noise source.

Other Environmental Benefits of Trees

In a study by the USDA Forest Service, the 16,000 street trees in Fort Collins, Colorado, contribute $2.2 million in environmental benefits. The community forest has many important benefits, including:

- Energy saving from heating and cooling
- Noise abatement
- Carbon dioxide reduction – In a Sacramento California study, the carbon sequestration from the community forest more than offsets the inputs from human activity.
- Air-pollution abatement
- Hydrology (stormwater runoff)
- Property values

The USDA Forest Service evaluated the benefits of community forests. For each dollar that a city invests in a community tree program, large trees return $1.92 in environmental benefits. Medium-size trees return $1.36, while small trees return $1.00.
To maximize environmental benefits, the goal in community forestry is to have

50% of the land covered with tree canopy. That is, if we were to look down from an airplane, trees would cover 50% of the area. Here in the west, we have a great need to plant more trees in our communities. In wooded communities, the need may be to thin the forest.

To maximize the benefits of our community forests, homeowners and community leaders need to recognize that the primary benefits occur from large trees. We need to enhance efforts to protect and maintain large trees. We need to plan for large trees in landscape design. Small specimen trees may add to the landscape design, but large trees provide significantly more environmental benefits. We need to plant trees in situations where they have the potential to reach a mature size with longevity.

Growing Space

Size is a primary consideration in tree selection. Trees should fit in the available growing space without pruning. This is of primary concern under utility lines as the utility has the right-of-way. Frequent pruning required to keep utility lines clear adds to our utility rates.

As discussed previously, environmental benefits are significantly greater for larger trees. Consider large tree species whenever the space allows. With proper structural training, large trees have minimal potential for storm and wind damage.

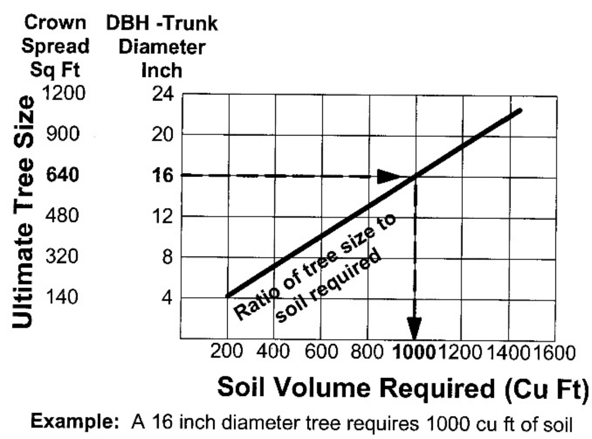
Homeowners often desire fast-growing trees. However, fast-growing species are typically more prone to insects, diseases, and internal decay. Fast-growing species typically have shorter life spans.

Rooting Space

Rooting space should be a primary consideration in tree selection. 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 11 shows the relationship between root space and ultimate tree size. For example, a tree with a 16-inch diameter requires 1,000 cubic feet of soil. On a compacted, clayey soil, rooting depth may be restricted to 1 foot or less, and spread would be an area 36 feet in diameter. Anything less will reduce tree size, growth rates, vigor, and longevity. [Figure 11]

Figure 11. Ultimate tree size is set by the rooting space.



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; it can be about any shape. Trees can share rooting space.

Trees in Planters

Trees are often placed in planters and other sites with limited rooting potential. If the roots cannot escape the planting site (root vault) into other soils:

1. Root growth slows when the root vault area is filled.
2. Tree growth slows.
3. Tree declines.
4. Routine replacement is required.

The average life of trees in sidewalk planters and other restricted root vault sites is 8 years. Home gardener and landscape designers need to understand that with restricted rooting space, growth potential, and longevity are reduced accordingly.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension). Artwork by David Whiting; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #632

Tree Selection: Right Plant, Right Place

Outline:

The average life of a tree in the landscape is only eight years due to poor design and planting techniques. This publication outlines considerations in tree selection for the home landscape.

Species Selection

Many species of trees and shrubs are well suited to Colorado landscapes. Colorado State University Extension publications listing trees and shrubs for Colorado, including the following:

CSU Extension Fact Sheets available online at www.cmg.colostate.edu.

- Deciduous Shrubs, #7.415
- Evergreen Shrubs, #7.414
- Evergreen Trees, #7.403
- Hedges, #7.208
- Large Deciduous Trees for Street and Shade, #7.419
- Native Shrubs for Colorado Landscapes, #7.422
- Native Trees for Colorado Landscapes, #7.421
- Shrubs for Mountain Communities, #7.407
- Small Deciduous Trees, #7.418
- Trees and Shrubs for Mountain Areas, #7.423
- Xeriscaping: Trees and Shrubs, #7.229

Other Publications

- ***Front Range Tree Recommendation List*** available at http://www.ext.colostate.edu/pubs/garden/treereclist.pdf

In addition, many communities and nurseries have tree lists for local areas. Some communities have small arboretums in local parks where a variety of trees may be viewed.

In selecting trees for a home landscape, remember that there is NO perfect tree. All trees have good and bad characteristics. Select trees based on site considerations as well as personal likes.

The best advice for selecting trees is to intentionally plant a diversity of species in the neighborhood and community. Avoid frequent use of only a few tree species as this increases the likelihood of insect and disease problems. Dutch elm disease spread through the United States due to the over-planting of elm trees. Ash trees became a common replacement for Elms. Now the lilac/ash borer is commonplace. Currently honeylocust is very popular, and pest problems on honeylocust are becoming common. Aspen is popular along the Colorado Front Range. While native to our mountains, it is not native to the high plains and has many problems in irrigated yards along Front Range communities.

Mature Size

Size is a primary consideration in tree selection. Trees should fit in the available growing space without pruning. This is of primary concern under utility lines as the utility has the right-of-way.

Because large trees give a higher return in environmental benefits, plant large tree species whenever the space allows. Large trees can be structurally strong if attention is given to structural training while young.

Growth Rates

Homeowners often desire fast-growing trees. However, fast-growing species are typically more prone to insects, diseases, and internal decay. Fast-growing species typically have shorter life spans.

Soil Considerations

Suitable rooting space is a major limiting factor in tree growth. Poor soil conditions contribute to 80% of tree health issues. Unfortunately, many homeowners and landscape designers fail to consider soil limitations in tree selection and planting. Impacts of poor soil conditions include the following:

- Many trees fail to establish or are slow to establish.
- Growth rates will be reduced.

- Tree vigor will be low, predisposing trees to insects, diseases and other stress factors.
- Mature size will be smaller.
- Longevity will be shorter.

Soil texture, structure, and tilth are considerations in tree selection. Some trees perform poorly in compacted or clayey soils (due to low soil oxygen levels). On compacted or clayey soils, drainage can be a limiting factor. Reference books often list trees that are “flooding or compaction tolerant” as an indication of trees more tolerant of low soil oxygen and more adaptable to compacted or clayey soils. Other trees do poorly in dry sandy soils (due to drought).

If the soil has *free lime*, iron chlorosis is a common problem for some species of trees in heavily irrigated lawns. Avoid planting species susceptible to iron chlorosis (like silver maple and aspen) in this situation. For additional information, refer to *CMG GardenNotes* #223, **Iron Chlorosis**. [Figure 1]

Figure 1. Iron chlorosis (yellowing of younger leaves with veins remaining green) on aspen.

Water Needs and Tolerances

Water needs and tolerances are primary considerations in light of Colorado’s drought cycle. Gardeners need to understand that the water needed to maintain life is unrelated to the water needed for tree growth. Drought tolerance for any tree changes with the life cycle of the tree. Trees listed as drought-tolerant may not be suitable to extremely dry sites or prolonged water stress.

Scientists cannot yet answer the common question, “How many gallons of water does this tree need?” At best, listing of trees more tolerant of dryer sites is only observational based on routine dry spells, not extreme drought situations.

Another common issue about tree selection is tolerance to wet soils. Due to poor irrigation system design, maintenance, and management, most home lawns are significantly over-watered. Some trees, such as crabapples and aspen, are rather intolerant of the excessive irrigation.

Management Concerns

Common management issues are a consideration in tree selection.

Pruning – Trees with a decurrent growth habit are more prone to storm and wind damage. Damage potential can be minimized if the trees are structurally trained while young.

Common insect and disease problems should be a consideration. What are the common pests of the tree? Which are only cosmetic, and which can affect tree health? How tolerant are you of cosmetic pests? Under what situations would management efforts become warranted? What is your interest and willingness to make pest management efforts?

For example, stressed ash trees are highly susceptible to lilac/ash borer that may kill trees. For gardeners unwilling to routinely treat for borers, ash would be a poor choice, particularly on a site with limited rooting area. Aspen are highly susceptible to poplar twig gall when planted in a heavily irrigated lawn. If you do not like this cosmetic damage, do not plant aspen in routinely irrigated sites. Honeylocust are highly susceptible to the honeylocust spider mite (which can defoliate the tree midsummer) when planted on dry sites or with restricted rooting areas. If you are not willing to treat for spider mites, do not plant honeylocust on dry sites or those with restricted rooting areas.

Other maintenance factors include:

- Fruiting habit
- Leaf litter nuisance
- Seed germination
- Root and basal suckering

Climatic Adaptation

Exposure to sun, wind, heat, and cold are considerations in tree selection. Issues related to winter hardiness and winter burn can be reduced with winter watering on susceptible species.

Hardiness zones are an indication of the expected minimum low winter temperature. However, in Colorado we occasionally have an extremely cold winter that challenges the hardiness zone data as we approach record lows.

Hardiness (the ability of a plant to withstand cold) comes from many interrelated factors:

Photoperiod and genetics – The length of night (photoperiod) is the first signal trees receive that winter is approaching. When parent materials are collected from the south and then moved north, they may not be adapted to the differences in photoperiod, and winter damage may be more pronounced. Growers are becoming aware of this important issue in selection of nursery stock.

Minimum temperatures that trees tolerate are set by the plants' genetics and influenced by recent temperatures.

Recent temperatures – A tree's tolerance to cold is heavily influenced by the temperature patterns of the previous few days. When temperatures gradually drop over a period of weeks, trees are generally tolerant of extreme cold. However, trees are less tolerant of extreme cold when it appears suddenly following moderate temperatures.

Rapid temperature change is a primary factor limiting our plant selection. In Colorado it is common to have a spring thaw followed by an "arctic express" back to winter. Temperatures readily drop more than 50°F in an hour.

Water – Woody plants going into winter with dry soil conditions lose approximately 20°F in hardiness. Colorado's dry fall and winter weather reduces plant hardiness. Fall watering, after leaves drop but before soils freeze, helps minimize hardiness issues.

Wind exposure is another factor reducing hardiness in open areas of the high plains. Winter watering helps manage this issue.

Exposure to sun, including reflected sun from snow or structures, contributes to winter bark injury and frost cracks.

Carbohydrate reserves – Plants under stress, with lower carbohydrate reserves, are more susceptible to winter damage. During the drought of 2002-2004, Colorado trees experienced extensive winter injury related to stress, even without extreme cold.

Microclimates – The typical yard has dryer and wetter sites, windy and less windy areas, and warmer and cooler areas. These microclimates may create a site that is more or less suitable for some specific plants.

Other Selection Criteria

- Potential damage to hardscapes (sidewalks, gutters, etc.) from root growth
- Utility right-of-ways for above-ground and below-ground utilities
- Vandalism in public-access sites
- Car damage along streets
- Turf competition and herbicide use
- Pesticide drift from adjacent properties
- De-icing salts

The majority of landscape management problems are traceable back to the design flaws. Care in tree selection and placement will help minimize management problems.

Size Considerations

Size and Establishment

To give the "instant tree" appearance, larger-caliper trees are often the choice for homeowners and public-access sites. However, the root systems of larger trees also take longer to redevelop in the establishment phase of the life cycle before the trees shift into the growth phase. During the establishment phase, canopy growth will be minimal. For this reason, smaller trees are recommended on sites where less than ideal growing conditions exist.

In Hardiness Zones 4 and 5, with good planting techniques and good soil conditions, it typically takes one growing season per inch of trunk caliper (measured at six inches above soil line) for roots to establish following transplanting. That is, a one-inch caliper tree will take one season for the roots to establish, while a three-inch caliper tree will take three seasons. In cooler regions with shorter growing seasons, it will take longer. With longer growing seasons, like the southern United States, the establishment phase will be measured in months.

On sites with poor soils and poor planting techniques, the establishment phase may be longer, and trees must live off carbohydrate reserves until roots become established. It is common to see trees planted with poor planting techniques and/or poor soil conditions that never establish, but rather decline over a period of time. In recent years, poor planting techniques have killed more trees than any insect or disease outbreak!

Moving Trees – A Weight Issue

Size (weight) is another factor in tree selection. It takes two people to move a two inch caliper tree (measured six inches above the soil line). Larger trees require mechanical help. Trees up to four inch caliper can be moved with front-end loaders used in landscape installation. For larger-caliper trees, special tree-moving equipment is required.

Minimum Root Ball Size

The minimum size of the root ball for trees and shrubs is set by the Colorado Department of Agriculture in the ***Rules and Regulations of the Colorado Nursery Act***. [Tables 1 and 2]

Maximum tree size to move with a spade is given in Table 3. It is common mistake to expect tree to live when moved with an undersized tree spade! [Table 3]

Table 1.
Minimum Root Ball Diameter for Nursery-Grown, and B&B Shade Trees

Tree Caliper*	Minimum Root Ball Diameter
½ to ¾ inch	12 inches
¾ to 1 inch	14 inches
1 to 1 ¼ inches	16 inches
1 ¼ to 1 ½ inches	18 inches
1 ½ to 1 ¾ inches	20 inches
1 ¾ to 2 inches	24 inches
2 to 2 ½ inches	26 inches
2 ½ to 3 inches	28 inches
3 to 3 ½ inches	32 inches
3 ½ to 4 inches	36 inches

*Measured 6 inches above soil line.

Table 2.
Minimum Root Ball Size for Coniferous Evergreens

Height	Caliper[1]	Minimum Root Ball Diamter[2]
1 to 2 feet	½ to ¾ inches	12 inches
2 to 3 feet	¾ to 1 inch	14 inches
3 to 4 feet	1 to 1¼ inches	16 inches
4 to 5 feet	1¼ to 1½ inches	18 inches
5 to 6 feet	1½ to 1¾ inches	20 inches
6 to 7 feet	1¾ to 2 inches	24 inches
7 to 8 feet	2 to 2½ inches	26 inches
8 to 9 feet	2½ to 3 inches	28 inches
9 to 10 feet	3 to 3½ inches	32 inches
10 to 12 feet	3½ to 4 inches	36 inches

[1] Measured at 6 inches above the ground
[2] Root ball size based on the larger of height or caliper.
Source, Colorado Department of Agriculture: Colorado Nursery Act

Table 3.
Maximum Size for Tree Spades

Spade Size	Deciduous Trees Caliper	Evergreen Trees Height
44-inch	2-3 inches	5-7 feet
60-inch	3-4 inches	7-9 feet
78-inch	4-6 inches	9-14 feet
85-inch	6-8 inches	14-18 feet

Types of Nursery Stock

Bare-Root Nursery Stock

Bare-root plants are sold without an established soil ball. Bare-root stock is generally limited to smaller-caliper materials. Some evergreen materials will not transplant well as bare-root stock.

The cost of bare-root stock is significantly lower than the same plant as a container-grown or B&B stock.

Roots dehydrate rapidly and must be protected. Bare-root stock is often marketed in individual units with roots bagged in moist sawdust or peat moss to prevent dehydration. Sometimes bare-root stock is temporarily potted to protect roots. Some nurseries maintain bare-root stock in moist sawdust. As plants are removed at sale, roots are packed in moist sawdust for transport to the planting site. These need to be planted within 24 hours of purchase.

Survivability drops rapidly once the plant leafs out. Some nurseries keep bare-root stock in cold storage to delay leafing.

Field-Grown, Balled and Burlapped Nursery Stock

Field-grown, Balled and burlapped (B&B) trees are dug from the growing field with the root ball and soil intact. In the harvest process, only 5-20% of the small roots are retained in the root ball, the other 80-95% is left behind in the field. This puts trees under water stress until roots can reestablish. [Figure 2]

Figure 2. Field-grown B&B nursery stock

To prevent the root ball from breaking, the roots are Balled and wrapped with Burlap and twine (knows as B&B). In nurseries today, there are many variations to B&B techniques. Some are also wrapped in plastic shrink-wrap, placed in a wire basket, or placed in a pot.

B&B stock is best transplanted in the spring or fall.

The weight of the root ball readily becomes an issue with larger-caliper trees. A two inch caliper tree is the largest size two people can expect to move. Equipment will be needed for larger trees.

In field production, the roots may be routinely cut to encourage a more compact root ball. While this process improves the transplantability of the tree, it slows growth, adding to production costs.

Container-Grown Nursery Stock

Container-grown nursery stock is grown in the container. Because the root system is not seriously disturbed, container-grown nursery stock can be readily transplanted throughout the growing season; spring, summer or fall.

Figure 3. Container-grown nursery stock.

Light textured potting mixes are generally used in container production to reduce weight and waterlogging potential in the pot. However, this can make the newly planted tree more prone to drought during the first two years.

Since the roots cannot spread, the root system of container-grown stock will be only 5-20% of that found in field-grown plants. Thus, growth rates in the nursery may be slower.

There are many variations of container production. In many systems, like "pot-in-pot" and "grow-bags," the container is in the ground. This protects roots from extreme heat and cold and prevents trees from blowing over.

Selecting Plants – Don't Buy Problems

There are several considerations in plant selection at the nursery, including the following:

- Because **codominant trunks** (trunks of equal size) account for the majority of storm damage, avoid purchasing trees with codominant trunks. A single-trunk tree should have one trunk to the top, and all branches should be less than 1/2 the diameter of the adjacent trunk. (Refer to pruning fact sheets for details.) [Figure 4]

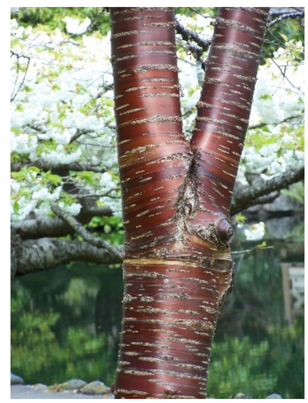

Figure 4. Codominant trunks account for the majority of storm damage. Avoid purchasing trees with codominant trunks or correct the situation with structural pruning.

- Consider what other **corrective pruning** will be needed to structurally train the tree. (Refer to pruning fact sheets for details.) Avoid trees with poor branching structure.

- Any **pruning wounds or bark injury** should be less than one inch or less than 25% of the trunk circumference.

- Trees should have good **growth** the past 2-4 years and good **leaf color**.

- Evaluate the potential long-term impacts of any **insect or disease problems**. While some insect and disease problems are not an issue, others could seriously affect the tree's health. Due to the water stress imposed by the harvest and planting process, young trees are less tolerant of most pests.

- **Planting depth of the tree in the root ball** – Generally, at least two structural roots should be within the top 1-3 inches of the soil surface, measured 3-4 inches out from the trunk. (Refer *CMG GardenNotes* #633, The Science of Planting Trees, for additional details and exceptions.)

  A visible trunk flare is another indication of proper planting depth in the root ball. However, on many small trees the trunk flair is hardly noticeable. A small gap between the trunk and soil indicates that the tree is planted too deep.

- **Healthy roots** are whitish, while dead roots are dark. **Girdling roots** can become a serious problem and will need to be cut in the planting process.

Shipment and Pre-Plant Handling

Pre-plant handling often predisposes new plantings to decline and death. Factors to pay attention to include the following:

- **Handle carefully.** The root ball is subject to cracking, killing the tree.
- **Lift by the root ball**, not the trunk. If lifted by the trunk, the roots may not be able to support the weight of the root ball soil, cracking the root ball.
- **Protect from mechanical injury** during shipment. The bark on young trees is tender and easily damaged by rubbing or bumping against the vehicle.
- **Protect from dehydration** during shipment. A shade cloth gives good wind protection. Many nurseries routinely wrap trees for shipment. Water upon delivery.
- **Protect from wind and heat** until planted.
- **Check water needs daily.**
- When possible, **plant immediately**.
- **Exposed roots** are readily killed by desiccation and should be cut off in the planting process.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension).
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- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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- Extension programs are available to all without discrimination.

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CMG GardenNotes #633

The Science of Planting Trees

Outline:

This *CMG GardenNotes* outlines research-based tree planting steps. The procedures apply to deciduous trees, evergreen trees, and shrubs planted in a landscape setting. As you review the content, pay attention to significant clarification in planting protocol. Based on the research consensus, it is not acceptable to plant a tree in a narrow planting hole with the burlap and wire basket left in place.

The Science of Planting Trees

Tree root systems are shallow and wide spreading. [Figure 1] Based on nursery standards, a field-grown, balled and burlapped (B&B) tree or container-grown tree has less than 5-20% of the fine absorbing roots of the same size tree in a landscape setting. This creates stress when the tree moves from the daily care in the nursery setting to the landscape**. The goal of the science of planting trees is promoting rapid root growth to reduce the water stress imposed by the limited root system.** *Post-planting stress* (transplant shock) describes the stress factors induced by the limited root system.

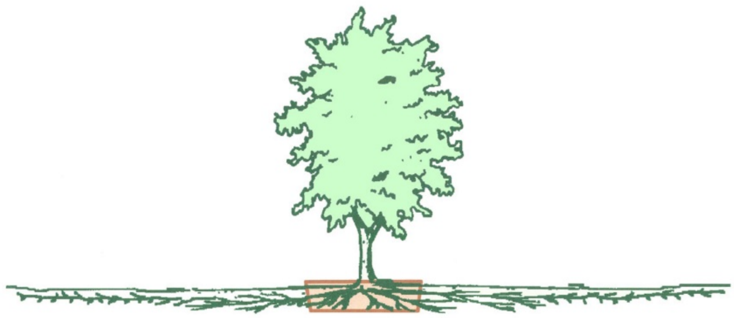


Figure 1. A tree's rooting system is shallow and wide spreading. Based on nursery standards, the container grown or field-grown, balled and burlapped tree has only 5-20% of the fine absorbing roots found on the same size tree in an open landscape. This places the new tree under stress.

Steps to Planting Container-Grown or Field-Grown B&B Nursery Stock

Note: Call before you dig. Whether you plan on planting the tree yourself or hiring the work done, the site needs to have underground utilities marked before digging to plant a tree. In Colorado, this is easy to do by calling the **Utility Notification Center of Colorado** at 1-800-922-1987 or 8-1-1.) It can also be done online at **colorado811.org**. The utilities will be marketed within 72 business hours, so plan ahead.

Step 1. Determine Depth of the Planting Hole

Planting trees too deep has become an epidemic leading to the decline and death of landscape trees. Trunk-girdling roots, caused by planting too deep, leads to more deaths of landscape trees than all other factors combined!

Trunk-girdling roots develop when a tree is planted too deep in the root ball and/or the root ball is planted too deep in the planting hole. Trunk-girdling roots may lead to decline and death some 12 to 20 years after planting. Trunk-girdling roots may be below ground.

To deal with this epidemic an industry-wide working group developed the following standards[1] for tree planting depth:

These standards have been adopted industry wide, including endorsement by the American Nursery and Landscape Association (ANLA), American Society of Consulting Arborists (ASCA), American Society of Landscape Architects (ASLA), Associated Landscape Contractors of America (ALCA), International Society of Arboriculture (ISA), and Tree Care Industry Association (TCIA).

Depth of Root Ball in Planting Hole

In tree planting, **the root ball sits on undug soil**. This prevents the tree from sinking and tilting as the soil settles. If the hole is dug too deep, backfill and firm the soil on the bottom to the correct depth. (Roots grow out from the root ball, not down.)

To deal with the *soil texture interface* (actually the differences in soil pore space) between the root-ball soil and backfill soil, it is imperative that the root ball rise slightly above grade with no backfill soil over top of the root ball. For small (one-inch caliper) trees, the top of the root ball rises one inch above grade. For larger (two to four inch caliper) trees, the top of the root ball rises about two inches above grade. Backfill soil should cover the "knees" tapering down to grade. [Figure 2]

If backfill covers the root ball, water and air will be slow to cross the texture interface. In this situation, water tends to move around the root ball and is slow to soak into the root ball. Root health will be compromised by lower soil oxygen levels. [Figure 3]

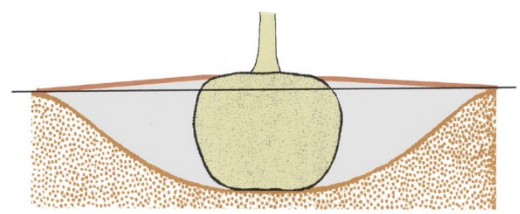


Figure 2. Depth of root ball in planting hole – Top of root ball rises 1-2 inches above soil grade. No soil is placed over top of the root ball. Backfill soil covers the "knees" tapering downward to the original soil grade. Root ball sits on un-dug/firmed soil to prevent sinking.

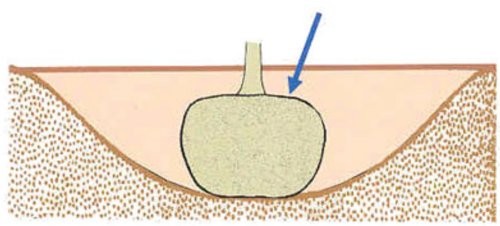


Figure 3. It is imperative that the root ball comes to the surface, with no backfill on top of the root ball. When backfill soil is placed over top of the root ball, the *soil texture interface* impedes water and air movement into the root ball.

Depth of Tree in the Root Ball

- Generally, at least two structural roots should be within the top one to three inches of the root ball, measured three to four inches from the trunk.
- On species prone to trunk-circling roots (crabapples, green ash, hackberry, littleleaf linden, poplar, red maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

Checking Depth of Tree in Root Ball

Check the depth of the tree in the root ball. Do not assume that it was planted correctly at the nursery.

- The presence of the root flare is an indication of good planting depth. However, small trees may have minimal root flare development, making it difficult to determine. Be careful not to mistake swelling of the trunk below the graft as the root flare.

- A good way to evaluate planting depth in the root ball is with a slender implement like a slender screwdriver, knitting needle, or barbeque skewer. Systematically probe the root ball three to four inches out from the trunk to locate structural roots and determine their depth. [Figure 4]

Figure 4. Systematically probe the root ball with a slender screwdriver. Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk circling roots (crabapples, green ash, hackberry, littleleaf linden, poplar, red maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

If the tree is planted too deep in the root ball, excess soil should be removed from the top in the backfill step of the planting process. Adjust the depth of the planting hole to compensate. [Figure 5]

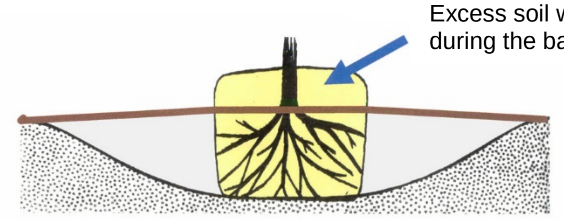
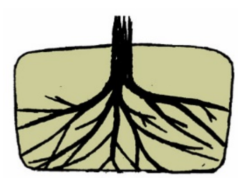


Figure 5. Adjust the depth of the planting hole to bring the root flare to the correct depth.

With trees planted too deep in the root ball, a better option is to not purchase the trees. In the root ball, the soil above the root flare generally does not contain roots so the total volume of roots may be too small to maintain tree health. In container-grown stock, trees planted too deep readily develop trunk-circling roots. [Figure 6]

Figure 6. Another issue with soil levels above the root flare is root ball size. With roots only in a portion of the root ball area, the root ball may be too small for the tree to thrive following planting.



Summary: Depth of Planting Hole

Depth of the planting hole should be 1-2 inches less than the height of the root ball, adjusted (as needed) to correct the depth of the tree in the root ball.

For example, if a two-inch caliper tree has a root ball height of 16 inches, depth of the planting hole would be 14 inches. However, if the top structural roots are located five inches down in the root ball, between two to four inches of soil needs to be removed from the root ball in the backfill process. Depth of the planting hole would be adjusted to 10-12 inches.

Figure 7. In digging, measure the depth of the planting hole with a straight board (like rake handle) and a measuring tape.

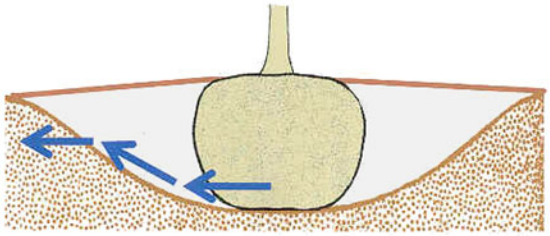
Figure 8. Checking depth of root ball in planting hole with a straight board (like a rake handle).

Step 2. Dig Saucer-Shaped Planting Hole Three-Times Root Ball Diameter

Saucer-Shaped Planting Hole

To support rapid root regeneration, research suggests a wide, saucer-shaped planting hole. If the roots have difficulty penetrating compacted site soil (due to low soil oxygen levels), sloped sides direct roots upward and outward toward the higher oxygen soil near the surface rather than being trapped in the planting hole. Roots that do not penetrate the site soil may begin circling in the hole, leading to trunk-girdling roots. [Figure 9]

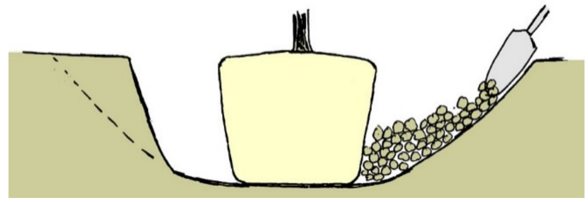
Figure 9. When roots cannot penetrate the site soil (due to low oxygen levels), the saucer-shaped planting hole directs the roots upward and outward into soils with higher oxygen levels.



Waterlogging concerns – The saucer-shaped planting hole actually gives the tree a larger margin for error in overwatering. In the saucer-shaped planting hole, three times the root ball diameter, the upper half contains 85% of the backfill soil, and the upper quarter contains 75% of the backfill soil. Water could saturate the lower 3/4 of the backfill soil and only affect 25% of the root system!

When the planting hole is dug with an auger, cut down the sides with a shovel to help eliminate the glazing and create the preferred sloping sides. An alternative is to rototill a 12-24" inch ring of soil around the planting hole after planting. [Figure 10]

Figure 10. When dug with an auger, cut down the sides into the saucer shape during backfill process.



Planting Hole Depth

Depth of the planting hole is determined in Step 1. To measure depth of the dug hole, place a straight board or shovel handle across the hole and measure from the board/handle height to the bottom of the hole.

For stability, it is imperative that the root ball sits on undug soil. If the hole is dug too deep, backfill and firmly pack the soil to the correct depth. Remember that the planting hole is shallow and wide. As a point of clarification, primary growth of roots is outward, not downward.

Planting Hole Width

Planting hole width is the key to promoting rapid root growth, reducing *post-planting stress.* In soils with great *tilth* (conditions supportive to ideal root growth), width is probably not a minor concern. However, in a compacted clayey soil, typical of much of Colorado, root growth slows when roots reach the undisturbed site soil beyond the backfill area. This is due to lower soil oxygen levels in the undisturbed soil.

Twenty-five percent wider – A planting hole with vertical sides that is only twenty-five percent wider than the root ball hinders root growth. If the soil is compacted and difficult to penetrate, the roots circle inside the hole just as if the root system were in a container. Size of the root system (before growth is slowed by the lower oxygen levels of the site soil) is insufficient to reduce *post-planting stress.* Narrow planting holes are sometimes used as a labor saving technique. However, on less than idea soils, it will slow root establishment and may predispose the roots to circling.

Two times root ball – A saucer-shaped planting hole twice the diameter of the root ball will allow the root system to grow rapidly to 150% of the root ball size before growth is slowed by the lower oxygen levels of the site soil. This is not enough to avoid *post-planting stress* under normal conditions. A planting hole two times root ball diameter is common in commercial plantings as a labor savings technique. However, on less than idea soils, it may slow root establishment.

Three times root ball – A saucer-shaped planting hole three times the diameter of the root ball allows the root system to grow rapidly to 400% of the root ball size before being slowed by the lower oxygen levels of the site soil. This is enough to reduce *post-planting stress* under normal conditions. For example, a two-inch diameter tree with a 24 inch (two foot) wide root ball needs a 72 inch (six foot) wide saucer-shaped planting hole. To promote root growth, the planting hole is wide, shallow, and saucer-shaped!

The shallow but wide planting hole is the primary technique for encouraging rapid root growth, which is the objective in the *science of planting trees*. This is an important change in the mindset of many folks who have been planting into a narrow, deep hole.

Summary: Planting Hole Specifications [Figure 11]

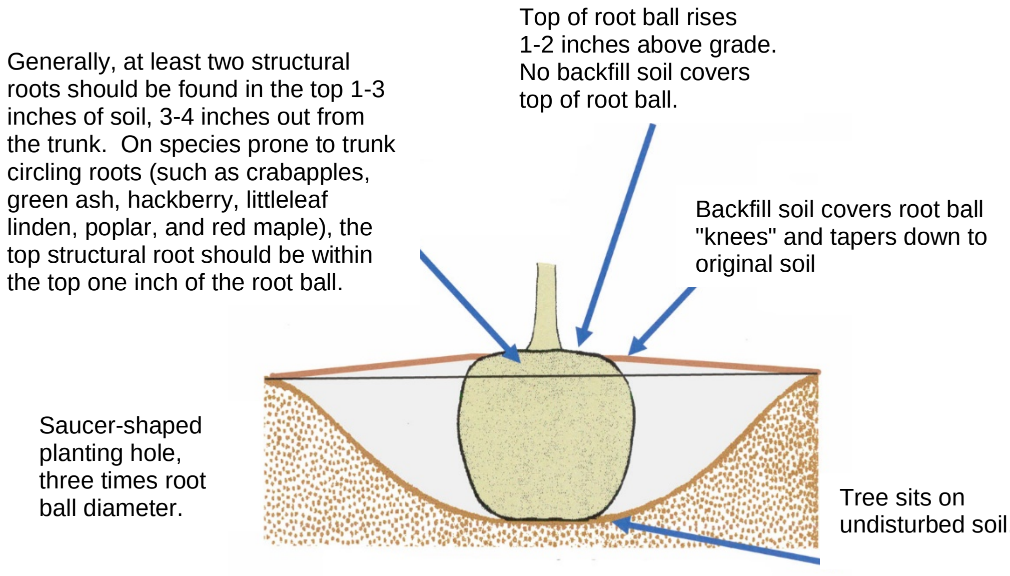


Figure 11. Planting hole criteria to promote rapid root establishment, reducing post-planting stress.

Modification for Wet Soils

On wet soils, raise planting depth so that one-third of the root ball is above grade. Cover root ball "knees" with soil, gradually tapering down to grade. Do not use mulch to cover knees, as roots will readily grow in moist mulch but will be killed when the mulch dries out. [Figure 12]

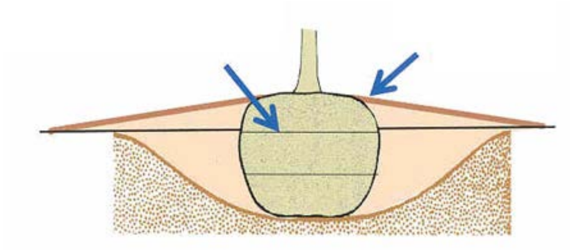


Figure 12. On wet soils, place root ball 1/3 above grade, covering knees with soil tapering down to grade.

Modification for Compacted Soils

On extremely compacted soils, rototilling a ring around the backfill area to a width of four, five, or more times the root ball diameter may be helpful. This should be done after planting is completed so the soil is not compacted by foot traffic during the planting process. [Figure 13]

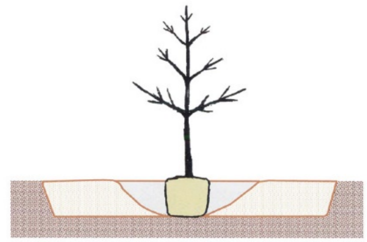


Figure 13. Rototilling a ring around the planting hole may help roots spread into compacted soil.

Planting on a Slope

When planting on a slope, plant "out-of-the-hill" by adjusting the grade around the planting hole as illustrated in Figure 14.

Figure 14. Planting on a slope:
Top row: When planting on a slope, adjust the grade to plant "out-of-the-hill."
Right: When planted "into-the-hill," roots on the uphill side will be too deep, slowing root establishment and growth.

Labor-Saving Techniques

A labor-saving technique is to dig the hole twice the root ball width with more-vertical sides. Place the tree in the hole, firm a ring of soil around the base of the root ball to stabilize it, remove wrappings, and check for circling roots. Then with a shovel cut the sides of the planting hole to form the saucer-shaped planting hole three times the root ball diameter. With this technique, part of the backfill soil does not have to be removed and shoveled back, but simply allowed to fall into the hole. Soil "peds" (dirt clods) up to the size of a small fist are acceptable. With this technique, it is not practical to mix in soil amendments, as amendments must be thoroughly mixed throughout the backfill soil. [Figure 15]

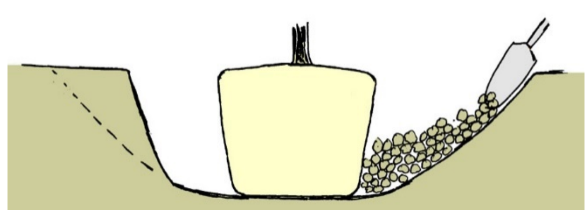
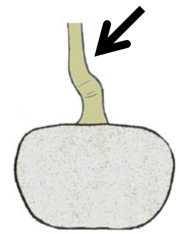


Figure 15. Planting hole widened into saucer-shape during the backfill process.

A small tiller or "garden weeder" makes for quick digging. Simply place the tiller where the hole will be and walk around in a circle. Stop periodically to remove the loosened soil from the hole, and continue walking and tilling in a circle. [Figure 16]

Figure 16. Digging the hole with a small tiller or "garden weeder."

<u>**Step 3. Set Tree in Place, Removing Container/Wrappings**</u>



In setting the tree in the planting hole, if the tree has a "dogleg" (a slight curve in the trunk just above the graft) the inside curve must face north to reduce winter bark injury. [Figure 17]

Figure 17. The inside curve of the graft crook or "dogleg" must face north to reduce winter bark injury.

Vertically align the tree with the top centered above the root ball. Due to curves along the trunk, the trunk may not necessarily look straight. It will appear straighter with growth.

In this step, techniques vary for container-grown trees and B&B trees.

Container-Grown Nursery Stock

“Container-grown” nursery stock refers to trees and shrubs grown in containers using a variety of production methods. Spread of the root system is limited to the container size. An advantage of container stock is that it can be planted in spring, summer, or fall. Smaller trees and shrubs are commonly grown in containers.

There are many variations of container production. In many systems, like “pot-in-pot” and “grow-bags,” the container is in the ground. This protects roots from extreme heat and cold and prevents trees from blowing over.

In container-grown nursery stock, circling roots develop over time. These may be on the outside of the root ball (particularly at the bottom of the container) or just inside the root ball and not visible from the surface. Current research finds that the old standard of slitting the root ball on four sides does not adequately deal with circling roots. New standards call for the outer 1-1½ inch of the root ball to be shaved off with a knife, saw, or pruners in the planting process. This encourages roots to grow outward and does not affect tree growth potential.

Figure 18. Container-grown nursery stock is prone to developing circling roots that will girdle the trunk several years after planting if not corrected.

Techniques with Container-Grown Stock

Actual planting techniques in this step vary with the type of container and extent of **root** development. Generic steps include:

a) Lay the tree on its side in or near the planting hole.
b) Wiggle off or cut off the container.
c) Shave off the outer 1-1 ½ inch of the root ball with a knife, saw, or pruners. This step is important to deal with circling roots.
d) Tilt the tree into place. Remember that the inside curve of any dogleg faces north.
e) Check depth of the root ball in the planting hole. If incorrect, remove the tree and correct the depth, firming any soil added back to the hole.
f) Align vertically.
g) Firm a shallow ring of soil around the bottom of the root ball to stabilize it. [Figure 19]

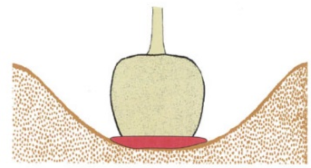


Figure 19. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball.

- The ideal container-grown tree has a nice network of roots holding the root ball together. After the container is removed, the tree is gently tilted into place.
- If some of the soil falls off (often on the bottom), it may be necessary to adjust the depth of the planting hole. Backfill and pack the bottom of the planting hole to the correct depth.
- If most of the soil falls off the roots, the tree is planted as a bare-root tree (see below).
- Fabric grow bags must be removed from the sides. They are generally cut away after setting the tree in place.
- Generally, paper/pulp type containers should be removed. Most are slow to decompose and will complicate soil texture interface issues. Pulp containers often need to be cut off, as they may not slide off readily.
- In handling large trees (3-inch caliper and greater) it may be necessary to set the tree in place before removing the container.
- If the container is easy to cut, it may help to keep the root ball intact by first cutting off the bottom of the container, carefully setting the tree in place and tilting to align vertically, then cutting a slit down the side to remove the container.

Figure 20. If the container is easy to cut, many planters prefer to first cut off the bottom, then move the tree in place (helps hold root ball together) and then slit the container side to remove it.

Field-Grown, Balled and Burlapped Nursery Stock

Field-grown, balled and burlapped (B&B) trees and shrubs are dug from the growing field with the root ball soil intact. In the harvest process, only 5-20% of the feeder roots are retained in the root ball. B&B nursery stock is best transplanted in the cooler spring or fall season.

To prevent the root ball from breaking, the roots are balled and wrapped with burlap (or other fabrics) and twine (hence the name B&B). In nurseries today, there are many variations to B&B techniques. Some are also wrapped in plastic shrink-wrap, placed in a wire basket, or placed in a pot.

Larger plant materials are often sold as B&B stock. In field production, the roots may be routinely cut to encourage a more compact root ball. While this process improves the transplantability of the tree, it adds to production costs.

Depending on how long the tree has been held in the B&B condition, circling roots may begin to develop. If this has occurred, shave off the outer 1-1½ inches of the root ball as described previously for container-grown trees.

Figure 21. Field-grown, B&B nursery stock needs to have the wrappings that hold the root ball together taken off AFTER the tree is set in place.

Techniques with Balled and Burlapped Nursery Stock

An advantage of the wider planting hole is that it gives room for the planter to remove root ball wrappings AFTER the tree is situated in the hole.

Based on research, **standard procedures are to remove root ball wrapping materials (burlap, fabric, grow bags, twine, ties, wire basket, etc.) from the upper 12 inches or 2/3 of the root ball, whichever is greater AFTER the tree is set in place.** Materials under the root ball are not a concern since roots grow outward, not downward.

Actual planting techniques in this step vary with the type of wrapping on the root ball. Generic steps include:

a) Remove extra root ball wrapping added for convenience in marketing (like shrink-wrap and a container). However, do NOT remove the burlap (or fabric), wire basket and twine that hold the root ball together until the tree is set in place.
b) Set the tree in place. Remember that the inside curve of any graft crook faces north.

c) Check depth of the root ball in the planting hole. If incorrect, remove the tree and correct the depth, firming any soil added back to the hole.
d) Align vertically.
e) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 22]

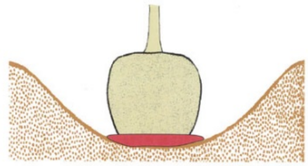


Figure 22. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball.

f) Remove all the wrapping (burlap, fabric, twine, wire basket, etc.) on the upper 12 inches or upper 2/3 of the root ball, whichever is greater.
g) If circling roots are found in the root ball, shave off the outer 1-1½ inches of the root ball with a pruning saw and/or pruners.

Consensus from research is clear that leaving burlap, twine, and wire baskets on the sides of the root ball are not acceptable planting techniques.

- Burlap may be slow to decompose and will complicate soil texture interface issues.
- Burlap that comes to the surface wicks moisture from the root ball, leading to dry soils.
- Jute twine left around the trunk will be slow to decompose, often girdling the tree.
- Nylon twine never decomposes in the soil, often girdling trees several years after planting.
- Wire baskets take 30 plus years to decompose and may interfere with long-term root growth.
- With tapered wire baskets, some planters find it easier to cut off the bottom of the basket before setting the tree in the hole. The basket can still be used to help move the tree and is then easy to remove by simply cutting the rings on the side.

Optional Step 4. Underground Stabilization

One of the trends in tree planting is to use underground stabilization of the root ball rather than above-ground staking. Underground stabilization is out of the way and will not damage the trunk's bark. For information on underground stabilization, refer to *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking or underground stabilization is not needed in many landscape settings.

Step 5. Backfill

In backfilling the planting hole, the best method is to simply return the soil and let water settle it. Avoid compacting the soil by walking or stamping on it. In the backfill process, the planting hole can be widened into the desired sauce shape.

No backfill soil goes on top of the root ball. Backfill soil covers the root ball "knees" tapering down to the original soil grade. [Figure 23]

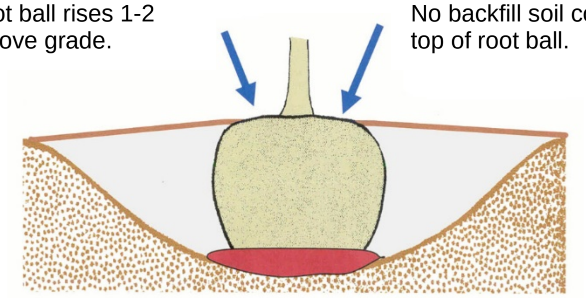


Figure 23. Backfill soil covers the "knees," tapering down to the original soil grade. It is imperative that no soil cover the top of the root ball.

In preparing any garden for planting, it is standard gardening procedure to ***modify*** the soil structure (i.e., loosen the soil) by cultivating. It is also routine to ***amend*** the soil by adding organic matter to improve the water-holding capacity of sandy soils or to increase large pore space in clayey soils. Modifying and amending, while related, are not the same process.

Ideally, soils in a tree's entire potential rooting area would be modified and amended to a 5% organic content.

Modifying the Backfill

When planting trees, soil in the planting hole is modified (loosened up) by digging the hole. The issue around "modifying the soil" is planting-hole width, as discussed previously. Due to lower levels of soil oxygen in the site soil, root growth slows as roots reach the undisturbed site soil beyond the backfill. A saucer-shaped planting hole three times the diameter of the root ball supports rapid root growth, reducing post-planting stress. Amending backfill soil in a narrow planting hole will not substitute for modifying soil in the wider saucer-shaped planting hole.

For backfill, soil "peds" (dirt clods) up to the size of a small fist are acceptable. The soil does not need to be pulverized. In clayey soils, pulverizing the soil will destroy all structure and may lead to excessive re-compaction with minimal large pore space.

A labor-saving technique is to dig the planting hole two times root ball diameter with rather vertical walls. Then in the backfill step, cut the hole to the three times root ball, saucer-shaped hole. In this method, part of the soil does not have to be moved twice. Peds (dirt clods) up to fist size are acceptable in the backfill (Figure 24).

Figure 24. A labor-saving method is to dig the planting hole two times the root ball diameter with more-vertical walls and ease the tree in place. Then cut the planting hole into the three-times-root-ball width and saucer shape during the backfill process. This way much of the soil does not have to be moved twice. Dirt clods up to fist size are acceptable in the planting hole.

Amending the Backfill

Amending the soil just in the planting hole is a complex issue. Too many soil-related variables play into this amended planting pit for a simple directive. In tree planting, it is a common procedure to amend backfill soil with organic matter. It is a good marketing technique for the nursery to recommend soil amendments with the sale of a tree.

Amending the backfill soil to five percent organic matter is standard procedure in garden soil management and may be supportive to root growth in the planting hole during the first two years.

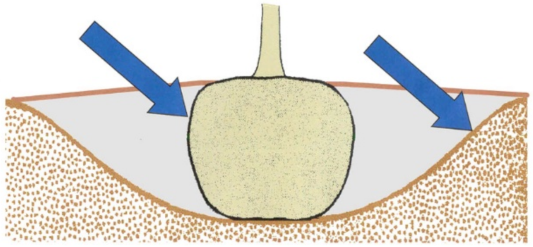
However, amending the backfill to twenty-five to fifty percent is a common mistake! It helps containerize the roots and may also hinder root spread beyond the planting hole. It may hold excessive amounts of water, reducing soil oxygen levels. As the organic matter decomposes, the total volume of soil in the planting hole diminishes, allowing the tree to topple over.

If amending the soil, the organic matter needs to be thoroughly mixed with the backfill soil. Never backfill with organic matter in layers or clumps as this creates additional texture interface lines. Amendments should be well aged. Never use unfinished compost or fresh manure as it may burn tender roots.

Texture Interface

Changes in soil texture (actually changes in soil pore space) create a *texture interface* that impedes water and air movement across the texture change. There will always be a texture interface between the root ball soil and backfill soil and between the backfill soil and undisturbed site soil. **Amending the backfill soil will not diminish the interface** (Figure 25).

To deal with the interface, it is imperative that the root ball comes to the soil surface with no backfill soil over top of the root ball. If backfill soil covers the root ball soil, the interface between the root ball and backfill soil will impede water and air movement into the root ball.



Changes in soil texture (actually soil pore space) create a texture interface that impedes water and air movement.

There will always be a texture interface between the root ball and backfill soil.

Figure 25. To minimize the texture interface, the root ball must come to the soil surface with no backfill over top of the root ball.

Summary: Modifying and Amending

For rapid root establishment, the focus needs to be on planting hole width and correct depth. In most situations, amending or not amending the backfill has little significance compared to other planting protocols.

Optional Step 6. Staking

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking is not needed in many landscape settings.

In areas with extreme winds, "anchor staking" may be needed for improved wind resilience. In some landscapes, new trees may need "protection staking" to protect trees from human activities (like the football game on the lawn.

Step 7. Watering to Settle Soil

Watering is done after staking so the gardener does not compact the wet soil while installing the stakes. Watering is a tool to settle the soil without overly packing it. [Figure 26]

Figure 26. Water tree during planting; notice how soil has settled.

Step 8. Final Grade

In the wide, shallow planting hole, the backfill soil may settle in watering. Final grading may be needed after watering.

Figure 27. Final grade. Note how the root ball soil is visible on the surface, with no backfill covering the top of the root ball.

Step 9. Mulching

A mulch ring of bark/wood chips is suggested around all trees to help protect the trunks from lawnmower damage. On newly planted trees, organic mulch can increase fine root development by 400% compared to grass competition. This results in 20% faster canopy growth. The increase in growth is due to the lack of competition between the tree and grass and weeds.

Site-specific water needs should be considered regarding the use of mulch. Mulch over the rooting area helps conserve moisture and moderate soil temperatures. However, on wet sites the mulch may hold too much moisture, leading to root/crown rot, and may be undesirable. Wood/bark chips may blow in wind and therefore are not suitable for open, windy areas.

With newly planted trees, do NOT place mulch directly over the root ball. Rather mulch the backfill area and beyond. Never place mulch up against the trunk as this may lead to bark decay. Over the backfill area and beyond, 3-4 inches of wood chip mulch gives better weed control and prevents additional soil compaction from foot traffic. [Figure 28]

Figure 28. Do not make mulch volcanoes. Mulch piled up against the tree trunk may lead to bark decay and reduced trunk taper. Excessive mulch can reduce soil oxygen

Planting Bare-Root Trees

Bare-root nursery stock is sold without an established soil ball and is generally limited to smaller-caliper materials. Some evergreen materials will not transplant well as bare-root stock.

Cost for bare-root stock is significantly lower than the same plant as container-grown or B&B stock. Survivability drops rapidly once the plant leafs out. Some nurseries keep bare-root nursery stock in cold storage to delay leafing.

Roots dehydrate rapidly and must be protected. Bare-root stock is often marketed in individual units with roots bagged in moist sawdust or peat moss to prevent dehydration. Sometimes bare-root stock is temporarily potted to protect roots. Some nurseries maintain bare-root stock in moist piles of sawdust. At the time of sale, plants are pulled from the sawdust and the roots are wrapped with some moist sawdust for transport to the planting site. These need to be planted within 24 hours of purchase.

Techniques for Bare-Root Nursery Stock

Bare-root trees are planted with the same basic standards as container-grown or B&B stock, with the modification that the roots are spread out on a horizontal plane as the backfill soil is added. It is critical to minimize exposure of the roots as feeder roots dehydrate in minutes. Generic steps include the following:

1. Unpack roots to measure root spread. Cover or repack to protect roots while the hole is dug. Some gardeners like to soak the roots in a bucket of water for a couple of hours. However, do not leave them in the water for more than a half day.

2. Dig a shallow, saucer-shaped planting hole three times the diameter of the root spread. Depth of the planting hole should accommodate the planting depth standards mentioned previously. [Figure 29]

    - Top of backfill will be one inch above grade.
    - Generally, at least two structural roots should be within the top one to three inches of the soil surface.
    - On species prone to trunk circling roots (such as crabapples, green ash, hackberry, littleleaf linden, poplar, and red maple), the top structural root should be within the top one inch of the root-ball soil surface.
    - The bottom root should rest on undug soil.

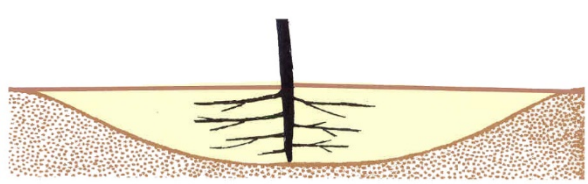


Figure 29. Planting bare-root trees

3. As backfill is added, spread roots out on a straight, horizontal plane.
4. Many bare-root trees will need staking.
5. Water the newly planted tree.
6. Final grade.
7. Mulch, as needed

Additional Information

Books: Watson, Gary W., and Himelick, E.B. ***Principles and Practice of Planting Trees and Shrubs***. International Society of Arboriculture. 1997. ISBN: 1-881956-18-0.

- Web: Dr. Ed Gilman's tree planting information at http://hort.ifas.ufl.edu/woody/planting.shtml.

Authors: David Whiting (CSU Extension, retired) with Joann Jones (CSU Extension, retired) and Alison O'Connor (CSU Extension). Photographs and line drawing by David Whiting; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #634

Tree Staking and Underground Stabilization

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking is not needed in many landscape settings.

Consequences of Staking

The consequences of staking with traditional methods that wrap and hold the trunk include the following:

- The tree grows taller, faster.
- Staking (the lack of tree movement) slows root spread.
- The tree has less growth in trunk caliper near the ground but more near the top support ties. Staking often produces a reverse trunk taper that increases the potential for storm damage.
- Staked trees experience more wind damage than unstaked trees of equal height (the top of the tree is not free to bend in the wind).
- Bark is often damaged by the ties. In a survey of 10,000 street trees, 90% were damaged by the ties.
- If the stake is close to the trunk, it can develop uneven xylem growth where the stake shades the trunk, making the trunk tilt to the side. Keep stakes at least 6 inches away from the trunk.

Purposes of Staking

No Staking – In most home landscape settings, no staking is necessary if the tree is set on undisturbed soil (where it cannot sink and tilt), with soil firmed around the base of the root ball before backfilling. Exceptions include the three types of staking below.

Protection Staking is used where the tree needs protection from human activities, such as the football game on the front lawn or from passersby along a street planting.

Protection staking may include standard staking techniques with three or four posts and straps or a structure surrounding the tree but not actually touching the tree trunk. [Figure 1]

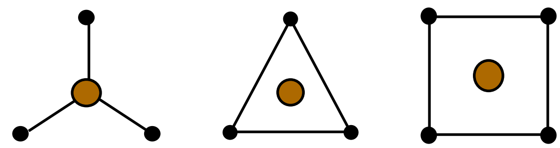


Figure 1. Configurations for protection staking

Anchor Staking – In areas of high winds, anchor staking may be needed. When anchor staking small trees, use two or three straps along the trunk about 18 inches above the ground. [Figure 2]

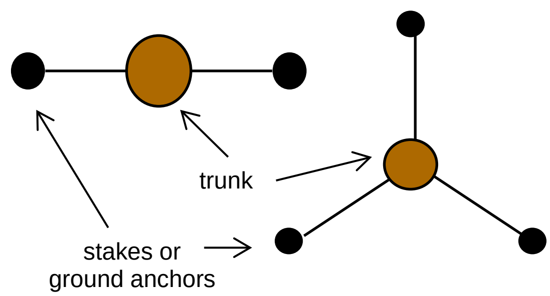


Figure 2. Configurations for anchor staking. Anchor staking may be needed in areas of high winds.

Support staking – If the tree has a floppy trunk that is not self-supporting, support staking will be needed. Straps would be located six inches above the point where the tree will stand upright, but at least three feet below the terminal leader.

Above Ground Staking Procedures

When staking, use flat, grommeted straps rather than ropes, wires or hose segments against the trunk. The straps spread the pressure over a wider area, reducing the potential for bark damage. Straps should lie flat against the trunk and should not be bunched up or twisted. Two or three straps are routinely used in tree staking.

Straps may tie back to wood or metal posts or to anchors in the ground. Plastic caps are available as a safety measure for the tops of metal posts. Place posts at least 15 to 18 inches out from the trunk. Never tie a post to the trunk, as the shading will cause the trunk to curve. [Figure 3]

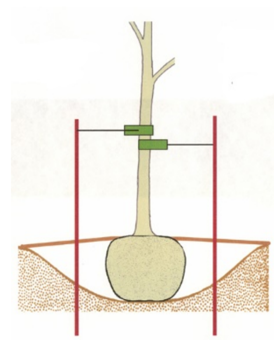
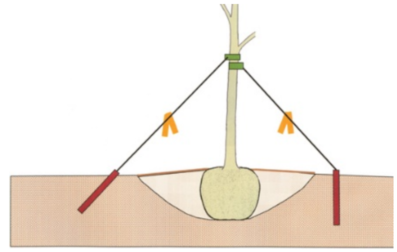


Figure 3. Routine staking includes two or three posts, at least 15-18 inches out from the trunk. Use flat straps to spread pressure over a wider area, reducing bark damage.

With guy-lines and ground anchors, place the guy-lines at a 45° angle. Flag the guy-lines to help people see them and prevent injury. In the illustration, the anchor on the left may be more secure than the anchor on the right. [Figure 4]

Figure 4. When staking with guy-lines, place guy-lines at a 45° angle. The ground anchor on the left is more secure than the anchor on the right.



In any staking system, it is best if the tree trunk has a little flexibility. Some wind movement encourages root growth and trunk taper development.

For 1-2 inch diameter trees, staking typically stays on for one to two seasons. On 3-4 inch diameter trees, staking may be needed for three to four seasons.

Underground Stabilization Methods

Several methods for underground stabilization are effective. They are applied prior to backfilling the planting hole. [Figure 5]

- **Two or three wood dowels** driven into the ground at the edge of the root ball. The dowels will decompose over time.
- **A 2×2 wood triangle over the top of the root ball is screwed into 2×2 wood stakes** driven into the ground at the edge of the root ball. The wood will decompose over time.
- **Two metal root "staples"** – Several brands are on the market. The long leg of the staple goes into the ground at the edge of the root ball. The short leg of the staple goes into the root ball. The metal staple may pose a problem if the tree stump needs to be ground out in the future.

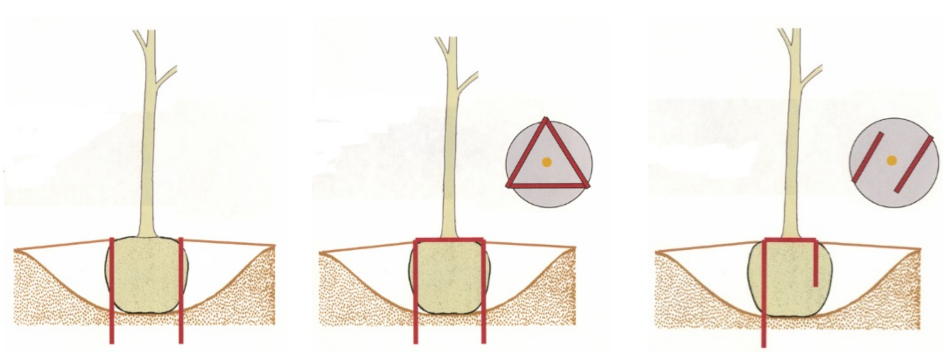


Figure 5. Methods for underground stabilization
Left: Two to three wood dowels are driven into the ground at the edge of the root ball.
Center: 2×2 lumber makes a triangle plate over the top of the root ball. It is screwed into wood stakes driven into the ground at the corners.
Right: Metal root "staples" are driven into the ground at the edge of the root ball and hook into the root ball.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension).
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MASTER GARDENER
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GardenNotes #635

Care of Recently Planted Trees

Root Establishment Phase

During the establishment phase in a tree's life cycle, primary growth occurs in the root system, with minimal growth in the canopy. The science of planting trees is aimed at encouraging this root growth, reducing *post-planting stress*. For additional information, refer to *CMG GardenNotes* #101, Plant Health Care, and #633, The Science of Planting Trees.

With good planting techniques and soil conditions, the establishment phase takes one growing season per inch of trunk diameter (in Hardiness Zones 4 and 5). On small trees (up to four inches in diameter), trunk diameter is measured at six inches above the soil line. That is, a one-inch caliper tree typically takes one year for roots to establish. A two-inch diameter tree typically takes two years. In cooler regions with shorter growing seasons, it will take longer. In warmer regions, like the southern United States, the establishment phase is measured in months.

With poor planting techniques and/or poor soil conditions, the establishment phase may take many years. It is common to observe trees that never establish, but rather simply hang on for a few years and gradually decline.

A significant increase in annual twig growth indicates that roots have become established and that the tree is shifting into the growth phase.

The purpose of this *CMG GardenNotes* is to summarize tree care during the establishment phase.

Watering

Regular irrigation after planting encourages rapid root development, for tree establishment. Under-irrigation often leads to slow establishment, canopy dieback, and bark splits (frost crack and sunscald) on the trunk. After the first couple of years, it is common to find under-irrigated trees that have minimal root growth. Recently planted trees and shrubs establish most quickly with light, frequent irrigation. For recently planted trees, primary water extraction is from the root ball and the root ball can become dry in just a day.

Larger volumes of water applied infrequently will not compensate for the need for frequent, light irrigation. On newly planted trees, soil amendments do not significantly reduce the need for frequent irrigation. Drought-tolerant species are not drought-tolerant until the root system becomes established. In sites without ideal irrigation management, smaller-sized nursery stock would be preferred because they establish faster.

When watering non-established trees, check the soil frequently, and water according to need. The soil could be dry in the root ball and wet in the backfill, or wet in the root ball and dry in the backfill. If the tree is planted in a newly sodded/seeded irrigated lawn, it is typically over-watered. [Figure 1]

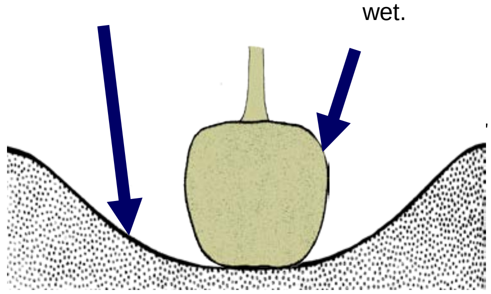

Figure 1. On non-established trees, check the water needs in the root ball and back fill soil frequently. Water according to observed needs.

The only way to know the watering needs of non-established trees is to check soil moisture levels. A useful tool for the home gardener is a houseplant water meter. While somewhat inaccurate, it can indicate wet or dry. (Note: If the fertility is high, it will read on the wet side. If fertility is low, it will read on the dry side.)

Check both the root-ball soil and the backfill soil. For a two-inch caliper tree in Hardiness Zone 5, it takes one growing season for the roots to extract significant amounts of water from the backfill soil, and two or more years for significant water extraction from the soil beyond the planting hole. [Figure 2]

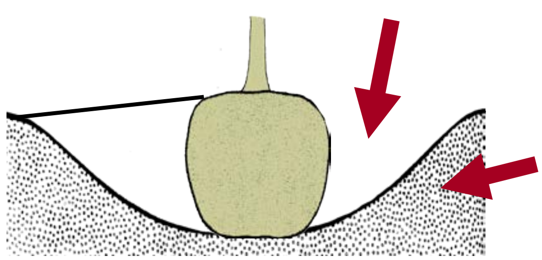

Figure 2. Check water needs in the root-ball soil and the backfill soil.

Learn by carefully monitoring the amount and frequency of irrigation needed for each tree. Estimated irrigation needs are given in Table 1.

Table 1.
Estimated Irrigation of Newly Planted Trees and Shrubs (during the growing season) – **Check soil moisture and water as needed.**

Size of Nursery Stock	Irrigation Need for Vigor
<2-inch caliper	○ **Daily for 2 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 2 months** – Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly until established** (one to two or more seasons).
2-4-inch caliper	○ **Daily for 4 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 3 months** – Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly until established** (two to four or more seasons).
>4-inch caliper	○ **Daily for 6 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 5 months**– Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly** until established (four or more seasons).

- **Check the actual water need before watering**. A common mistake on compacted and clayey soils (with poor drainage) is to apply too much water per irrigation, waterlogging the planting hole. Never apply irrigation if soil is saturated.
- Trunk diameter on small trees is measured at six inches above the soil line.
- As a rule of thumb for Hardiness Zones 4 and 5, establishment takes one season per inch of trunk caliper.
- In Colorado winters without routine moisture, water newly planted trees monthly. However, do not water if the ground is frozen.
- In our dry, semi-arid climate, there is benefit from applying additional irrigation outside the root-ball area. This can be done with a ringed soil berm that allows water to percolate into the soil or a soaker-type hose running around the backfill area.

Mulch to Protect Tree from Lawnmowers, Weed Eaters, and Grass Competition

Wood/bark-chip mulch is highly recommended on newly planted trees. The mulch protects the trees from lawn mower and weed eater injury. Trees with a mulch ring typically have 20% more early growth compared to trees where grass grows up to the trunk. This is due to the lack of competition with the grass and/or weeds.

In a landscape setting, the mulch ring is typically two to four feet wide up to the width of the dripline (spread of branches). Wood chip mulch three to four inches deep gives better weed control and prevents additional soil compaction by foot traffic.

On newly planted trees, do not mulch over the root ball. On established trees, keep mulch back six inches from the trunk. Never pile wood/bark chips up against the trunk. Wet chips can lead to bark decay. Never make mulch volcanoes! On wet sites, mulching may help hold excessive soil moisture and may be undesirable. On open windy sites, wood/bark-chip mulch blows away.

Fertilization

During the establishment phase, fertilization needs are none to minimal on woody plants. High-nitrogen fertilization rebalances the canopy-to-root growth ratio, encouraging canopy growth at the expense of root growth.

In situations where soil fertility is low—but water and other growth factors are not limiting—very light fertilization with a time-release product may be acceptable. Never use a quick-release fertilizer on trees.

Never fertilize trees in the establishment phase that are showing signs of stress. When a nonestablished tree is under stress, nitrogen fertilizer can push out canopy growth that the root system cannot support in hot windy weather. Woody plants do not respond to "starter fertilizers" like herbaceous plants.

Pruning

In the establishment phase of a tree's life cycle, pruning is undesirable. Pruning lowers the levels of auxin, a hormone produced in the canopy terminal buds that stimulates root growth.

Pruning should be limited to the removal of dead and broken branches and minimal pruning to maintain a single leader. In purchasing trees, select trees with good structure that will not require immediate pruning.

Structural training for the tree continues in the growth phase (after the roots have established and the canopy shows significant annual growth). For additional information on structural training, refer to *CMG GardenNotes* #614, Structural Pruning of Young Shade Trees.

In situations where trees will not receive any structural training while young, it may be desirable to correct structural major defects as part of the planting process. This is primarily removal of codominant trunks and spacing of secondary trunks. However, major pruning at planting will slow root establishment.

Author: **David Whiting**, Extension Consumer Horticulture Specialist (retired), Dept. of Horticulture & LA, Colorado State University. Artwork by David Whiting; used by permission.

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CMG GardenNotes #636

Tree Planting Steps

This publication summarizes the tree-planting process. For an in-depth discussion on tree planting, refer to *CMG GardenNotes* #633, The Science of Planting Trees.

The science of planting trees is aimed at promoting rapid root growth (regeneration) to quickly reduce the water stress imposed by the harvest and planting process. *Post-planting stress* (transplant shock) consists of the stress factors induced by the reduced root system.

Planting trees too deeply has become an epidemic leading to the decline and death of landscape trees. In the landscape, trunk-girdling roots account for 57% of all tree deaths. Trunk-girdling roots develop when a tree is planted too deeply in the root ball and/or the root ball is planted too deeply in the planting hole. Trunk-girdling roots may lead to decline and death some 12 to 20 years after planting. Trunk-girdling roots may be below ground.

Step 1.
Determine the depth of the planting hole

Depth of root ball in planting hole

To deal with the *soil texture interface* (differences in soil pore space) between the root-ball soil and backfill soil, it is imperative that the root ball rise slightly above grade with no backfill soil over top of the root ball. For small (one-inch caliper) trees, the top of the root ball should be about one inch above grade. For larger (2-4 inch caliper) trees, the top of the root ball should be about two inches above grade. Backfill soil should cover the “knees,” tapering down to grade. [Figure 6]

Depth of tree in the root ball

- Generally, at least two structural roots should be within the top 1-3 inches of the root ball, measured 3-4 inches from the trunk.
- On species prone to trunk-circling roots (Crabapples, Green Ash, Hackberry, Littleleaf Linden, Poplar, Red Maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

Checking depth of tree in root ball – Check depth of the tree in the root ball. Do not assume that it was planted correctly at the nursery.

- The presence of the root flare is an indication of good planting depth. However, small trees may have minimal root flare development making it difficult to determine. Be careful not to mistake swelling of the trunk below the graft as the root flare.
- A good way to evaluate planting depth in the root ball is with a slender implement like a slender screwdriver, knitting needle or barbeque skewer. Systematically probe the root ball 3-4 inches out from the trunk to locate structural roots and determine depth. [Figure 1]

Figure 1. Systematically probe the root ball with a slender screwdriver. Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk-circling roots, the top structural root should be within the top one inch of the root ball.

If the tree is planted too deeply in the root ball, excess soil should be removed from the top in the backfill step of the planting process. Adjust the depth of the planting hole to compensate. [Figure 2]

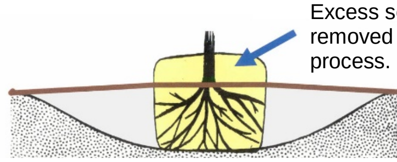


Figure 2. Adjust the depth of the planting hole to bring the root flare to the correct depth.

The depth of the planting hole should be 1-2 inches less than the height of the root ball. However, planting hole depth may need to be adjusted to correct the depth of the tree in the root ball.

<u>Step 2.</u> Dig a saucer-shaped planting hole three times the root ball diameter

- To maximize soil oxygen levels the top of the root ball rises 1-2 inches above grade (adjusted for proper rooting depth as determined in step 1).
- The root ball sits on undug soil, stabilizing the tree and preventing sinking and tilting.
- A saucer-shaped planting hole three times the root ball diameter with sloping sides allows the root system to grow rapidly to 400% of the root ball volume before being slowed by the lower oxygen levels in the site soil. <u>This is enough to minimize *post-planting stress*</u> in normal planting situations.
- The wide, saucer-shaped planting hole gives the tree more tolerance to over-watering problems and waterlogged soils.
- The wide planting hole allows for root ball wrappings to be removed <u>after</u> the tree is situated in the planting hole.
- A labor-saving technique is to dig the planting hole about two times the root ball diameter with somewhat vertical sides, then widen the hole into the desired saucer shape with the shovel during the backfill process. [Figure 3]

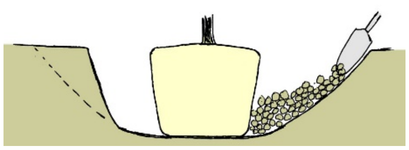
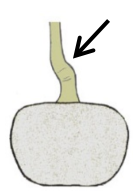


Figure 3. A labor-saving technique is to widen the planting hole into the desired saucer shape, three times the root ball diameter during the during backfill process.

<u>Step 3</u>. Set the tree in place, removing container/wrappings

In setting the tree into the planting hole, if the tree has a "dogleg" (a slight curve in the trunk just above the graft) the inside curve must face north to avoid winter bark injury. [Figure 4].

Figure 4. The inside curve of the graft crook or "dogleg" must go to the north to avoid winter bark injury.



Vertically align the tree, with the top centered above the root ball. Due to curves along the trunk, the trunk may not necessarily look straight. It will appear straighter with growth.

In this step, techniques vary for *Container-Grown Trees* and *<u>B</u>alled <u>A</u>nd <u>B</u>urlapped (B&B) Trees*.

<u>Container-Grown Nursery Stock</u>

“Container-grown nursery stock” describes a variety of production methods where the trees or shrubs are grown in containers (limiting root spread to the size of the container). In some systems, like “pot-in-pot” and “grow-bags,” the container is in the ground. An advantage of container stock is that it can be planted in spring, summer, or fall.

Actual planting techniques in this step vary with the type of container and extent of root development. Generic steps include:

a) Lay the tree on its side in or near the planting hole.
b) Wiggle off or cut off the container.
c) Shave off the outer 1-1½ inches of the root ball with a pruning saw or pruners. This is to deal with circling roots.
d) Tilt the tree into place with the inside curve of any graft crook facing north.
e) Check the depth of the root ball in the planting hole. If needed, remove the tree and correct the hole depth.
f) Align vertically.
g) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 5]

- The ideal container-grown tree has a nice network of roots holding the root ball together. After the container is removed, the tree is gently tilted into place.
- If most of the soil falls off the roots, the tree is planted as a bare-root tree.
- If some of the soil falls off (often on the bottom), it may be necessary to adjust the depth of the planting hole. Backfill and pack the bottom of the planting hole to the correct depth.
- Fabric grow bags must be removed from the sides. They are generally cut away after setting the tree into place.
- Generally, paper/pulp containers should be removed. Most are slow to decompose and will complicate soil texture interface issues. Pulp

containers often need to be cut off, as they may not slide off readily.

- In handling large trees (3-inch caliper and greater) it may be necessary to set the tree into place before removing the container.

Field-Grown, B&B Nursery Stock

Field-grown, balled and burlapped (B&B) trees and shrubs are dug from the growing field with the root ball soil intact. In the harvest process, only 5-20% of the feeder roots are retained in the root ball. B&B nursery stock is best transplanted in the cooler spring or fall season.

To prevent the root ball from breaking, the roots are balled and wrapped with burlap (or other fabrics) and twine (hence the name B&B). In nurseries today, there are many variations to the B&B technique. Some are also wrapped in plastic shrink-wrap, placed into a wire basket, or placed into a pot.

An advantage of the wider planting hole is that it gives room for the planter to remove root ball wrappings AFTER the tree is situated in the hole.

Based on research, **standard procedures are to remove root ball wrapping materials (burlap, fabric, grow bags, twine, ties, wire basket, etc.) from the upper 12 inches or 2/3 of the root ball, whichever is greater, AFTER the tree is set into place.** Materials under the root ball are not a concern since roots grow outward, not downward.

Actual planting techniques in this step vary with the type of wrapping on the root ball. Generic steps include:

a) Remove extra root ball wrapping added for convenience in marketing (like shrink-wrap and a container). However, do NOT remove the burlap (or fabric), wire basket and twine that hold the root ball together until the tree is set into place.
b) Set tree into place with the inside curve of any graft crook facing north.
c) Check the depth of the root ball in the planting hole. If needed, removed the tree and correct the hole depth.
d) Align vertically.
e) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 5]

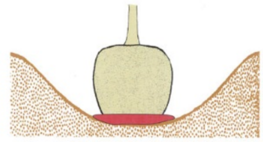


Figure 5. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball

f) Removed all the wrapping (burlap, fabric, twine, wire basket, etc.) on the upper 12 inches or upper 2/3 of the root ball, whichever is greater.
g) If roots are found circling the root ball, shave off the outer 1-1½ inches of the root ball with a pruning saw or pruners.

The consensus from research is clear that leaving burlap, twine, and wire baskets on the sides of the root ball is not an acceptable planting technique.

- Burlap may be slow to decompose and will complicate soil texture interface issues.
- Burlap that comes to the surface wicks moisture from the root ball, leading to dry soils.
- Jute twine left around the trunk will be slow to decompose, often girdling the tree.
- Nylon twine never decomposes in the soil, often girdling the tree several years after planting.
- Wire baskets take 30-plus years to decompose and interfere with long-term root growth.
- Some planters find it easier to cut off the bottom of a tapered wire basket before setting the tree into the hole. The basket can still be used to help move the tree and is then easy to remove by simply cutting the rings on the side.

Optional Step 4. Underground stabilization

When properly planted, set on undug soil, most trees in the landscape do not require staking or underground stabilization. Staking or underground stabilization may be needed in windy areas. For additional information on staking, refer *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

Step 5. Backfill

When backfilling, be careful not to over-pack the soil, which reduces large pore space and thus soil oxygen levels. A good method is to simply return soil and allow water to settle it when irrigated.

Soil "peds" (dirt clods) up to the size of a small fist are acceptable in tree planting. In clayey soils, it is undesirable to pulverize the soil, as this destroys large pore space.

Changes in soil texture (actually changes in pore space) between the root ball soil and the backfill soil create a *soil texture interface* that impedes water and air movement across the interface. To deal with the interface, the top of the root ball must come to the surface (that is, no backfill soil must cover the top of the root ball). Backfill soil should cover the root ball knees, gradually tapering down.

<u>Optional Step 6</u>. Staking

When properly planted, set on un-dug soil, most trees in the landscape do not require staking or underground stabilization. Staking may be desirable to protect the trees from human activities. Staking or underground stabilization may be needed in windy areas.

Install staking before watering so the planting crew does not pack down the wet soil. For additional information on staking, refer to *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

<u>Step 7</u>. Water to settle soil

<u>Step 8</u>. Final grade

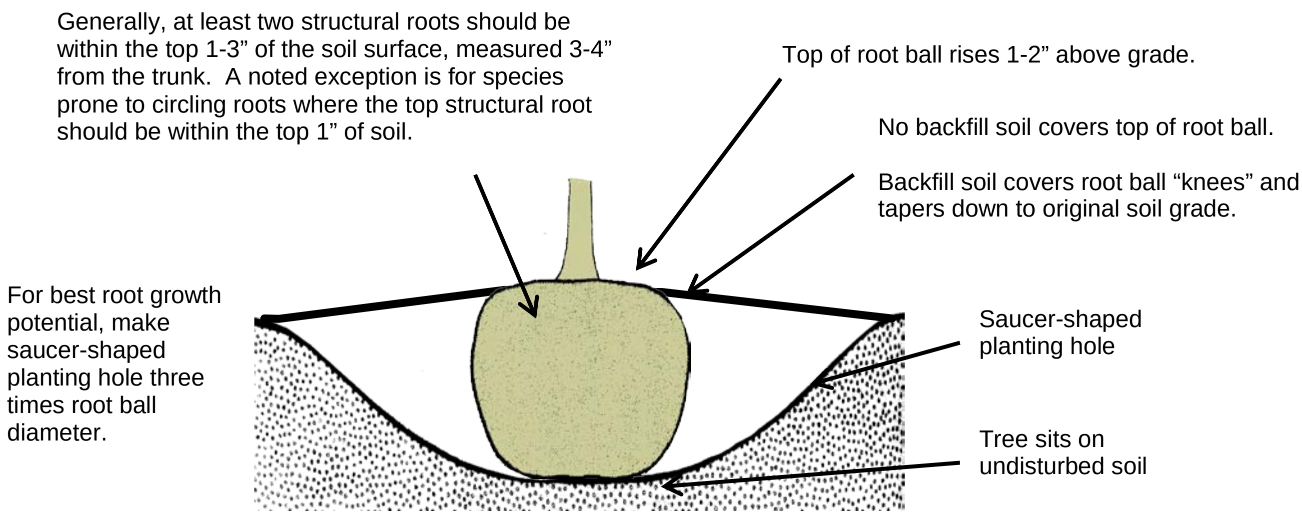
With the wide planting hole, the backfill soil may settle in watering. Final grading may be needed after watering.

<u>Step 9</u>. Mulch

Do not place mulch directly over the root ball on newly planted trees. As a rule of thumb, 3-4 inches of wood/bark chips gives better weed control and prevents soil compaction from foot traffic when placed over the backfill area and beyond. Additional amounts may reduce soil oxygen.

Do not place wood/bark chips up against the trunk. Do not make mulch volcanoes. On wet soils, mulch may help hold excessive moisture and be undesirable. Wood/bark chips are not suitable in open windy areas.

Figure 6. Planting Summary



Author: David Whiting (CSU Extension, retired), with Alison O'Connor (CSU Extension). Line drawings by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.

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CMG GardenNotes #651

Fertilizing Shade Trees

When gardeners fertilize lawns, they see a quick response as the lawn greens up within days. The response is different with trees; it happens over a period of months as a re-balance of canopy and root growth. When growth-limiting nutrients (nitrogen) become available through fertilization, the tree shifts more resources into canopy growth and correspondingly less into root growth.

Nitrogen is the nutrient most limiting to tree growth. Symptoms of nitrogen stress in woody plants are unlike those in lawns and herbaceous plants. Trees with nitrogen stress simply slow canopy growth rates, but do not show the characteristic yellowing of older leaves like lawns and herbaceous plants.

Nitrogen should be applied to trees only in a controlled release/slow release form.

A tree's need for phosphorous and potassium is rather low. Colorado (western) soils are typically adequate in phosphorous and potassium. Phosphate fertilizers have not been shown to increase tree growth even on soils marginal low in phosphorus. Excessive levels of phosphorus can aggravate an iron chlorosis problem.

Iron is a common deficiency in some tree species. Iron chlorosis is usually aggravated by spring- time overwatering and by trunk girdling roots (tree planted too deep).

Fertilizer Application Rates

The need for fertilizer varies with the tree's growth phase.

Establishment phase - recently planted trees

During the root establishment phase, the growth objective is root growth. Nitrogen fertilizer increases canopy growth with a corresponding decrease in root growth, which is undesirable in this phase.

As a rule-of-thumb for Hardiness Zone 4-5, the establishment phase for recently transplanted trees lasts one year for each inch of trunk caliper (measured at 6" above ground level). In other words, the establishment period for a one inch caliper tree is typically one year, and three years for a three inch caliper tree. The establishment phase may be longer on sites with poor soil tilth, limited irrigation, and with poor planting techniques.

Unlike herbaceous plants, woody plants do not respond to "rooting fertilizers" (water soluble fertilizers) applied at planting. During the root establishment phase, fertilizer applications should be kept to a minimum, as follows:

- If the soil organic content is moderate to high (3-5% organic matter), no additional fertilizer is warranted.
- If the soil organic content is low (1% or less), a light application of a controlled release (slow release) nitrogen may be beneficial. Application should not exceed 0.1 pound actual nitrogen per 100 square feet (based on the area off the planting hole). Do not apply fertilizer on a site with growth limiting factors such as a limited irrigation.

Growth phase

Significant branch growth indicates a shift from the root establishment phase into the growth phase. In this growth phase, fertilization can encourage faster growth if desired. Application rate is based on several factors:

1. Natural growth rate of the tree – Use higher rates on faster growing species if rapid growth is desired.
2. Growth limiting factors such as limited irrigation, severe soil compaction, or limited root spread potential – Do not force growth. Heavy fertilization can push canopy growth that the roots cannot support in summer heat and wind.
3. Soil organic content
4. Desired growth rate. If rooting and/or canopy space will be limited for the maturing tree, you may not want to push growth.

The table on page 3 illustrates rate adjustments based on these factors.

Mature maintenance phase

As trees reach a mature size and growth slows, the need for nitrogen drops. In the maturing maintenance phase the standard maximum rate is 0.2 to 0.4 pounds nitrogen per 100 square feet over a 4-year period. It may be applied annually or with multi-year applications using controlled release fertilizers. Over fertilization may push canopy growth that a limited rooting system cannot support in summer heat and wind, leading to early decline. The table below shows rate adjustments based on soil organic content.

Application rate based on growth phase and soil organic content

The fertilizer application rate should be adjusted according to soil organic content as indicated in the table below.

Tree fertilizer rates based on growth phase and soil organic content

	Nitrogen application rate[1 & 4] (Pounds nitrogen per 100 square feet)		
Soil organic content	**Low** (0-1%)	**Medium** (2-3%)	**High** (4-5%)
Establishment phase	0 to 0.1 lbs/year	0	0
Growth phase			
Faster growing species[2]	0.2 to 0.4 lbs/year	0.1 to 0.2 lbs/year	0
Routine rate	0.1 to 0.2 lbs/year	0.05 to 0.1 lbs/year	0
Mature phase[3]	0.2 to 0.4 lbs / 4 years 0.1 to 0.2 lbs / 2 years 0.05 to 0.1 lbs / year	0.1 to 0.2 lbs / 4 years 0.05 to 0.1 lbs /2 years 0.025 to 0.05 lbs / year	0

1 Do not exceed lower rates to trees with growth limiting factors (such as limited irrigation, severe soil compaction, or limited root spread potential).
2 Use high rate only on fast growing species without any growth limiting factors where rapid growth is desired.
3 For multi-year applications, use controlled/time release products.
4 In lawn areas, do not apply more than 0.1 pounds nitrogen per 100 square feet per application. When higher rates are needed, split the application.

Time of year

The best time of year to fertilizer is early spring (4-6 weeks before bud break) or late fall after leaves drop (and soil temperatures are above 40^o). Avoid late summer and early fall fertilizations as they may interfere with winter hardiness.

Area to fertilize

Fertilizer application rate is based on the area of the ***Tree Protection Zone, TPZ***. To calculate a tree's TPZ area, first determine the ***Critical Root Radius,*** CRR, and then calculate the area in the TPZ using the CRR. The CCR typically extends a little beyond the drip line. The TPZ area is typically about 40% larger than the area in the drip-line for mature trees.

Calculating the CCR by the circumference method

1. Measure the circumference (inches around the tree) at 4.5 feet high.
2. Divide the number by 2.

3. Express the results in feet. This is the critical rooting radius.

Example:

1. Circumference = 24 inches
2. 24/2 = 12
3. CRR = 12 feet

Calculating the area (square feet) in the TPZ

To calculate the area in the TPZ, use the formula:

CCR^2 x 3.14 = TPZ

Example: 12 feet x 12 feet x 3.14 = 452 square feet

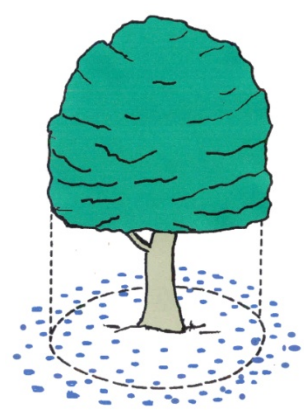
Unrestricted rooting area – For trees with an unrestricted rooting area (i.e., open lawn area) base the fertilizer application rate on the ***Tree Protection Zone, TPZ.*** This is the area where the fertilizer will be applied.

Trees with confined root zones – Calculate the fertilizer rate based on the **open** area within the TPZ, (i.e., the TPZ area not covered with sidewalks, driveways, streets, buildings, etc).

Fertilizer Application Methods

Broadcast applications are quick and easy. However, an actively growing turf takes up most of the soluble fertilizer within 48 hours.

An alternative is to apply the fertilizer in a series of holes or plugs drilled into the soil around the TPZ. Use caution to avoid hitting sprinkler lines and underground utilities.



Make plug holes:

- 1 ½ to 2 inch diameter
- 4-6" inches deep
- 2 foot intervals
- 2-5 rings around TPZ area
- Backfill with sand, compost, or vermiculite

Trees in Turf

In full sun, a healthy lawn has 20 to 400 times more root length than woody plants. The lawn will absorb most of a water-soluble nitrogen fertilizer applied within 48 hours. The following table summarizes the relationship to lawn fertilizer and tree fertilization.

Trees in Turf

	Tree Grow Phase	
Lawn Quality	**Growth Phase**	**Mature Maintenance Phase**
Routinely fertilized, actively growing, thick	**L**awn fertilization adequate for trees If rapid growth is desirable on faster growing species, supplemental vertical fertilization may be beneficial. Do not force growth when limiting factors exist, such as limited water, severe soil compaction or limited root spread potential.	**L**awn fertilization adequate for trees
Thin	Before fertilizing, evaluate why the lawn is thin and how this affects potential tree growth.	High nitrogen rates could push undesired tree canopy that roots cannot support in summer heat and wind.

Fertilizing Stressed Trees

When plants appear stressed, a common reaction is to fertilize. However, this can actually aggravate stress. Before fertilizing a stressed tree, evaluate whether or not a push of canopy growth with the corresponding decrease in root growth is desirable.

Nitrogen fertilization shifts the tree's balance of growth, favoring the canopy. If the stress is root related (i.e., soil compaction, restricted root spread, construction damage, extensive storm damage), this shift will aggravate it. Do not apply high levels of fertilizer to trees with root problems.

The tree invests energy reserves to take up nutrients. Thus, the short-term effects of a heavy fertilization will be an immediate reduction in a tree's carbohydrate levels, aggravating stress. If the tree shows severe stress, do not apply high levels of fertilizers. Work to alleviate stress factors to the extent possible.

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

Revised August 2017

CMG GardenNotes #653

Wrapping Trees For Winter

Why Use Wrap

Tree wrap is used to protect young, thin-barked trees during the winter months. Wrapping trees helps protect against sunscald and frost cracks, both of which are temperature related. Not all trees need to be wrapped. Species such as linden, maple, ginkgo, crabapple and redbud will benefit from tree wrap. Trees with thick, corky bark, like bur oak, do not need to be wrapped.

Sunscald

Sunscald is also known as "southwest injury" since it tends to occur on the south or southwest side of the tree. During the winter, the south/southwest side of the tree is warmest, due to the location and angle of the sun during the winter months. Sunny warm winter days "wake up" cells in the cambium (the living tissue in the tree), causing them to move water and nutrients. As temperatures drop at night, the cells freeze and burst, causing bark splitting. Sunscald creates a jagged wound along the trunk that can take a long time to seal over and be an entry point for disease and insects.

Figure 1 Sunscald damage

Frost Cracks

Frost cracks are vertical cracks in the trunk or stems of trees. Warm winter days cause the cells to warm up and expand. As the sun sets, the outer bark temperature cools quickly, but the inside of the tree remains warmer, which results in splitting. Younger trees are most susceptible. Frost cracks are usually not as detrimental to tree health as sunscald.

The rules for using tree wrap are as follows:

1. Wrap trees at the end of November and removed in early spring (mid-April). Tree wrap should not be left on all year.
2. Use a light-colored crepe-paper type wrap; using plastic, dark colored materials or burlap can result in tree damage. Crepe-paper wrap has some elasticity to it and sheds water, keeping the trunk dry.
3. Start wrapping at the bottom of the tree, overlapping by 1/3 until you reach the first branch. Tape the wrap to prevent it from slipping at the top of the tree. Or consider stapling the wrap to itself around the first branch. Do not staple the wrap into the tree!

Once the bark of the tree has hardened and become furrowed, it is not necessary to wrap trees. Trees should only be wrapped for the first one to three years following planting. It cannot be emphasized enough that wrapping is only a seasonal treatment.

Using Latex Paint

Latex paint is often used in nurseries and orchards since it is a cheaper and less labor-intensive option to wrapping trees individually. Paint is not as aesthetically pleasing and will take time to wear off. Only use water-based latex paint and not oil-based, as it can damage trees. Apply the paint in late fall when temperatures are above 50 degrees F so it can dry quickly.

Watch this short video on tree wrapping:
https://www.youtube.com/watch?v=B_KOaHXETb4

Figure 2 Tree wrap

Author: Alison O'Connor, Colorado State University Extension. Photos courtesy Alison O'Connor.

July 2017

CMG GardenNotes #654

Staking Trees

Many gardeners believe that tree staking during the planting process is necessary, but it is really only required in certain situations. More important than staking a tree is to ensure it is planted properly. Refer to the Colorado Master Gardener Garden Notes #633 or the shortened version #636 at www.cmg.colostate.edu.

When to stake

Staking is only necessary in the following situations:

1. Windy sites: When a tree is planted in a wind tunnel or in an area that is perpetually prone to wind and/or damage from wind, then staking can be justified.

2. Protecting the newly planted tree from people or activities: If the tree is planted in a public space that gets high amounts of traffic or is prone to vandalism, stakes may be used to help protect the tree. Sometimes just having posts (without staking straps attached) around the tree may divert vandals or harmful activity.

3. Supporting the weight of the tree because the tree cannot stand on its own. In this situation, the tree should not be planted, since quality of nursery stock is an important component when planting trees. However, if the tree was planted but cannot stand on its own, staking straps should be attached six inches above the point where the tree can support itself, but at least three feet below the terminal leader. Again, there is a responsibility of consumers to demand quality nursery stock—planting inferior trees should not be a standard practice.

Staking Straps

Always use wide canvas straps with grommets at either end to attach staking wires to trees. These wide straps help distribute the pressure evenly. Wire threaded through hose concentrates the pressure, causing girdling and other damage.
For details about staking trees properly, refer to the Colorado Master Gardener Garden Notes #634 at www.cmg.colostate.edu.

Staking can lead to increased tree height at the expense of caliper (diameter) development. It can also lead to a smaller root system, since the tree may not have the ability to sway/move with wind (which builds caliper and roots). Staking has also been found to damage the trunk as soon as six months after planting, causing girdling and compression injury to the trunk.

When stakes are used, they should be removed after **one growing season**. Stakes are often forgotten if left on the tree longer, leading to long-term damage. Materials can girdle or grow into the tree, creating weak points and potential failure.

Author: Dr. Alison O'Connor, Colorado State University Extension. Photos courtesy Mary Small, Colorado State University Extension

August 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #655

Dealing with Leaves in the Landscape

Many gardeners find that raking and clearing leaves from their landscapes in the fall is tedious and never-ending task. Depending on the age of the neighborhood, the size of trees and the number planted in or near the property, it can take a fair amount of time and energy to manage them.

Uses For Leaves

Leaves are a valuable resource in the landscape. While they are not considered a fertilizer replacement, (it would take 100 pounds of leaves per 1000 square feet of turfgrass to apply one pound of nitrogen if the leaf nitrogen value was 1%), they do have other benefits. Try to avoid sending the leaves to a landfill and use them in the landscape.

1. ***Mow the leaves into the lawn.*** Set the lawnmower deck to the highest setting. Remove the bagging attachment and make at least two passes over the lawn, chopping the leaves into small pieces. As long as you can see some grass through the leaves, the layer is not too thick. Research has found that mowing leaves into the lawn will return nutrients to the soil, provide food for earthworms, increase moisture for the turf roots and reduce weeds. ***Leaves do not lead to thatch accumulation***.

Research at Purdue University found that mulching leaves into the lawn at high rates did not affect turf quality, color or soil pH. A study at Michigan State University found that mulching leaves into the lawn reduced perennial weed populations like dandelions and annual weeds like crabgrass after three years. The small leaf pieces sift down onto the turf surface and prevent weed germination from bare soil. It is important that the leaves are shredded or mulched and not left whole on the lawn.

2. ***Add leaves to compost bins***. Tree leaves are "brown" material and can be added to compost bins in combination with "green" materials. For more information on composting, refer to the Colorado Master Gardener Garden Notes #246 at www.cmg.colostate.edu.

3. ***Add leaves to garden beds or raised beds*****.** Consider leaves a free source of organic matter. You can add up to six to eight inches of leaves (best if chopped by the lawnmower) into the vegetable garden. Water the surface, add some fertilizer to kick-start decomposition and let microbes break down the leaves through the winter. In the spring, till them into the soil or directly plant into the area. Be cautious about over-amending garden soils and consider having your soil tested first.

4. ***Use as mulch in the landscape*****.** Leaves can be used as mulch around tender plants or those that are newly planted. Place a wire cage around the plant and pile three to six inches of shredded leaves inside the cage, next to the plant. As growth begins in the spring, remove the cage and leaves.

Author: Dr. Alison O'Connor, Colorado State University Extension. Photos from csu.cohorts.blogspot.com (Dr. Tony Koski) and (compost) farm3.staticflickr.com/2435/4022031843_65a2086098_z.jpg

August 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #656

Herbicide Use Around Landscape Trees

There are times when using pesticides around trees is necessary and it is important to understand how they can potentially affect tree health. The most common pesticides used around trees in the home landscape are herbicides.

How herbicides can damage trees

1. Direct "hits" to the canopy, suckers or trunk that contact live tissue.

2. Absorption through the root system, which can extend several times the width of the canopy and can be extensive. Depending on soil type, tree roots are generally located within the top 12" of soil. In compacted or mostly clay soils, more than half of tree roots can be located in the top six inches of the soil.

3. Drifting or volatization (become a gas) with movement to sensitive tree tissue when conditions are too windy, too hot or when the relative humidity is low.

Figure 1 Volatilization Injury to Ash Leaves

It is critical to read and follow all directions on the label of a pesticide product before using it. Reading the label in its entirety helps the homeowner determine if the product can cause damage to woody landscape plants. Some trees are more sensitive to certain herbicides than others.

It is also important to understand the herbicide's mode of action (how it works). Some may be contact herbicides, some may be root absorbed and some may be systemic.

Table 1. Post-emergence Herbicides that are Safe to Use Around Trees

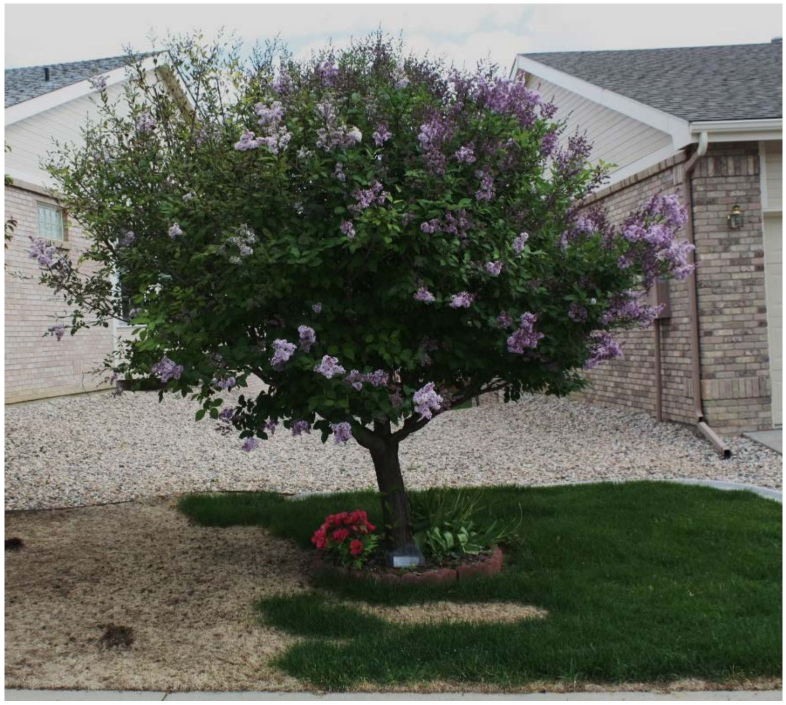
Class of Herbicide	Products	Mode of Action
Amino Acid inhibitors	• glyphosate (Roundup, Kleenup)	Foliar (systemic), but can be mixed with sterilants
Burndown products (non-selective)	• Diquat • Essential oil herbicides • Glufosinate (Finale) • Horticultural vinegar (20%) • Pelargonic acid (soaps) (Scythe)	Foliar (contact)
Phenoxys	• 2,4-D • Clethodim (Grass Out) (grasses only) • dichlorprop • Fluazifop (Grass B Gon) (grasses only) • MCPA • MCPP	Foliar (systemic)

Table 2. Preemergence Herbicides Safe for Use Around Trees.

Chemical Name	Trade Name
Isoxaben	Gallery
Oryazlin and trifluralin	Snapshot
Oryzalin	Surflan
Prodiamine	Barricade
Trifluralin	Preen

Weed and grass growth at the base of the trees is one area where herbicides may be applied frequently. In this situation, consider using mulch, mowing, hand pulling the weeds and grass, using glyphosate or burndown products (i.e. horticultural vinegar). When using glyphosate, only apply to the weeds or grass and do not spray the trunk, suckers or exposed roots of trees. Pre-emergence weed control products may be used under trees in spring.

Figure 2 Accidental root absorption of herbicide applied to rock mulch.



Author: Dr. Alison O'Connor, Colorado State University Extension. Photos courtesy Mary Small and Alison O'Connor, Colorado State University Extension.

Revised August 2017

CMG GardenNotes #657

Watering Mature Shade Trees

Why Trees Need Water

All living things need water to survive and trees are no exception. Trees use water for physiological functions and growth processes. In the landscape, water moves from soil in three ways.

1. Available water is *absorbed* through plant root systems, transported upward and lost via transpiration from leaves and bark.
2. Water *evaporates* from the soil surface.
3. Water *drains* through soil due to gravitational forces.

As soils dry, water molecules are held more and more tightly by soil particles. These water molecules become unavailable for plant use, resulting in the *permanent wilting point* of plants (the point of "no return"). As drought and desiccation increase, normal plant functions may cease. During drought stress, normal physiological functions of plants are interrupted, including:

1. Reduction in photosynthesis; water is an important component of photosynthesis and the process is negatively affected during dry periods.
2. Stomata, which regulate water and gas exchange in the leaf, may close. This prevents water vapor and oxygen from leaving the plant, as well as carbon dioxide entering the plant (which is essential for photosynthesis).
3. There is likely a reduction in carbohydrate production and storage (due to reduced photosynthesis).
4. Plant growth is reduced (leaves, shoots, roots, fruit, etc.)

Plants under drought stress also have weakened defense systems, which can lead to problems with certain insects and diseases. Fortunately, trees can tolerate *some* drought and dry conditions. It is very difficult to detect short-term drought stress in trees. Prolonged drought stress, however, may result in wilting, early leaf drop, smaller-than-normal leaf size, early fall leaf color, scorch on leaf margins, purpling or browning of leaf tissue and increase in disease or insect pressure.

Tree Establishment

Established trees in the landscape don't require water as frequently as those that are recently planted. (Trees generally take a season to establish for each inch of trunk caliper; a 2" tree will take two years to establish). In Colorado's dry climate, trees will need supplemental irrigation during dry periods in the summer and during fall and winter. Keeping your trees well-watered will contribute to their overall health and survivability in the landscape. A general rule of thumb is that the bigger the tree, the more water it will need.

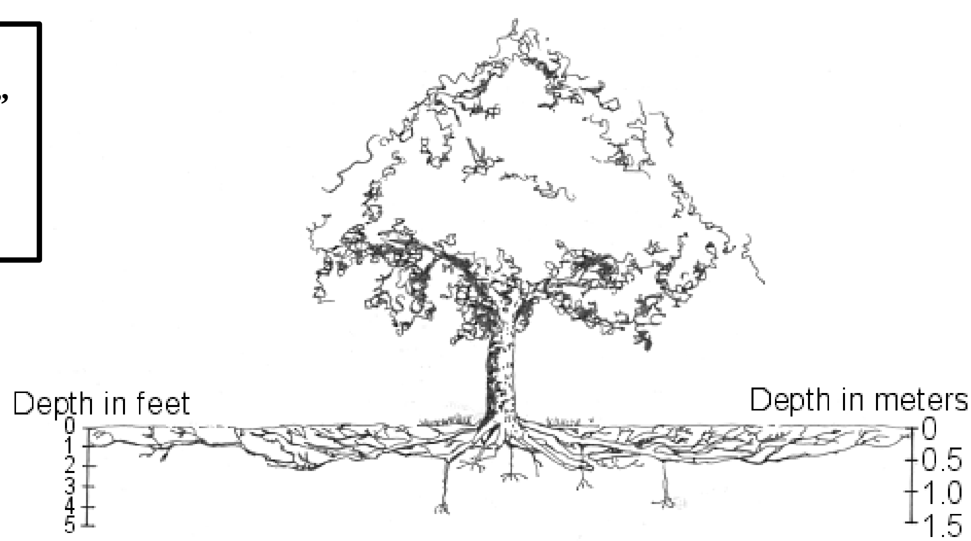
Tree Roots and Their Location

Tree roots tend to be shallow and most are located within the top 36" of soil. In compacted clay soils, up to 50% of roots may be located in the top six inches of the soil with nearly all roots located in the top 12 inches.

Tree roots can extend several times the width of the canopy. Trees planted near or in a lawn will share water with turf roots. Whichever was planted first has the advantage. New trees in an established lawn will have fewer roots to compete; mature trees with an extensive root system will outcompete turf grass.

In compacted or clay soils:

- **90-95% of roots in top 12"**
- **50% of roots in top 4-6 "**
- **Spread up to 5x canopy width**



Determining When to Water

It is difficult to look at a tree and determine if it needs water. Instead, take a slender screwdriver and poke it into the soil in several places around the tree, both inside and outside the dripline (where the canopy extends). If the screwdriver can easily penetrate the soil to a depth of six to eight inches, there is no need to apply water.

Amount of Water

The amount of water to apply will vary depending on the size and age of the tree, the time of year, soil type, watering method and other factors. Aim to apply one to two inches of water every two weeks during the growing season. If you prefer to measure in gallons, apply 10 gallons of water for each inch of trunk caliper - diameter- (e.g. a 4” caliper tree needs 40 gallons of water). These amounts are *recommendations only*. Adjust as necessary for your local situation and precipitation.

Methods of Watering

In general, it is easier to apply the entire amount slowly over one period of time instead of over a period of days. However, if your soil is very dry and cannot absorb the water - resulting in runoff - consider watering over several days to allow for absorption.

Trees growing in sandy soils will need to be watered more frequently than trees in clay soils, since sand drains more quickly and doesn’t hold water well.

It is much easier to keep soil continually moist throughout the season than to rehydrate dry soils. Dry soil often become hydrophobic and rewetting it takes a long time with multiple applications of small amounts of water.

There are many ways to water mature trees in the landscape: lawn irrigation, hose and sprinkler, drip irrigation, soaker hoses and self-watering devices.

<u>Lawn Irrigation</u>

When mature trees are planted in/near the lawn, using a lawn sprinkler system is an easy and effective way to water them. (Figure 1) Remember that the turf and tree roots are located in the shared rooting area and both are using the applied water. A good goal is to apply enough water to the lawn to compensate for evapotranspiration (ET); this is the amount of water used by the plants and lost from evaporation. The amount will

Figure 1

vary throughout the season. A typical bluegrass lawn may need one inch of water early in the summer (May-June), up to two inches during July and August and one inch in September and October. You can consider running additional cycles (perhaps a couple times per month) to supply additional water to tree roots. To measure how much water you are actually applying in an irrigation cycle, place several cups in the area and measure the amount of water in them. Multiply this by the number of days the system runs per week:

0.5 inches applied/cycle x 3 days per week = 1.5 inches of water applied per week
1.5 inches of water applied per week x 4 weeks/month = 6" of water per month

<u>Hose and Sprinkler</u>

A hose and sprinkler is an effective way to water trees. (Figure 2) A hose and sprinkler should always be used when the lawn irrigation system is turned off. Place several cups in the pattern of the sprinkler to collect output, or attach a water meter to the hose to determine how much water was applied. The most effective place to water mature trees is just outside the dripline (NOT at the trunk). Depending on the type of sprinkler, it may take 30-60 minutes of run time to apply one inch of water.

Figure 2

<u>Drip Irrigation</u>

Drip irrigation is often used to water newly planted trees. One mistake many homeowners make is leaving the drip irrigation in the original location for years. Emitters must be moved out and additional ones added as the tree grows or drought stress may occur. Depending on the location and tree species, drip irrigation may be eliminated after the tree matures. When using drip, understand the systems' emitter size and output to calculate the amount of gallons applied during each irrigation cycle. For example:

2 gallons/hour emitters x 4 emitters x 30 minutes per irrigation cycle = 4 gallons per cycle

<u>Soaker Hoses ("leaky pipe hose")</u>

Soaker hoses are probably most effective on smaller trees, but can be used on larger trees if there is enough hose available to apply in the tree's dripline. Soaker hoses apply water very slowly and need to run for long periods of time. It may take several hours to apply one inch of water, depending on pressure and hose size. A small container could be placed beneath the hose (or dug in a shallow hole) to collect water and determine total irrigation output. Do not coil soaker hose around trunks of mature trees.

Self-watering Devices

These systems, sometimes known as "Gator Bags", are best used *only* on newly planted trees. They are not an effective or practical way to water mature trees. Even with newly planted trees there are some potential problems. First, the bag must be monitored to ensure that it is filled with water. Second, bags are often dark in color and when left around the trunk of the tree, can trap excess heat. Third, bags may keep the trunk and surrounding soil overly moist, leading to disease and insect problems. Self-watering devices may be used for the short term, but are not a reliable way to irrigate.

Deep Root Watering Devices

Since the majority of tree roots are not located deep within the soil profile, deep root waterers are not an effective method of irrigating. In addition, the device must frequently be moved around the tree, which is time consuming. A hose and sprinkler is a better option.

Following your method of irrigation, stick a slender screwdriver into the soil. If you cannot penetrate to a depth of six to eight inches, water again. Repeat this process until you have adequate soil moisture.

Fall and Winter Watering

Watering trees in Colorado's dry fall and winter months is extremely important. Moist soils hold more heat than dry soils, leading to additional growth in the fall and increased time for establishment. Adequate soil moisture also leads to better plant hardiness and ability to survive cold, dry winters. Aim to water trees and other woody landscape plants monthly when natural precipitation between October and April is less than an inch per month.

Precipitation can be in the form of snowmelt or rain, but snow moisture can vary. Water on days when the temperature is above 40 degrees. Apply an inch of water early in the morning to allow it to soak into the soil before freezing at night. For additional information, refer to CSU Extension Fact Sheet #7.211 at www.extension.colostate.edu

Figure 3 Snow holds varying amounts of water

Obey All Ordinances

Be smart when watering and avoid irrigation during the hottest part of the day (10am to 6pm), when evaporation can occur more readily. Follow all HOA guidelines and town/city restrictions.

Authors: Dr. Alison O'Connor and Eric Hammond, Colorado State University Extension. Figure 1 source: By M.O. Stevens (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons; Figure 3 courtesy of Mary Small, Colorado State University Extension

August 2017

CMG GardenNotes #658

Mulching Trees

Mulch Importance and Benefits

Mulch is important to the long-term health of trees.

- It helps protect them from string trimmer and lawn mower damage.
- It helps retain soil moisture and reduces evaporation from the soil surface by 25-50%.
- Mulch helps moderate soil temperature extremes and controls erosion.
- It enables tree roots to outcompete grass roots for available nutrients and water.
- Fine root hairs of trees develop 400% more under mulch than under grass. This is important because root hairs absorb most of the water and nutrients for the tree.
- Mulch suppresses weed growth and gives landscapes a finished, polished look.

Mulch Disadvantages

While mulch has many benefits, there are some disadvantages.

- Used in moist areas, organic mulch can create conditions ideal for trunk or root rot, especially when placed too close to the trunk. Rot in this part of the tree leads to instability and makes a tree more susceptible to wind throw.
- Organic mulches may be attractive to voles that use it as shelter and then chew on tree bark for food.
- Lighter-weight mulch materials can blow away in very windy areas,
- Herbicides directed at weeds emerging through mulch may accidentally touch roots, green bark and sucker sprouts, leading to tree injury.
- When mulch is applied too deep around a tree stem- girdling root problems often follow and may kill a tree several years after planting.

Mulch Options

There are many options when it comes to choosing mulch, but not all mulch is best for tree health. Plastic mulch/sheets suppress weed growth, but might overheat the soil and damage roots. In addition, plastic mulch doesn't allow for proper oxygen flow to the tree root systems so roots tend to grow directly under the plastic, leading to potential problems. Large rocks do a poor job of suppressing weed growth and can overheat the soil and tree roots. Rock mulch may also have increased weed growth, as soil settles between rocks, providing ideal conditions for weed germination. Rubber mulch can lead to drainage problems and leach toxic metals into the soil. When choosing a tree mulch that is attractive, beneficial, and convenient it is hard to beat bark chunks, shredded bark, wood chips, and pine needles.

Mulch Application

Properly applying mulch is just as important as selecting it. Keep the mulch at least 6 inches away from the bark of the tree. This helps keep the lower trunk dry and reduce the likelihood of bark decay and rot.

Never apply mulch directly over the newly planted root ball since this encourages roots to grow up into the mulch and around the trunk or each other. This growth can girdle the tree within several years. Instead, mulch the backfill area and beyond if possible, to a 3 to 4 inch depth. Excessively mulched trees, sometimes called "mulch volcanoes", reduce the amount of available oxygen to tree roots, causing oxygen starvation and tree decline or death.

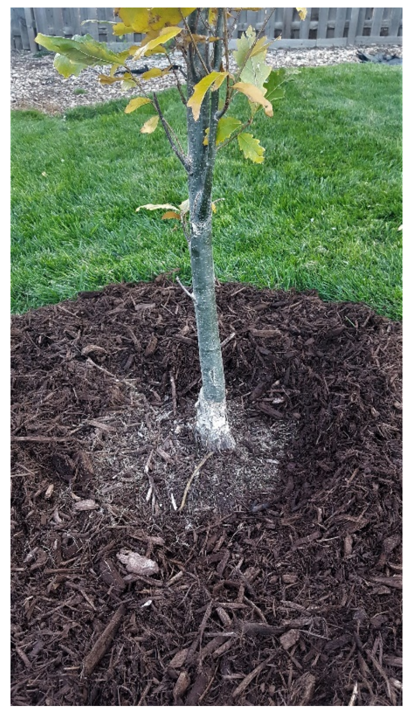


Figure 1. Keep mulch away from the trunk and off the root ball.

Authors: Tyler Mason, PhD candidate, Colorado State University Department of Horticulture and Landscape Architecture: Dr. Alison O'Connor and Mary Small, Colorado State University Extension. Photos courtesy Alison O'Connor, Colorado State University Extension.

October 2017

CMG GardenNotes #659

Understanding Tree Roots

Outline:

Functions of Tree Roots

Support\anchorage

Upended tree shows extent of root plate

A tree's root system keeps its trunk and canopy upright against the forces of wind and gravity. The strength of anchorage provided by a tree's root system depends on a variety of factors including soil type, soil moisture levels, tree species, root health and the depth and width of a tree's root plate. Sandy and overly wet soils provide worse anchorage.

The "root plate" is the area close to the trunk that contains the primary structural roots The root plate occupies an area ~3 to 6 times the diameter of the trunk at DSH\DBH (Diameter at 4.5ft).

Absorption of water and mineral nutrients

Roots absorb water and nutrients for use by the plant. Mineral nutrients are only absorbed from forms dissolved in the soil solution. In some species, the architecture of the tree's vascular system is such that specific roots supply correspondingly specific branches with water and nutrients. For example, in ring porous species such as the oaks (*Quercus* spp.), a given root or suite of roots supplies a specific branch or suite of branches which are often on the same side of the tree as the root. Similarly, in many conifers, water and nutrients move up the trunk in a spiral pattern supplying branches along the way. In this case damage to a root manifests in branches along the spiral the root supplied. The specific vascular architecture of many species is not known.

Production of plant growth hormones

Cytokinins, gibberellins and abscisic acid are all produced by roots. Cytokinins are involved in cell division, cell differentiation, axillary bud growth and leaf senescence.

Gibberellins are involved in stem elongation, bud break and other processes. Abscisic acid is involved in drought stress response, maintaining apical dominance, suppressing stem elongation and promoting dormancy.

Storage of energy as sugars and starches

Energy created through photosynthesis can be transported to the roots of a tree as sugars, and then is stored as starch.

Describing Tree Roots

Types of tree roots

Woody roots (also called transport roots)

Example of woody roots

There are larger roots that may be up to 1 cm to 30 cm (.4 to 12 inches) or more in diameter in some cases. These roots provide anchorage, serve as storage sites for starches and sugars and are part of the system that transports water, nutrients and other compounds through the tree from fine feeder roots to leaves. They absorb very little water or mineral nutrients from the soil.

Specialized Woody Roots

1. **Tap Root**- A primary root that grows downward from the seed radical. Some species exhibit taproots when younger but by the time they reach maturity few trees have a true deep taproot due to low soil oxygen levels deeper in the soil.
2. **Sinker Roots**- Roots that grow downward from lateral woody roots. Formation of these roots is species and soil dependent. They are not common in landscape trees.

Fine feeder roots (absorptive roots)

These are smaller roots that are 2 mm (.4 to .008inches) or less in diameter.
These roots are the primary sites of water and mineral nutrient absorption. They are often short lived and can been killed or suppressed by low soil oxygen levels, drought or

fluctuations in soil temperature. Such events are stressful but healthy trees rapidly reproduce fine feeder roots.

Fine feeder roots are commonly colonized by symbiotic fungi. These fungi can help extend the reach of the root system, aid in the mineralization of plant nutrients, increase the trees' drought tolerance and help it to resist some diseases.

It is common for fine feeder roots to form grafts with the fine feeder roots of other members of the same species.

Size and extent of the root system

Width

A mature tree's root system often occupies a much wider area than its canopy. Depending on the species of tree and soil conditions the spread of a trees' root systems may be 2 to 5 times the width of its canopy or even greater in some cases.

Depth

The depth of a trees root system is governed by the availability of water, mineral nutrients, soil oxygen and the species of tree. In clayey, compacted or perpetually wet soils (soils with a shallow water table) roots tend to be shallower due to low soil oxygen levels in the deeper layers of such soils. In sandy soils, roots also tend to be massed near the soil's surface. Sandy soils have low levels of mineral nutrients and having a large concentration of roots near the surface allows trees to capture nutrients released from decomposing leaf litter. In loamy soils, tree roots tend to be deeper as there is sufficient oxygen and nutrients to support their growth.

The rule of thumb for estimating rooting depth in clayey, compacted or perpetually wet soils (soils with a high water table) is that 90-95% of roots will be in the top 12 inches and 50% will be in the top 4 inches of soil. In favorable soils conditions 90-95% of roots will be in the top 36 inches and 50% will be in the top 12 inches of soil.

Surface area

The surface area of a root system is likely larger than that of the plants' leaves BEFORE you take into account symbiotic fungi.

Conditions that adversely affect roots

Heavy equipment traffic compacts soils

Soil Compaction

Soil compaction occurs when soil is compressed, pushing soil particles closer together. This reduces the overall volume of pore space in a soil and particularly reduces the volume of larger air holding pores. In landscapes, compaction can be caused by foot traffic, maintenance equipment or other vehicle traffic and other factors. Many soils are compacted during construction.

Compaction affects tree roots in a several negative ways. It can lower soil oxygen levels which adversely affect root and tree health (see below). Compaction also increases the strength of soil making it physically harder for roots to grow through it. This can slow the establishment and growth of a tree.

Low soil oxygen levels

Roots require oxygen to perform respiration (the process that turns the products of photosynthesis into usable energy). As roots (and other soil life) consume oxygen it is replenished though diffusion from the atmosphere. When adequate oxygen is not in the soil, root growth slows. Low soil oxygen levels also leads to stomata (located on plant leaves) closing which reduces water and nutrient uptake, reduces translocation of water, nutrients and hormones within the plant and can potentially led to wilting. Low soil oxygen can also lead to root cells "self- poisoning" due to accumulation of the byproducts of anaerobic respiration.

Conditions leading to low soil oxygen levels

Overwatering\Waterlogged Soils

In soils that are perpetually wet, soil pores are mostly filled with water (soil solution). Relatively few pores are filled with air. There also may be few clear contiguous pathways from the air-filled pores to the soil surface, slowing the rate of diffusion of oxygen between the atmosphere and the soil.

Compaction

Compaction reduces the overall volume of pore space in a soil and especially reduces the volume of "large" pore spaces. The "large" pores are those that tend to be filled with air after gravitational water has drained. They are also the easiest pathways for diffusion of gasses. So, compaction reduces the volume of air-holding pores in soil and can reduce the rate of diffusion between the atmosphere and the soil.

Improper mulching

Appling organic mulch too thickly can slow diffusion of gasses, including oxygen, from the atmosphere into the soil. Generally, no more than four inches of organic mulch should be applied to avoid this. Plastic sheet or fabric mulches limit the exchange of gasses between the atmosphere and the soil.

Grade Changes

Adding soil over the top of an established root system can have the same effect as adding a mulch layer that is too thick.

Other common root issues

Girdling Roots

Girdling roots are roots that are wrapped around other parts of the plant. Stem girdling roots are roots wrapped around or growing across the stem of a tree. Root girdling roots are wrapped around another root (somewhat less of a concern).

Stems girdling roots compress newly produced phloem (and eventually xylem) which impairs the ability of the tree to move material through these tissues. This leads to stress and potentially, decline.

Girdling roots

Symptoms

i. Flat sections of a tree's trunk where it enters the soil (non-flared).
ii. Swelling above and below the girdling root.
iii. Generally poor health or dieback without any obvious cause.

Causes of Girdling Roots

i. Root deflection and circling at the edge of a container.
ii. Root deflection at edge of planting hole.
iii. Trees placed too deeply in nursery containers. This leads to roots growing upward and potentially to circling roots in a container above the root flare.
iv. Upward growing roots as the result of low soil oxygen due to deep planting, root pruning in the field during nursery production or combination of the two.
v. Mulch over the root ball or root flare.

Dealing with girdling roots

A root collar excavation, which is the process of removing the soil from the base of the tree, can be performed to expose the root flare and any girdling or potentially girdling roots. Girdling roots can then be removed, preferably back to a point where they will grow outward from the trunk. Some roots may be too in-grown to remove and may result in greater damage to the tree if removal is attempted.

Proper management and pruning of root systems in nurseries and at planting as well as proper planting practices can prevent girdling roots from forming.

Surface roots

Surface roots

Trees roots may develop at or partially above the soil surface creating a nuisance in turf and a potential health risk for the tree as exposed roots are often wounded by mowers or other landscape maintenance activities.

Some trees are prone to developing surface roots. However, their formation is encouraged by low soil oxygen levels that are caused by compaction or overwatering or both.

Once surface roots develop, little can be done. A soil of courser texture can be added over the surface roots but it is **<u>likely a short term solution</u>**. As roots increase in diameter they will surface again. Adding too much soil or too fine a soil can reduce soil oxygen levels and harm the tree. Mulching the area so that it no longer needs to be maintained as intensively is the best management option.

Installation and maintenance practices that promote better soil aeration can help prevent surface roots. Such practices include amending soil with organic matter and regular core aeration of turf.

Suckering

Suckers growing around base of tree

Roots may produce adventitious shoots known as suckers. Suckers arise from adventitious or latent buds along a trees' root system. (They are different from seedlings with are the result of seeds created through sexual reproduction.) Production of suckers is partially species dependent and some species are more prone to suckering. Damage to roots from trenching, flooding or other causes can also in courage suckering. Removing a tree can cause its remaining root system to sucker. Suckering can also be a response to general stress.

What can be done?

ii. Avoid planting species that are prone to suckering.
iii. Avoid damaging tree root systems.

iv. Try “Sucker Stopper” which is an artificial plant growth hormone that prevents buds from opening. Read label directions before using as it works better on some species than others.
v. Try herbicides - if you do not care about the health of the tree that is producing the suckers, herbicides can be used.
vi. Tolerate suckers.

Key Points for Talking With Clients about Tree Roots

- Tree root systems are much wider than their canopies, if space permits.
- Tree root systems are relatively shallow.
- Proper planting practices and species selection are the best way to avoid common root issues.

Author: Eric Hammond, CSU Extension.

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CMG GardenNotes #652

Tree Preservation During Construction

In tree preservation, take steps to prevent construction damage, as little can be done to correct it!

This CMG GardenNotes was written as an overview of tree preservation issues in a construction site. For additional information refer to:

- ***Trees and Development, A technical Guide to Preservation of Trees During Landscape Development*** by Nelda P Matheny and James R Clark. International Society of Arboriculture. 1998. ISBN: 1-881956-20-2
- ***Up By Roots: Healthy Soils and Tree in the Build Environment*** by James Urban. International Society of Arboriculture. 2008. ISBN: 1-881956-65-2

Guiding Principles of Tree Preservation

1. Goals in tree preservation include both *construction* AND *tree preservation.*

- Both goals have to be valued.
- Both sides have to make compromises.
- Polarizations of attitudes include 1) that it is cheaper, easier and faster to remove all trees at the start and 2) that all trees need to be saved. For tree preservation, comprise must be found in the middle.
- The goal is not to preserve trees just until occupancy occurs, but rather for twenty plus years.

2. **Preservation requires commitment of all parties, as a team effort.**

- Owners
- Engineers
- Architects and landscape architects
- Grading and demolition crews
- Construction and landscape crews
- Government agencies
- Arborists, who's role includes
  - Technical resources and tree knowledge
  - Familiar with local regulations and regulatory staff
  - Familiar with local growing conditions

3. **Tree preservation cannot wait until construction or afterwards.**

- Tree preservation takes place in the planning phase.
- Construction crews then follow the plans.

4. **All trees cannot and should not be preserved.**

- Trees require that space be protected for their roots.
- Trees in poor health simply will not tolerate construction stress.
- Trees with poor structure have limited value.

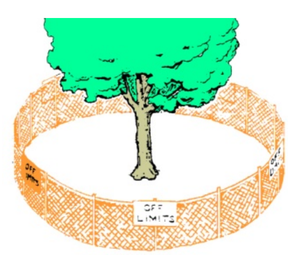
5. **Tree preservation patterns must respect patterns of tree growth.**

- All players in design and construction must respect the ***Tree Protection Zone, TPZ.*** .

Trees have a root plate system, shallow and wide spreading.

6. **Tree preservation requires above and below ground space.**

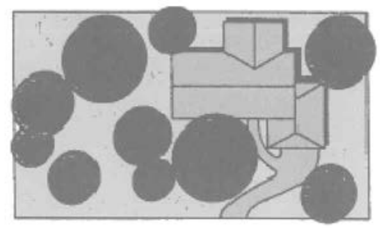
- Inside TPZ there is NO grading, trenching, parking, stock piling of building materials or dumping of waste products.



7. **Preservation focuses on preventing injury to trees, as little can be done to correct injury.**

8. **Construction impacts to trees are cumulative.** Small impacts add together for stress and tree decline.

9. **Tree preservation requires accurate site information.**



- Location of buildings, utilities and hardscape features
- Location of trees
- Species identification and tolerances to construction stress
- Evaluation of tree health and potential for preservation

10. **Arborists and design/construction professionals must communicate.**

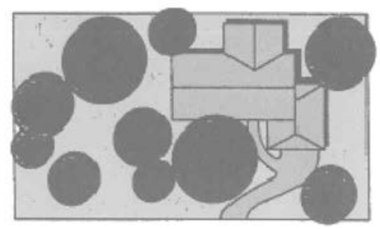
- Talk in technical terms.
- Both sides must be willing to compromise.

11. **Community attitudes and practices must support both tree preservation and development.**

- A compromise must be found between the polarizations of 1) aggressive tree preservation ordinances and practices that prohibit construction and 2) ignoring tree preservation in favor of construction.
- The same standards should apply to both private and public sector development.

Development Sequence

1. **Site design including _tree report_**



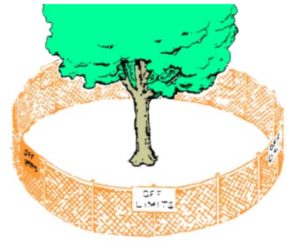
- Requires communication and compromise between all parties.
- This is the most important step in tree preservation.

2. **Review and approval by public agency**

- Conditions of approval
- Bonding: appraised value of trees preserved
- Permits

3. Site work

1. Tree work



- Tree work needs to be completed before other activities start.
- Due to construction schedule, the time frame for tree work may be very short.
- Tree protection needs to be in place during site work.

2. Demolition and clearing
3. Grading
4. Utilities and roads

4. Construction and landscaping

- Tree protection needs to be in place during site work.
- Implement *tree maintenance during construction plan.*
    - How/who will the tree be protected during construction?
    - How/who will the tree be watered and cared for during construction?

5. Occupancy

- Implement *post-construction maintenance plan.*
- In tree preservation, it should be expected that the tree lives for twenty plus years, not just until site occupancy.

Tree Report

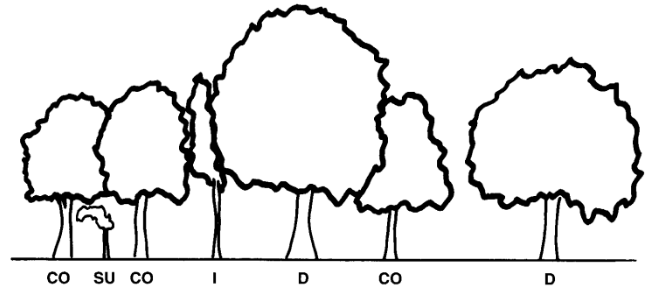
Step A – Inventory and Evaluation

- Identify trees suitable for preservation.
    - Species
    - Size
    - Health and vigor
    - Structural integrity
    - Age – Young trees are more tolerant of construction stress.

    - Species tolerance to construction stress
    - Maintenance requirements

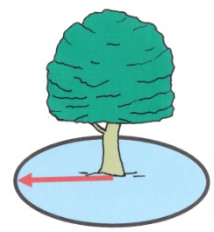
    - Trees suitability to new use
        - Group or specimen trees – Trees are often easier to preserve in a grouping rather than specimen trees.

- **Crown class**



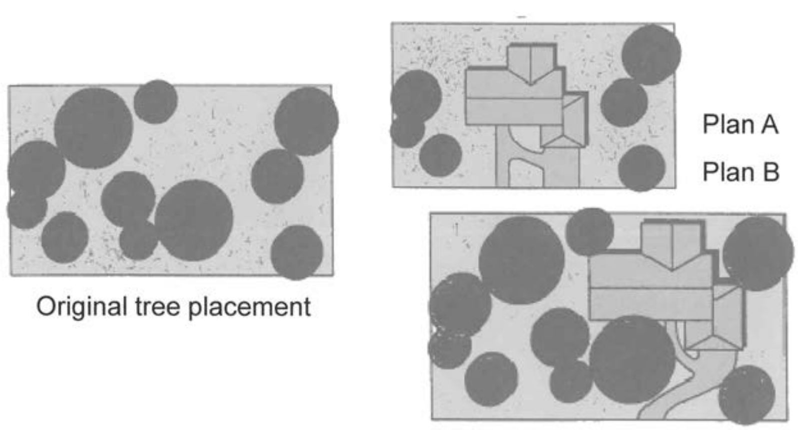
- ✓ ***Dominant trees*** make the best options for preservation.
- ✓ ***Co-dominant trees*** are best preserved in groupings.
- ✓ ***Intermediate trees*** make a poor choice for preservation.
- ✓ ***Subordinate trees*** make a poor choice for preservation due to inferior structure and sudden exposure.

Step B – Assess potential impacts by calculating the *Tree Protection Zones* for each tree.

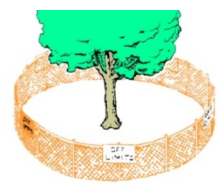


- Trees under stress and/or decline are less tolerant of construction related stress and do not merit preservation.

Step C – Modify plan to accommodate TPZ and building plans



Step D – Identify tree work



- Work to be done by arborist not construction workers.
- There may be limitations on time of year for work to be done.
- There may have short time frame to complete work before construction begins.

Step E – Outline *Tree Maintenance During Construction Plan*

- Who and how will trees be protected during construction?
- Who and how will the tree be watered and cared for during construction?
- Who and how will the *tree protection plan* be communicated to all workers?
- Who and how will tree protection be monitored during construction?
- What penalties will be in place for individuals and companies who violate the tree protection plan?

Step F – Outline *Post-Construction Maintenance Plan*

- What will be done and who is responsible?
    - Soil management
    - Pruning: Cleaning
    - General care (watering, pest management**)**

Assessing Tree Tolerance

Species

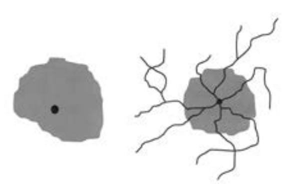
- For comparison, classify species as **good**, **moderate** or **poor** tolerance.
- There is no comprehensive list of species tolerances.
- Ask experts about their experience with specific species.

Age and longevity

- For comparison, classify as **good**, **moderate** or **poor** tolerance.
    - Young trees typically have good tolerance.
    - Medium age trees typically have moderate tolerance.
    - Over-mature and declining trees have poor tolerance and do not merit preservation.

Health and vigor – Trees in poor health will not survive construction related stress.

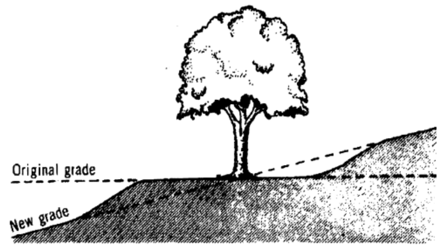
Actual crown and rooting area may not be uniformly distributed.



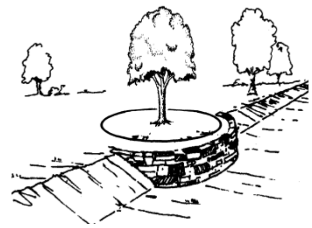
Structural stability – Preservation efforts are not warranted on structurally unsound trees.

Cuts and fills

- **Fills** are more tolerance on flooding tolerant species
- **Cuts** – more tolerance on drought tolerant species



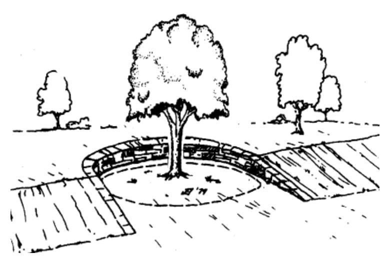
- **Removing soil inside TPZ**
    - On root severance **tolerant** species, may disturb up to **25% of TPZ area** (not diameter).
    - On root severance **sensitive** species, allow **extra space** beyond TPZ.



Root Severance Tolerance

Tolerant	Intermediate	Sensitive
Up to 25% of TPZ area	TPZ area	Allow extra space in TPZ
Ash: green, white, black	Birch: paper & yellow	Beech
Aspen: quaking & big-tooth	Buckeye: Ohio	Butternut
Birch: river	Catalpa	Ironwood
Boxelder	Cherry: black	Oak: white, northern pin and black
Cottonwood: eastern	Kentucky coffee	Walnut: black
Fir: balsam & white	Hawthorn	
Hackberry	Hickory: Bitternut	
Honeylocust	Maple: sugar	
Locust: black	Spruce: Colorado blue	
Maple: silver & red	Oak: bur & bi-color	
Mt. Ash		
Pine: white, jack, & red		
Spruce: black, white		
Willow		

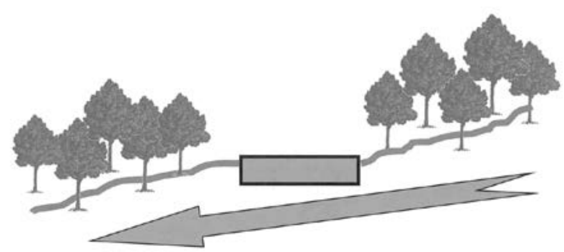
- **Adding soil inside TPZ**
    - If a compaction/flooding **tolerant** species, *may* successfully add **up to 6” *porous* fill**.
    - If a compaction-flooding **sensitive** species, **do NOT change grade**, and TPZ (as calculated with diameter method) may be too small.



Root Covering Tolerance

Tolerant	Intermediate	Sensitive
Add up to 6" porous soil	TPZ area	No change in TPZ
Ash: blue & green	Ash: white	Aspen: quaking & big-tooth
Cedar: northern white	Buckeye: Ohio	Basswood
Birch: river	Butternut	Beech: blue
Boxelder	Cherry: black	Birch: paper & yellow
Fir: balsam	Kentucky Coffee	Cedar: eastern red
Catalpa	Elm: American & slippery	Fir: white
Cottonwood: eastern	Hackberry	Ironwood
Maple: silver & red	Hawthorn	Locust: black
Spruce: Colorado blue & black	Hickory: bitternut	Maple: sugar
Tamarack	Honeylocust	Oak: red, white, black, & northern pin
Oak: bi-color	Mt Ash	Pine: white, jack, red, & scotch
Willow: black	Spruce: white	Plum: wild
	Oak: bur	
	Walnut: black	

Changes in soil hydrology (soil water)

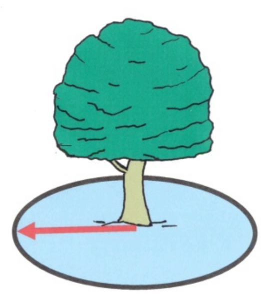


- **Ability to recover from stress factors**
  - Insects and diseases
  - Irrigation changes

Tree Protection Zone, TPZ

Trunk Diameter Method

The trunk diameter is probably the best method for general use on landscape trees. Size of the TPZ is based on the diameter of the trunk, increasing as the tree ages and become less tolerant of stress factors. It may be calculated by measuring the trunk circumference or diameter at DSH (diameter at standard 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.



Trunk Diameter Method by Circumference

TPZ radius = 1 feet per 2 inches of trunk circumference

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

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

Trunk Diameter Method by Diameter

TPZ radius = 1.5 feet per inch of trunk diameter at DSH

1. Measure the tree's diameter at DSH (4.5 feet) in inches.
2. Multiply the diameter (in inches) by 1.5
3. This is the radius, in feet, of the TPZ

For example
1. Diameter = 8 inches
2. 8 x 1.5 = 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 X 12 feet X 3.14 = 452 square feet

Stress Tolerance and Age Method

This method is used in a construction site when compromise must be made to minimize the TPZ, allowing for construction activities.

1. Evaluate species tolerance to construction stress (good, moderate, poor)

- ✓ Transplant response
- ✓ Drought response
- ✓ Rooting pruning response
- ✓ Compartmentalization (decay response)
- ✓ Native range – tolerance to stress outside native ecosystem

2. Identify tree age

- Young = < ¼ life expectancy
- Mature = ¼ - ¾ life expectancy
- Over-mature = > ¾ life expectancy
- Older trees are less tolerant of stress and require larger TPZ

3. From the table, calculate minimum TPZ radius and area

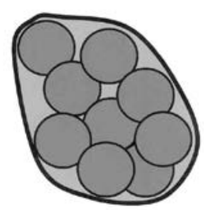
Stress Tolerance	Tree Age	Radius of TPZ* Feet/ inch trunk diameter
Good	Young	0.5
	Mature	0.75
	Over-mature	1.0
Moderate	Young	0.75
	Mature	1.0
	Over-mature	1.25
Poor	Young	1.0
	Mature	1.25
	Over-mature	1.5

- Additional space may be needed on compacted, clayey soils.

TPZ modifications

- Methods above are based on trees in open area with unlimited rooting space.
- Additional space may be needed for shallow rooted trees, like spruce and on compacted clayey soils.
- If low branches will interfere with work, extend the TPZ to include all the dripline area.

Trees in groupings



1. Calculate and plot the TPZ for each tree
2. Plot outer edge of tree group as the TPZ for the grouping

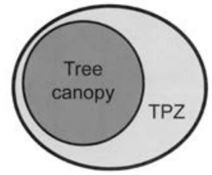
Multiple trunk trees

1. Calculate the trunk area for each trunk at DSH (4.5 feet).
2. Add the areas together.
3. Calculate the diameter of a tree that would have this size area in a single trunk.

   Area = Radius^2 x 3.14
   Radius = $\sqrt{}$area / 3.14

4. Use this as the trunk size to estimate the TPZ

To accommodate site needs, the TPZ area may be



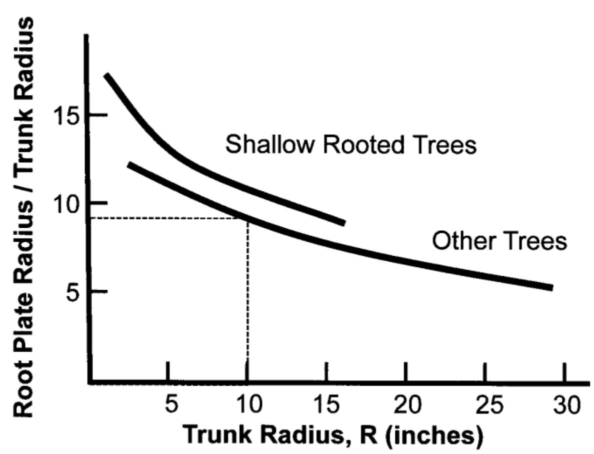
- Offset slightly
- Not necessarily round

Sites with urban hardscape restricting root spread

- Methods, as described above, will need adjustments.
- Need to actually check for root location.
    - Backhoe (A good operator knows when he hits roots and will stop before cutting them.)
    - Hand digging
    - Air spade
- New sidewalks and parking areas are generally OK if they say inside the footprint of the old area without invading the rooting area.
- New buildings are generally OK if they say stay inside the footprint of the old building without invading the rooting area.

Tree Stability

- For wind stability, do not invade the root plate.
    - **General formula**: radius of root plate is 3-6 times DSH (trunk diameter at standard height, 4.5 feet)
    - **Bartlett Tree Lab Model**: radius of root plate is
        - 5 times DSH on one side AND
        - 3 times DSH on other three sides
    - **Mattheck Model**

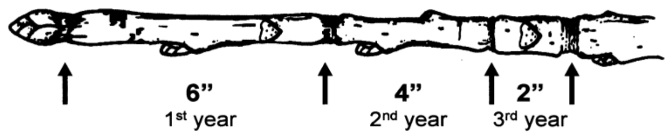


For example, a 10 inch trunk radius needs a root plate/trunk radius coefficient of 9. This would be 90" root plate radius (90"/10" = 9).

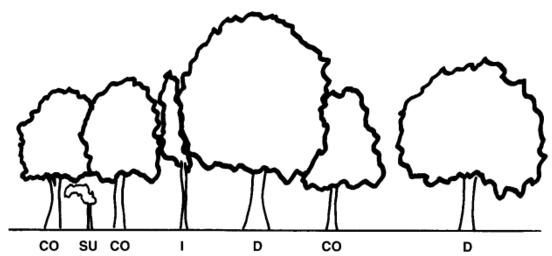
Symptoms of Construction Damage

Symptoms of construction damage include generic symptoms of stress and decline. Trees generally decline due to root decline and death.

- Reduced canopy growth – Compare how annual growth changes from year to year.



- Dieback on upper canopy
- Dieback of upper canopy on side related to root damage
- Small, poorly colored leaves
- Adventitious sprouting along trunk or lower scaffold branches
- Heavy seed set
- Mechanical injury to trunk and limbs
- New Edge” damage – Foliage and bark damage due to increased exposure to sun and wind.



Bottom line: Take steps to prevent construction damage, as little can be done to correct it.

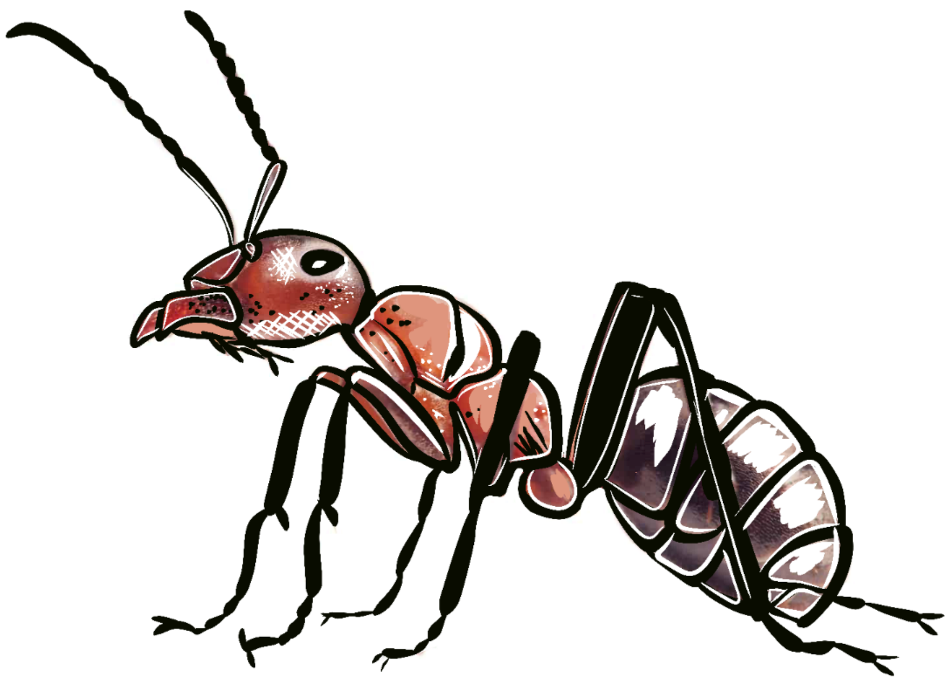
Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University Extension.

October 2014

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #100-113

Integrated Pest Management & The Diagnostic Process



Formica, Ant
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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.

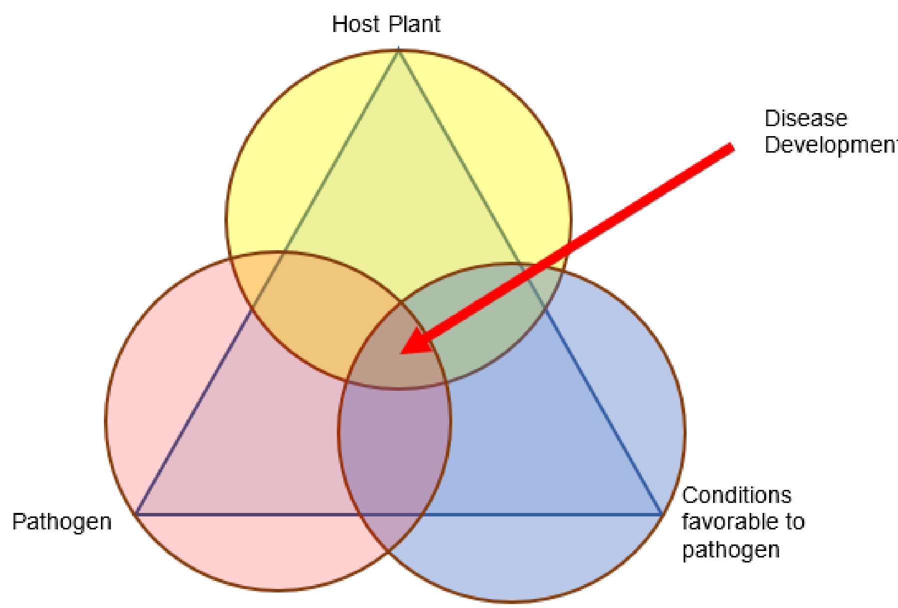
Because insect and disease problems and their consequences vary significantly from crop to crop, application of IPM principles is *situational*. The IPM techniques used in an alfalfa field (perennial crop), a wheat field (annual crop), and an apple orchard (perennial crop with minimal tolerance for pest 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?

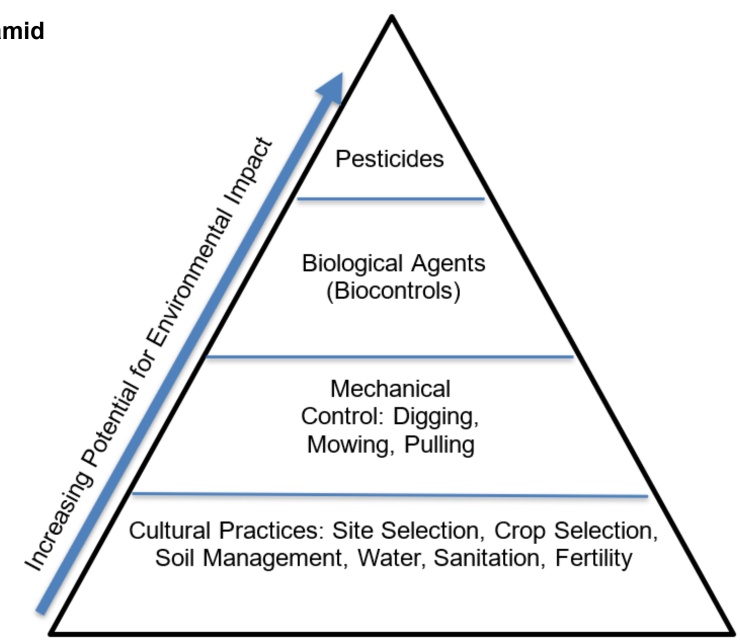
5. Determine the Treatment Options in **This Situation**.
    - On what should management focus (host, pest, conditions?)
    - What treatment options are available?
        - Cultural.
        - Mechanical.
        - Biological.
        - Chemical.

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

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

Turfgrass Management

Learning Objectives

At the end of class, the student will be able to:

- Describe how lawn management practices influence turf quality and why incorrect management decisions lead to common lawn care problems.
- Describe which grass species are best-adapted for lawn use, and the most important factors to consider when choosing a species for a new lawn (or when renovating an existing lawn)
- Describe how mowing height and frequency affect the aesthetic quality and stress tolerance of turfgrass; why grass clippings should be recycled back to the lawn during mowing.
- Describe why nitrogen is the most important nutrient in a lawn fertilization program, how and when to fertilize a lawn, and how to select the appropriate lawn fertilizer.
- Describe the environmental factors affecting turf water use and how to use that knowledge to most effectively irrigate a lawn (how MUCH water to apply, and how OFTEN?).
- Describe thatch, understand why it forms in the lawn, what common problems its accumulation may cause, and how thatch is most effectively managed.
- Describe the negative effects of soil compaction on turf health and how to improve soil physical conditions by using common cultivation practices.
- Describe how to establish a new lawn, using seed, sod or plugs. What is meant by lawn renovation and how this process can be used to improve the quality of an existing lawn.
- Describe the most common lawn weeds, why weeds occur in the lawn, and how to most effectively manage weeds using cultural practices and, if necessary, herbicides.
- Describe the process of diagnosing common lawn problems and know where to find the most useful resources (books, websites) to assist in the diagnostic process

- CMG volunteers approach diagnostic situations as a process. Students will be able to:
  - Describe concepts of *Plant Health Care* (PHC; IPM as it applies to lawn care)
  - Outline the life cycle of a lawn and describe how lawn/turf needs change with the age of the lawn
  - List steps in the diagnostic process
  - Using the diagnostic process, diagnose routine lawn pest problems

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Turfgrass Management curriculum developed by Tony Koski, Extension Turf Specialist, Department of Horticulture and Landscape Architecture, Colorado State University

Tony Koski, Ph.D.
Extension Turf Specialist
Department of Horticulture and LA
Phone: 970-491-7070
E-mail: tony.koski@colostate.edu

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References

Colorado State University Extension

Grass Species Selection for the Home Lawn

CMG GardenNotes

- Best Turf Varieties: Variety Recommendations for Bluegrasses, Tall Fescues, Fine Fescues Ryegrasses, and Buffalograss – #562
- Buffalograss Lawns – #565
- Fine Fescue Lawns – #564
- Hybrid (Kentucky X Texas) Bluegrasses for Turf Use in Colorado – #563
- Native Grass Lawns – #567
- Sources of Grass Seed, Sod and Plugs for Colorado Lawns – #566
- Turfgrass Species Selection Guidelines – #561

Mowing

Extension Fact Sheets

- Lawn Care - #7.202
- Eliminate Grass Clipping Collection - #7.007

Lawn Fertilization

Extension Fact Sheets

- Lawn Care - #7.202
- Nitrogen Sources and Transformations – #0.550
- Organic Materials as Nitrogen Fertilizers – #0.546
- Soil Testing – #0.501
- Soil Testing – Selecting an Analytical Laboratory – #0.520
- Soil Testing – Soil Test Explanation – #0.502
- Soil Testing – Soil, water and plant testing – #0.507

Lawn Irrigation

Extension Fact Sheets

- Lawn Care - #7.202
- Irrigation: Inspecting and Correcting Turf Irrigation Systems - #4.722
- Watering Established Lawns - #7.199
- Operating and Maintaining a Home Irrigation System - #7.239

Thatch and Compaction Management

- Lawn Care - #7.202

Lawn Establishment and Renovation

Extension Fact Sheets

- Lawn Care - #7.202

- Renovating the Home Lawn - #7.241

CSU TurfNotes

- Lawn Renovation: Terminology and Guidelines - #820

Turf Weed Management

Extension Fact Sheets

- Lawn Care – #7.202
- Control of Weedy Grasses in Home Lawns – #3.101

Books

- ***Integrated Turfgrass Management for the Northern Great Plains***. 1997. Baxendale, F.P. and Gaussoin, R.E. (eds.) University of Nebraska. Publication EC97-1557. 236 pages.
- ***Fundamentals of Turfgrass Management***. 2003. Christians, N.E. John Wiley & Sons. 368 pages. 2nd edition.
- ***Identifying Turf and Weedy Grasses of the Northern United States***. 2005. Pederson, D. and Voigt, T. University of Illinois Extension. 63 pages. Publication C1393. http://www.pubsplus.uiuc.edu
- ***Lawns: Your Guide to a Beautiful Yard.*** (2002 and 2007). Christians, N., Ritchie, A. and Mellor, D. Meredith Publishing. 1st edition ISBN 0696212706; 2nd edition ISBN 9780696229695.
- ***Weeds of the West***. 1991. The University of Wyoming. 630 pages.

Review Questions

Turfgrass Species/Variety Selection

1. What is the best grass to plant in Colorado lawns?
2. What is the best grass to plant if you don’t want to water a lawn?
3. What grass can grow with only a “little” irrigation?
4. Can zoysiagrass grow in Colorado? What will happen if I plant it anyway?
5. What is the best grass for a shady lawn?
6. Which grass grows best in salty soil?
7. What is the best grass to plant over my septic leach field?
8. What grass can I plant if I don’t want to mow my lawn very often?
9. I would like to have a backyard putting green. What kind of grass is used?

Mowing the Lawn

1. What is the best mowing height for lawns?
2. My neighbor mows their lawn 2 or 3 times a week. I mow only on Saturday morning. Who is right?
3. Should I mow higher or lower during the summer?
4. Will I have less turf disease if I mow my lawn shorter in the fall, just before winter?

5. Shouldn't grass clippings be collected because they create thatch in lawns?

6. My lawn gets a brownish cast after I mow. What is the problem?

7. I see wheel marks in my lawn after it is mowed. What causes this to happen?

8. How should I mow my lawn when it gets very tall?

9. Do I have to buy a mulching mower to return my grass clippings?

10. What is the best mower? Rotary or reel?

11. Can I compost my grass clippings, or use them as mulch, in my gardens?

Lawn Fertilization

1. What is the best fertilizer for my lawn?

2. How often should I fertilize my lawn?

3. How important is it to use a "complete" lawn fertilizer?

4. Is liquid lawn care better (or worse?) than dry/granular lawn care?

5. How do I know if I am applying the correct amount of fertilizer to my lawn?

6. Should I "winterize" my lawn? What does that mean, and what does it do for my lawn?

7. Is it OK to fertilize after aerifying my lawn?

8. Isn't organic fertilizer better for my lawn than synthetic fertilizer?

9. Will I have to fertilize more or less if I leave my grass clippings on the lawn?

10. Should the fertilizer that I use have iron in it?

11. Should sulfur be used to lower a lawn's pH?

Lawn Irrigation

1. Doesn't Kentucky bluegrass need more water than all other lawn grasses?
2. For how long should I run my sprinkler system?
3. Is it OK to water my lawn every 3-5 days, even though my neighbors water their lawns every day?
4. Is it bad to water my lawn every day?
5. Will I get "fungus" if I water at night?
6. At what time of the day is it best to water my lawn?
7. Should I water my lawn in the winter?
8. I have brown spots in my lawn, even though I water every other day. What is causing these dry spots?
9. My new tall fescue lawn (which is supposed to save water) seems to need as much water as my old bluegrass lawn. What is the problem?
10. How should I water my newly seeded/sodded lawn?
11. Should I water my lawn after I fertilize it?
12. Should I ever water my buffalograss lawn?

Thatch and Compaction Management

1. What is thatch?
2. Why do my neighbors' lawns NEVER seem to get thatchy, while mine always seems to be that way?
3. Can I topdress my lawn to get rid of thatch?
4. Do power rakes (dethatchers) work well?
5. Are there any liquid or granular "dethatching" products that work? How about ones which claim to relieve soil compaction?
6. What are some symptoms of soil compaction in a lawn?
7. What is the best time of the year to aerate a lawn?
8. How many times per year should a lawn be aerified?
9. How deep should the aeration core holes be?
10. What should I do with all of those plugs that the aerifier pulls out?
11. Should I topdress the lawn with something to fill in the aerification holes?
12. Does wearing golf spikes aerify my lawn? What about "lawn aeration sandals"?

Lawn Establishment and Renovation

1. Is it better to seed or sod a new lawn?
2. What time of the year can lawns be sodded?
3. When is the best time to seed a lawn?
4. Does soil really need to be tilled before planting a new lawn?
5. Should I bring in topsoil before I plant my new lawn?
6. Before planting my new lawn, how much sand should I add to my soil to loosen it up and improve its drainage?
7. How important is it to amend soil before planting a lawn?
8. What is the best soil amendment?
9. Is hydroseeding a good way to start a lawn?
10. Is "plugging" a good way to start a buffalograss lawn? How does it work?
11. Does "overseeding" help a lawn in any way?
12. When is the best time to overseed a lawn?
13. Is there a way to start a new lawn without going through the process of removing old sod and tilling the soil?

14. How does lawn renovation differ from starting a new lawn from scratch?

Weed Management in Lawns

1. Where do lawn weeds come from? How do they get into a lawn?
2. How do I get rid of the crabgrass in my lawn?
3. Is it important to identify lawn weeds before spraying them with a herbicide? Why?
4. I used a preemergence herbicide this spring and I still have weeds. What went wrong?
5. Can I aerify or dethatch my lawn after I apply my preemergence herbicide?
6. What is the best way to get rid of dandelions? Can I use a preemergence herbicide for dandelions?
7. Is it OK to pull weeds?
8. Do "weed-and-feed" products work well?
9. Are there any "organic" or "natural" weed control products that work?
10. What is the best way to control weeds in my newly seeded lawn?
11. Weeds have come up in the "seams" in my new lawn. Should the sod company replace the sod?
12. What is the best time of the year to spray for weeds?
13. What is the best herbicide to spray for dandelions and other broadleaf weeds?
14. Is it better to spray the entire lawn, or just spot-treat individual weeds? Won't I miss some weeds if I spot-treat?
15. Is it OK to spray lawn weeds growing under my trees? Will the trees be OK?

Miscellaneous Lawn Questions

1. How do I take care of "dog spots" in my lawn?
2. I have high and low spots in my lawn. How can I level them out?
3. Will my lawn care companies mowers and aerifiers bring diseases into my lawn from other lawns?
4. When should I do soil testing on my lawn?
5. If I want to expand my garden areas, what is the best way to kill off areas of my lawn?
6. Is it OK to flood a part of my lawn to make a skating/hockey rink for my children?
7. Can I empty the water from my swimming pool onto my lawn without killing the grass?
8. How long can grass seed last if I don't use all of it?
9. What kind of grass do I have growing in my lawn? How can I find out?
10. My lawn is "lumpy", but my neighbor's is not. What causes the lumps, and why do I have them?

Plant Health Care and the Diagnostic Process

1. Define IPM and PHC.
2. Describe concepts central to PHC?
3. Give examples of common PHC tools used in home lawn care.
4. What is the PIC cycle? What does it explain about lawn problems?
5. In diagnosing *contributing* disorders, why is it important to also identify the *predisposing* and *inciting* factors to the extent possible?
6. List the four steps in the diagnostic process.
7. Give examples of BIOTIC (living) factors that cause turf problems.
8. Give examples of non-living (abiotic) factors that cause lawn problems.
9. Why is it important to correctly identify the turf species in a lawn that is having problems?

10. Define *symptom* and *sign*. Give examples of each.

11. Explain why it is important to understand what is normal versus abnormal when dealing with lawn problems?

12. Why is it important to know the AGE of a lawn as part of the diagnostic process?

13. Why is it important to "start from scratch" with every diagnostic situation?

<u>Diagnosing Abiotic Lawn Disorders</u>

1. Explain how knowing the context of the situation helps in diagnosing the disorder.

2. Explain how painting a mental picture of a lawn problem helps in diagnosing a disorder.

3. Explain how repeating back the details in your own words helps in diagnosing a disorder.

4. Explain how to tactfully change directions with a client when the evidence for the cause of a lawn problem leads down another road.

5. Why is it important to discuss management options ONLY after the problems have been diagnosed?

6. In the landscape setting, what is the universal limiting factor for root growth?

7. What percentage of lawn problems are related to root/soil/water issues?

8. Describe techniques to evaluate soil/root disorders and soil compaction.

9. Why is it important to know if a client uses a professional lawn care company, or is a do-it-yourselfer?

10. Why is it important to look at the ENTIRE landscape (trees, flowers) when diagnosing a lawn problem?

11. Why look to see if the problem is occurring in the back yard/front yard as well – or in neighboring lawns? What can that tell you?

12. What kind of tests can be done to determine whether or not chemical injury has occurred on a lawn?

<u>Diagnosing Biotic Pest Problems on Lawns</u>

1. List the four steps in the diagnostic process.

2. What is the "disease triangle" and how does it apply to diagnosing lawn disease problems?

3. What percentage of summer lawn problems in Colorado are related to irrigation amount/frequency, or other aspects of lawn irrigation?

4. If a client tells you that they get the SAME problem every year, in the same part of the lawn, what are some potential causes of the lawn problem?

5. What is the proper way to obtain a sample of turf for diagnostic purposes? How should it be stored and transported?

6. What do you tell a client who believes that "fungus" has been tracked onto their lawn by a lawn care company's mowing or aeration equipment?

MASTER GARDENER
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CMG GardenNotes #551

Basic Turf Management

Outline:

Reasons for Lawn Problems…

Although there are many specific reasons to which one could attribute lawn problems, the most common general reasons include:

- Poor management decisions (soil compaction, improper mowing, irrigation, fertilization, pest management)
- Using poorly adapted species or cultivars. Limitations in resources (water, time/labor, dollars)

Mowing

The two most important facets of mowing are mowing **height** and **frequency**. The **preferred height** for all species in a lawn is two and half to three inches. Mowing to less than two inches can result in decreased drought and heat tolerance (due to shallow rooting and reduced photosynthesis) and encouraged weed invasion. Higher encourages insects, diseases, and weeds. Mow the lawn at the same height all year. There is no reason to mow the turf shorter in late summer or in the fall.

Mow the turf often enough so no more than one-third of the grass height is removed at any single mowing. This may mean mowing a bluegrass or fescue lawn every three to four days during the active spring growth period, but only once every seven to 10 days at other times of the year when growth is slowed by heat, drought or cold. If weather or another factor prevents mowing at the proper time, raise the height of the mower temporarily to avoid cutting too much at one time. Cut the grass again a few days later at the normal mowing height. [Figure 1]

Figure 1. Mow often enough that no more than 1/3 of the grass height is removed in any single mowing.

Let **grass clippings** fall back onto the lawn while mowing, unless they are to be used for mulching elsewhere in the landscape. Grass clippings decompose quickly and provide a source of recycled nutrients (equivalent to 1 to 1½ fertilizations per year) and organic matter for the lawn. Although a mulching or recycling mower makes this easier to do, clippings can be recycled into the lawn using any mower (as long as the 1/3 rule of mowing frequency is used). Grass clippings do not contribute to thatch accumulation.

Lawn Clippings and Surface Water Pollution

Lawn clippings and leaves mowed, swept, or blown onto the street are the major source of phosphorus pollution in urban lakes and streams. With side discharge lawnmowers, mow in a direction to prevent clippings from being blown onto the street, driveway, and other hard surfaces. Do not sweep or blow lawn clippings into the gutter and street. [Figures 2 and 3]

Figure 2. In a Minnesota study, 60 to 80% of the phosphate loading of surface water in an urban setting came from lawn clippings and leaves that were mowed or blown into the streets.

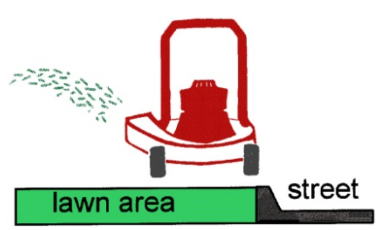

Figure 3. When mowing the lawn, mow in a direction to prevent clippings from being blown into the street.

Also, leave an unmowed grass buffer strip edging any lakes, streams, ponds, and wetlands. [Figure 4]

Figure 4. To reduce surface water pollution, leave an unmowed buffer strip around lakes, streams and ponds.

In a natural setting, rain and snowmelt absorbs mostly into the soil. Air-borne pollutants and pollen washed out of the air are broken down by soil microorganism activity. The nitrogen and phosphorus released from the decay of grass, leaves, and other organic matter recycle back into the soil.

However, in the landscape setting, the water cycle is greatly changed by large areas covered by hard surfaces (streets, driveways, walks, parking lots, compacted soils, and buildings). In a typical landscape setting 55% of a rainfall moves as surface runoff, compared to only 10% in a naturalized setting. Nutrients from grass and leaves (along with fertilizers, pesticides, and other water-soluble pollutants) readily wash off the hard surfaces into the storm sewer system. Here the pollutants end up in local streams, ponds, and lakes.

Fertilization

Selecting a Lawn Fertilizer

Nitrogen (N) is the most important nutrient for promoting good turf color and growth. However, do not over-stimulate the turf with excess nitrogen, especially during the spring and summer. Over-fertilization can contribute to thatch buildup with some species, as well as increased mowing and irrigation requirements. Under-fertilization of some species (bluegrass and ryegrass, for example) can result in poor turf color and turf thinning, which can encourage weed and disease problems. Turf species differ in both the amount of nitrogen required to keep them healthy, as well as the best time of the year to fertilize them.

Balanced or complete fertilizers contain various amounts of phosphorus, potassium, iron, and sulfur. They are a good safeguard against a potential nutrient deficiency and there is no harm in using a “complete” fertilizer. However, if you leave clippings on the lawn, these nutrients are recycled back into the lawn, so there is little likelihood of seeing these deficiencies. Besides nitrogen, the most commonly deficient nutrient in lawns is iron (Fe).

Organic fertilizers will work as effectively as synthetic types. However, it is important to understand the release characteristics of the different fertilizers so that they can be used at the correct times of the year. Organic fertilizers typically release nutrients more effectively when soils are warm and moist. Many synthetic types work well when soils are cooler, but some synthetic types work like the natural organic sources.

Better lawn fertilizers include a quick release form of nitrogen for quick green-up, plus slow-release forms of nitrogen for sustained greening. Examples are listed in Table 1.

Table 1. Example of Quick and Slow Release Fertilizers

Quick-Release Nitrogen for fast green-up	Slow-Release Nitrogen for sustained green
Ammonium sulfate	Resin-coated urea
Ammonium nitrate	Sulfur-coated urea
Potassium nitrate	Isobutylidene diurea (IBDU)
Urea	Methylene urea
	Urea formaldehyde
	Compost and manure
	Poultry waste
	Poultry feathers

When to Fertilize and How Much to Apply

The natural grass growth cycle influences proper fertilization time for lawns. Figure 5 illustrates typical root and shoot growth patterns of cool season turfgrass species. [Figure 5]

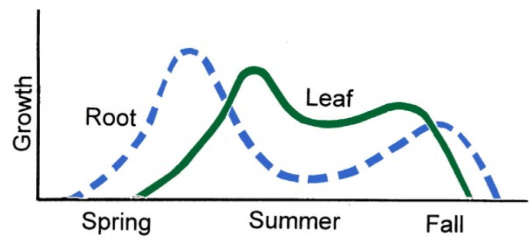

Figure 5. Growth cycle of roots and shoots for cool season turf.

Figure 6 on the right illustrates the influence on shoot growth when nitrogen fertilizer is applied. Heavy spring fertilization promotes shoot growth, reducing carbohydrate energy reserves and stress tolerance. [Figure 6]

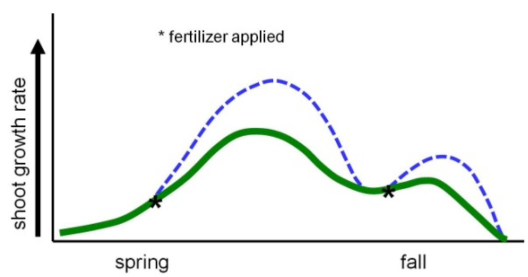

Figure 6. Influence on shoot growth for nitrogen fertilization.

Benefits of Fall Fertilization on Cool Season Home Lawns

- Enhances storage of carbohydrate energy reserves
- Strengthens root system
- Increases shoot density
- Increases stress tolerance
- Better fall and winter color
- Earlier green-up in spring

Timing and Application Rate

Timing and application rates are given in Table 2. If lawn clippings are returned to the lawn, reduce application rate by ¼ to 1/3.

Table 2. Fertilizer Application Schedule for Established Colorado Lawns[1, 2]

Turfgrass species		Mid-March to April[3]	May to mid-June	July to early August	Mid-August to mid-September	Early October to early November[4]
(Nitrogen application rates are in pounds of nitrogen per 1,000 square feet of lawn area.)						
Cool Season Species	High maintenance Bluegrass and Ryegrass	½ to 1	1	Not required	1	1-(2)
	Low Maintenance Bluegrass	½	½-1	Not required	1	(1)
	Turf-Type Tall Fescue	½	½-1	Not required	1	(1)
	Turf-Type Fine Fescue	½	½-1	Not required	½-1	Not required
Warm Season Species	Buffalograss, Blue Grams, and Bermudagrass	Apply no N	½-1	½-1	Apply no N	Apply no N

1 Nitrogen applications can often be reduced by 1/4/ to 1/3 when grass clipping are returned to the lawn during mowing. Nitrogen and other nutrients contained in the clippings are recycled to the lawn as they decompose. **Grass clippings do not contribute to thatch accumulations in lawns.**

2 On sandy soils, use slow-release nitrogen fertilizers (sulfur-coated ureas, IBDU, and natural orgainic-based fertilizers) throughout the year to reduce the potential for leaching loss. On very sandy soils, do not fertilizer turf after late September. Nitrogen can leach into ground water during the winter months.

3 The March-April nitrogen application may not be needed if fertilized in late fall (September to November) the previous years. If spring green-up and growth is satisfactory, delay fertilizing until May or June.

4 Make the final fall nitrogen application (October-November) while the grass is still green and at least two to three weeks before the ground begins to freeze. Optional N applications shown in (). Use extra nitrogen applications where a higher quality turf is desired or on a heavily used turf.

Fertilizers and Water Pollution

Home lawn management techniques play a significant role in protecting or polluting surface water. Popular press has incorrectly labeled lawns as a major contributor to water pollution. It is not the lawn, but rather the management style of the gardener that become the problem.

Fertilizers and pesticides (herbicides, insecticides, and fungicides) spread onto hard surfaces (driveways, sidewalks, streets, and compacted soils) will move with surface water into neighboring lakes, streams, and ponds. (Surface water running down the street gutter is not treated before release into local lakes, streams, and ponds.)

However, phosphate fertilizer applied to a lawn or garden soil is bound to the soil and does NOT leach into ground water. The phosphate could move into surface water with soil erosion.

Organic fertilizers are not necessarily safer for the environment. The pollution potential is based on where the fertilizer is applied and application rates. Any fertilizer becomes a potential pollution problem when over-spread into hard surfaces. Over application of both manufacture and organic fertilizers have been linked to ground water contamination.

Potential pollution problems arise from the careless application rather than the type of fertilizer applied. In most Western soils, lawns do not need phosphate fertilizers.

Irrigation

Many factors influence lawn water requirements, and no two lawns will have exactly the same needs. Table 3 gives the typical water requirement (rain plus irrigation) per week. A healthy, high-quality bluegrass or ryegrass lawn may require up to 2 to 2.25 inches of water per week under hot, dry, windy summer conditions; but may require much less when the weather is cool or cloudy. Turf-type tall fescue may perform well with less irrigation than a bluegrass lawn, if it can grow a deep root system and the soil in which it is growing is holding usable water. In many cases, however, a tall fescue may require as much water as bluegrass to look good. [Table 1]

Table 3.
Typical Water Requirement (Rain Plus Irrigation) for Colorado Lawns

	Late April	May & June	July & August	September	Early October
Inches of water per week (irrigation plus rain)	0.75”	1.0”	1.5”	1.0”	0.75”

Buffalograss and blue grama lawns can remain green for weeks without watering, even during the hottest summer weather, with rainfall.

Shady lawns (not in the rooting zone of large trees) and areas protected from the wind require less water over the growing season than more exposed turf. However, the roots of mature trees and shrubs also need water. You may have to water more in mature landscapes where the roots of many plants compete for water. Healthy turf encouraged by proper mowing, fertilizing, and cultivation, uses water more efficiently.

How Much Water?

Each time you water the lawn, apply enough water to moisten as much of the root zone as possible. Use a soil probe or shovel to determine what the average rooting depth is in your lawn. If the roots grow down 6 inches deep, water so the soil is moistened to that depth. It is important to know not only how deep the turf roots grow, but also how deep your irrigation water penetrates. Watering too deeply, especially on sandy soils, wastes water and allows it to percolate past the root zone. [Figure 7]

Figure 7. Typical water (rain plus irrigation) is given in Table 5. However, actual water use jumps around from day to day based on temperature, wind, humidity, and solar radiation (sunny or cloudy).

How Often Should a Lawn be Watered?

Grass growing on a sandy soil must be watered more often than the same grass growing on clay or loam soils. Even after a thorough watering, sandy soils hold little plant-available moisture. They require more frequent irrigation with smaller amounts of water.

Conversely, turf growing on clayey soils can be irrigated less frequently, with larger quantities of water. Watering less often means more efficient water use because of less loss to evaporation. It can also reduce the number of weeds that appear in the lawn. With most soils, do not apply all of the water in a short period of time. If applied too quickly, water will run off of thatchy turf, from sloped areas, or from turf growing on heavy clay or compacted soils. In these cases, it is more effective to apply only a portion of the water and move the sprinkler or switch to another station to water another section of the lawn. Cycling through irrigation stations (“soak cycles”) will promote infiltration and reduce runoff and puddling in low spots. This allows water to soak into the soil rather than run off.

Core cultivation (aeration) can resolve some infiltration problems by reducing thatch and compaction. Wetting agents may enhance water movement into the soil, but they should not be considered a cure-all, especially when compaction and thatch are problems.

What are Some Signs that Turf Needs to be Watered?

A sure sign that turf requires irrigation is a wilted appearance. One symptom is “footprinting,” where footprints on the lawn that do not disappear within an hour or so following traffic. This symptom is soon followed by actual wilting, where the turf takes on a grayish or purple-to-blue cast. If only a few such spots regularly appear in the same general location, spot water them to delay watering the entire lawn for another day or so. These indicator spots help predict that the entire lawn will soon need watering.

A hardened or toughened lawn, attained through less frequent, deep irrigation, often withstands minor drought and generally has fewer disease problems. It is important, however, that the turf not be allowed to become overly drought-stressed between waterings. This weakens the turf and makes it more susceptible to insect and disease damage and to weed invasion.

During extended dry periods from late fall to spring, it may be necessary to "**winter water**" every four to six weeks if the ground is thawed and will accept water. Pay particular attention to exposed slopes, sites with shallow soil, and south- or west-facing exposures, where winter mites may infest and kill drought-stressed turf during the winter and early spring.

The most efficient **time of day** to water is late evening and early morning (between 9 p.m. and 9 a,m.). It generally is less windy, cooler, and more humid at this time, resulting in less evaporation and more efficient use of water. Water pressure is generally better, optimizing sprinkler distribution patterns. Contrary to popular belief, watering at night (after 9 p.m.) does not encourage disease development in turf.

Thatch

Thatch is a tight, brown, spongy, organic layer of both living and dead grass roots and stems that accumulates above the soil surface. Factors that lead to thatch problems include the following: [Figure 8]

- **Sod over compacted soil** – When sod is laid over compacted soils, a thatch problem will develop in a couple of years.
- **Soil compaction** is a common contributor to thatch build-up as it slows the activity of soil microorganisms.
- **Over fertilization** is a common contributor to thatch build-up as the lawn may be growing faster than the microorganism can break it down.
- **Grass species** – Thatch tends to be a problem on Kentucky bluegrass, bentgrass, and fine fescue lawns. It is rarely a problem with tall fescue or buffalograss.
- **Frequent heavy irrigation** may contribute to thatch as lower soil oxygen levels slow the activity of soil microorganisms.
- **Pesticides** – Excessive use of some pesticides may also slow soil organism activity.

Figure 8. Thatch is a tight, brown, spongy, organic layer of both living and dead grass roots and stems that accumulates above the soil surface.

Grass clippings do not contribute to thatch accumulation and should be returned to the lawn during mowing to recycle the nutrients they contain.

Measure thatch depth by removing a small piece of turf, including the underlying soil. Up to ½ or ¾ inch of thatch is acceptable and will enhance traffic tolerance. The thatch depth can increase quickly beyond this point, making it difficult to control later. As the thatch layer thickens, it becomes the main rooting medium for the grass. This predisposes the turf to drought stress or winterkill and increases the possibility for insect, disease and weed problems. In addition, fertilizers and pesticides applied to a thatchy lawn work less effectively.

Power Raking for Thatch Management

This method of thatch removal has been used for years. Light (shallow) power raking may be beneficial if done often. Deep power raking of a thatch lawn can be damaging, and often removes a substantial portion of the living turf. Used properly, power raking of wet, matted turf can speed spring green up by letting air move into the root zone and warm the turf. Compost all removed thatch and organic material to kill any living grass before it is used as a mulch or soil amendment.

Core Cultivation or Aerating.

This can be more beneficial than power raking. It helps improve root zone conditions by relieving soil compaction, while controlling thatch accumulation. Soil compaction, in fact, is one factor that contributes to thatch buildup. Aeration removes plugs of thatch and soil two to three inches long (the longer, the better) and deposits them on the lawn. Enough passes should be made to achieve two-inch spacing between holes.

What is done with the cores is a matter of personal choice. From a cultural perspective, there may be an advantage to allowing the cores to disintegrate and filter back down into the lawn. Mingling soil and thatch may hasten the natural decomposition of the thatch. The little fluffs of thatch and turf that remain behind can be collected and composted. Depending on soil type, core disintegration may take a few days to several weeks. Irrigation helps wash the soil from the cores. Running over dried cores with a rotary mower can be effective but will dull the blade. If the cores are removed from the lawn, compost before using as a mulch or soil amendment.

Soil Compaction

Soil compaction is the most common problem in lawn quality. With reduced soil oxygen levels, rooting systems will be more shallow. With compaction, the grass roots have reduced access to water and nutrients. Irrigation and fertilization will need to be light and more frequent.

Aerating (removing plugs) once or twice a year will help reduce soil compaction in an established lawn area <u>if enough passes are made to yield plugholes at two-inch intervals</u>. The best time of year to aerate a lawn is late August to late September, as fewer weed seeds germinate this time of year. Aerating the lawn area around a tree is also the best method to promote tree vigor. [Figure 9]

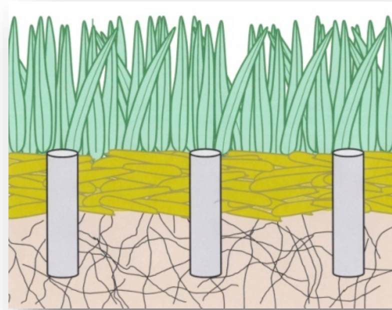

Figure 9. Core aeration helps reduce soil compaction when enough passes are made over the lawn to yield plugholes at two-inch intervals.

Weed Management

Lawn weed killers provide only temporary control if management factors that favor weeds are not addressed. In a thin turf with heavy traffic, weed problems may intensify following the use of weed killers. When the weeds (which help absorb the wear and tear of foot traffic) are removed with weed killers, the lawn may thin. The thin lawn opens the soil to increased weed problems.

Soil compaction is the primary cause of weed problems. Weed management factors include the following.

Core aeration – Soil compaction favors weeds and discourages lawn growth. Common lawn weeds including annual bluegrass, black medic, chickweed, clover, crabgrass, knotweed, prostrate spurge, and plantain thrive in compacted soils. Clover may be a good companion crop for lawns in compacted soils, filling in between the thin grass.

Mowing – High mowing height (shading) and frequent cutting discourages weeds.

Watering – Deep, infrequent watering will drought out many common shallow rooted lawn weeds. [Figure 10]

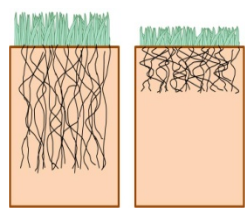

Figure 10. Deep infrequent watering will drought out many common shallow root lawn weeds.

Limited fertilizer – A thick, actively growing turf chokes out most weeds. However, fertilizer will not thicken up a turf when soil compaction is the growth-limiting factor.

For additional information on turf weed management, refer to these CSU Extension Publications available online at www.cmg.colostate.edu.

- ***Annual Grassy Weed Control in Lawns***, Extension Fact Sheet #3.101

Insect and Disease Management

In semi-arid climates like Colorado, turf insect and disease problems are minimal, compared to other areas of the nation.

Frequent use of lawn insecticides may increase the occurrence of lawn insect problems. Some garden insecticides have a potential to kill birds feeding in the treated areas (refer to the insecticide label). Thus, avoid unwarranted treatments of lawn areas.

When controlling soil insects, the insecticide must be watered into the root zone to be effective. Some insecticides get heldup in the thatch and do not water in effectively.

In semi-arid climates like Colorado, lawn diseases are minimal, compared to other areas of the nation. With Colorado's dry climate, fungicides do little to nothing for home lawn disease management. Cultural practices (fertilizer, watering, and soil compaction) are the keys to disease management. [Table 3]

Table 3. Influence of Cultural Practices on Kentucky Bluegrass Diseases

	Soil Compaction	High N	Low N	Thatch	Irrigation	Mowing
Asochyta Leaf Blight	yes	yes		yes	timing	yes
Necrotic Ring Spot	yes	yes		yes	drought with heat	yes
Leafspot and Melting Out	yes	yes	yes	yes	timing (wet/dry cycle)	yes
Gray Snow Mold	yes	yes				
Dollarspot	yes		yes	yes	drought	low
Stripped Smut			yes	yes		
Fairy Ring	yes		yes	yes		

Authors: Tony Koski, PhD, Extension Turf Specialist, and David Whiting, Extension Consumer Horticulture Specialist (retired); Department of Horticulture & LA; Colorado State University. Artwork by David Whiting and Tony Koski; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #552

Broadleaf Weed Control in Lawns

Dandelion, clover, plantain and other broadleaf weeds are among the most common and troublesome turf pest problems in lawns. Even though most broadleaf weeds can be easily controlled with herbicides, a completely weed-free lawn is neither practical nor environmentally sensible. A safe and sound approach to lawn weed control is to grow a healthy lawn, spot-treat weeds with the correct weed control product as they appear, and avoid the temptation to have a 100% weed-free lawn.

The best way to minimize weed problems in your lawn is through the use of good cultural practices: proper mowing height and frequency, sensible fertilization, and adequate irrigation. On the other hand, lawn weeds are encouraged by: mowing your lawn too short or not often enough; fertilizing too much, not enough, or at the wrong time of the year; and over- or under-watering.

Where Do Lawn Weeds Come From?

- Seeds of broadleaf weeds occur naturally in all soils, and can persist for 30 or more years. They will germinate when a lawn is thin and not healthy, when the seeds are brought to the surface by human or pet traffic, or when the turf is damaged or killed by drought, heavy traffic, insect feeding, or disease activity.

- Cheap, low-quality grass seed often contain unwanted weed seed. If the seed label lists ANY weed seed as a component, DON'T buy it! The best quality grass seed (sold by professional seed suppliers) will almost always be 100% weed-free, and will often cost nearly the same as poor quality products which contains weed seed. READ THE SEED LABEL! The Weed Content of any grass seed you buy (expressed as a %) should be 0%.

- Weed seeds are often brought to a landscape in topsoil or low quality compost. Make sure that all soil or compost comes from a reputable supplier and is guaranteed to be weed-free.

Using Herbicides to Manage Lawn Weeds

The most common herbicide choice is a general- purpose mixture comprised of two or three of the following individual herbicides or active ingredients: 2,4-D; MCPP (mecoprop); and dicamba (Banvel). Multiple active ingredients will control a wider spectrum of broadleaf weeds, than a single active ingredient. Read and follow all directions on the herbicide label if you choose to apply a herbicide to your lawn.

The best time to apply a general-purpose broadleaf herbicide for the control of perennial broadleaf weeds such as dandelion, plantain, and clover is early-September to early November. As winter approaches, perennial broadleaf weeds are storing energy reserves in stems and roots; a fall-applied herbicide will enter the plant and travel to these plant parts with the food reserves. The second best time is in the late spring or early summer period after the weeds have flowered. If applying in the late spring, be extremely cautious with these herbicides near ornamentals, trees, flowers, and vegetable gardens because these plants can be damaged by these herbicides through direct application, drift, and/or volatilization (the herbicide turns into a vapor). This is another reason why we prefer to apply these herbicides in the fall.

- If you only have a few weeds in your lawn, simply spot-apply a herbicide rather than applying to the entire lawn. Apply just enough to wet the leaf and do not apply to the point that the herbicide is dripping off the leaf.
- Apply to actively growing, preferably young weeds.
- Do not apply herbicides when the soil moisture is low and weeds are drought-stressed; an actively growing, healthy, non-stressed weed is the easiest one to control.
- Apply herbicides on a calm, clear day when the air temperature is between 50 and 85F; applying when temperatures exceed 90^{o} F increases the potential for volatilization injury to other plants in the landscape.
- Don't apply if rainfall will occur within 12 hours; avoid applying irrigation for at least 12 hours following a herbicide application.
- Don't mow the lawn for 2 days before and after the herbicide application.
- Do not apply to new turfgrass seedlings until the grass has been mowed at least three times.
- Delay applying a broadleaf herbicide to new sod for 4 to 5 weeks after planting.

Summer Broadleaf Weed Management

Summer annual broadleaf weeds (e.g., spurge, knotweed, purslane, etc.) are very difficult to control for a number of reasons. Depending on the species, these weeds germinate at different times during the summer and mature in a very short period of time. Thus, a single application of herbicide might only control a single weed species because other species have not germinated or have grown too large to be controlled. Summer annual weeds often have a thick, waxy cuticle layer on their leaf surface to prevent water loss; this layer may also make it more difficult to get herbicide into the weed.

Some annual broadleaf weeds can be effectively controlled by preemergence herbicides. For example, summer annuals like spurge, knotweed, purslane and puncturevine can be controlled with products containing prodiamine, pendimethalin or isoxaben.

Difficult-to-Control Weeds

Weeds such as bindweed, thistles, and wild violets are difficult to control because they spread by underground stems. Multiple herbicide applications may be necessary to completely control difficult perennial weeds, including dandelions. Post-emergence broadleaf herbicides containing 2,4-D, MCPP, dicamba, triclopyr or sulfentrazone should be used.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
- Colorado Master Gardener *GardenNotes* are available on-line at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.
- No endorsement of products mentioned is intended nor is criticism implied of products not mentioned.
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December 2010

CMG GardenNotes #553

Dog Urine Damage on Lawns:

Causes, Cures and Prevention

Urban Legends About Urine Damage

Dog urine damage is a common problem for home lawns, and one that has generated numerous home remedies and commercial products claiming to be cures for the spots. This lawn problem is misunderstood when it comes to causes and cures. Dog spotting on turfgrass is caused by the deposition of a high concentration of nitrogen (N)-containing compounds and associated salts on a small area in the lawn. These deposits are often concentrated in a relatively small portion of the lawn, resulting in turf injury or death. Some common "urban legends" surrounding dog urine damage to lawns are:

- **Only female dogs cause spotting in lawns.**

FALSE. Dog spotting in lawns is most often caused by dogs that squat when they urinate, thus depositing a large volume of concentrated urine in a small area. Most "squatters" are female dogs, but some males do this as well, especially in their own yard. Many male dogs tend to "mark" vertical objects in the landscape (trees, posts, etc.), which presents problems for landscape plants.

- **Dog spots are more common with certain breeds of dogs.**

MOSTLY FALSE. Dog spotting is more likely to occur (or be more obvious) with larger dogs, since they produce larger amounts of urine. Dog spots can occur with smaller breeds, especially if the dog tends to urinate in a limited area of the lawn.

- **Dog spots occur because urine is alkaline (has a pH above 7.0).**

  FALSE. Dog spots occur because a high concentration of N and salts has been deposited in a very small area of the lawn. In some cases, the added N causes dark green spots and rapid grass growth, without injuring the grass. In other cases, the result is a brown spot – often surrounded by a halo of dark green grass. The browning is caused by the concentrated nitrogen deposited in the center, which burns the leaf tissue, and may or may not cause tissue death. The lower concentration of salts on the periphery fertilizes the grass – resulting in a darker green ring.

- **Dog spots can be prevented by using food supplements that acidify a dog's urine.**

  FALSE. Dog spots do not occur because a dog's urine is alkaline. Products advertised to "naturally" reduce urine alkalinity (including the amino acid, dl methionine, also known as methioform) may cause urinary system problems and can affect calcium deposition in growing bones of younger dogs. The addition of baking soda, potassium citrate and other salts are likewise not recommended as curatives for dog spots. A veterinarian should always be contacted before giving a dog a food supplement known to affect urine pH. There are medically sound reasons for altering urine pH, but the prevention of dog spots in lawns is not one of them. *There are no dietary supplements that have been scientifically proven to reduce either the incidence or severity of dog spotting in lawns.*

- **Dog spots can be "cured" by sprinkling the affected area with baking soda, gypsum, dishwashing detergent, etc. to neutralize the urine.**

  FALSE. The only "product" that can neutralize the urine's negative effects is water. Gypsum and baking soda (sodium bicarbonate) are salts and may compound the problem. Dishwashing detergents, which act as wetting agents or surfactants, may enhance water movement into and through the soil. While this theoretically could promote leaching and dilution of accumulated salts, some dishwashing detergents can burn grass plants.

Dealing with Dog Spots

<u>What can be done with the dog(s)?</u>

- Train the dog to use a non-turf area in the landscape, such as an area covered with mulch or gravel, or select a location where dog spotting will not become an aesthetic problem and damage can be tolerated. <u>*This is the ONLY sure solution for the problem!*</u>

- Always provide adequate water for your pet; increased water consumption will dilute urine, reducing the potential for turf injury.

- While the addition of salt, garlic, tomato juice and other "home remedies" to your pet's food can increase water consumption (thus diluting their urine), your veterinarian should always be consulted before doing so. The increased salt intake can cause problems for older dogs, as well as for those with heart or kidney conditions.

- Except for the addition of water to a dog's food, no additive or supplement should be fed to your pet without first consulting with your veterinarian. Certain additives may increase a dog's water intake, but can have detrimental and unintended consequences for its health.

<u>If the affected spots are green and grass growth is stimulated (no browning is apparent):</u>

1. Increase nitrogen fertilization frequency and/or the amount of fertilizer to help mask the urine-induced stimulation of growth and color; dark green spots will be especially visible on lawns that are not receiving adequate nitrogen fertilization.

2. Maintain adequate irrigation to prevent accumulation of salts in the soil; drought or lack of water can allow salts to accumulate and injure or kill turf.

<u>If the affected spots are brown, (the turf may or may not be dead):</u>

1. Increase irrigation amount and/or frequency to help dilute salts that have accumulated in the soil. This may help still-living turf recover, and will dilute salts in those areas where the turf has been killed (allowing for more effective re-seeding).

2. When turf has been killed, the dead sod and some soil (0.5-1 inch of soil) can be removed. Re-sod the area with new grass.

3. Individual dead/damaged spots can be re-seeded as follows:

    - In a **<u>Kentucky bluegrass lawn:</u>** Spot seed with Kentucky bluegrass (marginally effective) or perennial ryegrass (more effective). Tall fescue, K31 tall fescue, "dwarf" fescue, or annual (Italian) ryegrass should NOT be used for spot-seeding a bluegrass lawn.

    - In a **<u>tall fescue lawn:</u>** Spot seed with turf-type tall fescue (sometimes called "dwarf" fescue). Perennial ryegrass can also be used, but it has a finer texture and the newly seeded spots will look different from the rest of the lawn. Do NOT use K31 fescue or annual (Italian) ryegrass for spot-seeding a tall fescue lawn.

    - **<u>Fine fescue lawns:</u>** Seed with fine fescue seed. The use of perennial ryegrass or tall fescue is NOT recommended, as the spots will have a different color, texture, and growth rate.

    - **<u>Zoysiagrass and bermudagrass lawns:</u>** Patch using sod from a sod farm, or by transplanting sod from an inconspicuous area of same the lawn.

Consult your veterinarian before supplementing a pet's diet with any product or food additive claiming to reduce dog spots in lawns. Similarly, no "spray-on" product for lawns, claiming to prevent or "cure" dog spots, has been scientifically proven to be effective.

Authors: *Alison Stoven O'Connor, Ph.D, CSU Extension Horticulture Agent, Larimer County; and Tony Koski, Ph.D., Extension Turf Specialist;* Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
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Revised October 2014

CMG GardenNotes #554

Earthworms and Nightcrawlers
In The Home Lawn

Earthworms and nightcrawlers can be considered beneficial in lawns because they aid in the decomposition of turfgrass thatch and grass clippings, which helps to recycle nutrients and organic matter into a lawn's soil. The tunneling and burrowing caused by earthworm activity provides a natural cultivation effect which helps oxygen and water to enter the turf root zone more easily.

Earthworms are sometimes regarded as pests because their burrows and ejected waste material, called castings, can cause a lawn surface to become anywhere from slightly to extremely bumpy. The bumpy, uneven surface can be difficult to mow and walk on. Extreme earthworm activity can sometimes cause lawns to become less dense, especially when earthworms are active in shady parts of the landscape.

Several species of earthworms are found in the U.S. The nightcrawler, *Lumbricus terrestris* Linnaeus, and the red earthworm, *Lumbricus rubellus* Hoffmeister, are the most common larger species. Smaller species belong to the genera *Allolobophora* and *Eisenia*. Earthworms are generally found in the top 12" to 18" of the soil because this is where food is most abundant. The worm ingests soil and organic matter that is swallowed and ground in the gizzard. The castings are used to line the burrow or are deposited on the lawn's surface, at the burrow's entrance, which causes the lawn's surface to become bumpy. Earthworm activity is greatest when soil is warm and moist, becoming active when soil thaws in the spring. The worms will move deep into the soil if it becomes dry during the summer.

Pesticide Use and Earthworms

Compared to turf pesticides used during the 1930s to the 1970s, those used on lawns today are unlikely to kill, discourage, or otherwise negatively affect earthworm populations. Applications of insecticides, with the goal of reducing or eliminating earthworm activity, will not affect earthworms and are NOT recommended. When used as recommended, label rates, herbicides and fungicides will not adversely affect earthworms in lawns.

Reducing Earthworm Activity in Lumpy Uneven Lawns

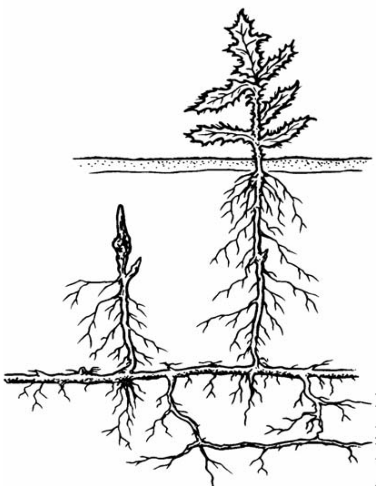
In many lawns earthworm activity can cause the surface to become mildly to excessively lumpy and uneven. Where earthworm populations approach nuisance levels, some measures can be taken to discourage activity or to reduce the impact of earthworm activity on surface smoothness.

- Core cultivation of the lawn and spreading of the plugs throughout the lawn may cause some leveling of a severely bumpy surface.
- The use of heavy rollers to flatten the lawn surface can be effective. However, heavy rolling is likely to cause soil compaction and should be followed by core cultivation.
- Topdressing (spreading a thin layer of soil or other material) the bumpy lawn with soil/sand is not recommended as a way of smoothing the surface. Introducing layers of soil that differs from what is already present in the lawn can cause problems for water and air exchange on the lawn's surface. The creation of layers and interfaces on the lawn's surface can result in poor rooting and can complicate lawn irrigation because water uptake can be seriously reduced by soil layering. Applications of compost, on the other hand, can be useful as a temporary aid for smoothing the lawns surface.
- Earthworms prefer moist soil. Less frequent irrigation, that allows the soil surface to dry out between irrigation events, may reduce surface activity of the earthworms.
- Dethatching mowers, also known as power rakes, can be used to level the earthworm mounds. Adjust the power rake so that the teeth operate low enough to shave off the tops of the worm mounds, but not so low that the crowns and roots of the grass plants are pulled up. It is best to do this early in the spring, before the lawn has begun greening up.
- Applications of sulfur, ammonium sulfate, ammonium chloride, lime, gypsum, or other fertilizers will NOT reduce earthworm activity.
- Lawn care operators may not, by law, apply any pesticide for the purpose of controlling earthworms.
- Employees of Colorado State University may not recommend any pesticide application for the purpose of controlling earthworms in any turf area.

The presence of earthworms in the home lawn is an indicator of a healthy soil environment. Earthworms aid in the breakdown of thatch and other organic matter and create tunnels, which promote water infiltration, oxygen movement, microbial activity, and deeper grass rooting. Rich in nutrients, their castings are a combination of minerals moved from deep in the soil and from their main food sources: grass clippings and thatch. Although the bumpiness caused by earthworm mounds can be annoying, the homeowner should consider the benefits provided to their lawn's health and avoid the temptation to use pesticides to reduce or eliminate earthworm populations in the lawn.

Authors: Tony Koski, Ph.D., CSU Extension Turf Specialist, Department of Horticulture & LA. Reviewed September 2022 by Tony Koski.

Reviewed September 2022



Weed Management

Class Reading / Reference

CMG GardenNotes on Weed Management

- Weed Management, #351
- Weed Identification, #352
- Weed Associations with Specific Environments and Cultural Conditions, #353
- Homework: Weed Management, #354

Learning Objectives

Students will be able to:

- Define what a "weed" is from the perspective of the home landscape
- List the problems that weeds can cause in the home landscape
- Describe why plants become weeds in the home landscape
- Understand the difference between noxious, exotic, native and invasive weeds
- Describe environmental, ecological and cultural/management factors that contribute to landscape weed problems
- Understand why weed identification is important and what resources are available to assist in weed identification
- Describe the different weed life cycles and how that knowledge is vital for developing weed control strategies
- Describe the different landscape settings in which weed problems arise, and how each of those settings each can present a unique set of weed management challenges
- Understand the principles of Integrated Pest Management (IPM) and how to apply those principles to managing specific landscape weed problems
- Describe cultural and management techniques for control of landscape weeds
- Describe the different types of herbicides and how/when each type can most effectively be used as part of a weed management program

Authors: Tony Koski, Ph.D., Irene Shonle, Ph.D., Kurt Jones, and David Whiting, Colorado State University Extension

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Weed Identification and Management Resources

CSU Extension Resources

Extension Fact Sheets

- Control of Annual Grassy Weeds in Lawns, #3.101
- Musk Thistle, #3.102
- Weed Management for Small Rural Acreages, #3.106
- Leafy Spurge, #3.107
- Canada Thistle, #3.108
- Diffuse and Spotted Knapweed, #3.110
- Russian Knapweed, #3.111
- Biology and Management of the Toadflaxes, #3.114
- Cheatgrass and Wildfire, #6.310

CSU Turf web site at www.csuturf.colostate.edu

- Turf fact sheets
- Identification and Management of Perennial Weedy Grasses in Lawns
- Broadleaf Weed Control in Home Lawns

Weed Identification Books

- ***Weeds of the West.*** 2000. T. Whitson. CSU Extension, Publication XCM-147.
- ***Weeds of Colorado***. 1997. R. Zimdahl. CSU Extension, Publication 521A.
  Weeds of California and Other Western States. 2007. DiTomaso, J. M. and E. A. Healy. Univ. Calif. Agric Nat. Res. Publ. 3488.
  Aquatic and Riparian Weeds of the West. 2003. Joseph M. DiTomaso and Evelyn Healy.
- **Color Atlas of Turfgrass Weeds**. 2008. L. B. McCarty, John W. Everest, David W. Hall, and Tim R. Murphy
- ***Weed Control in Turf Grass and Ornamentals***. 2008. A. J. Turgeon, L. B. McCarty, and Nick E. Christians

Online Weed Identification Keys

- North Carolina State University at http://www.turffiles.ncsu.edu/turfid/itemselector.aspx
- U. California Extension at http://www.ipm.ucdavis.edu/PMG/weeds_intro.html
- Michigan State University at http://www.msuturfweeds.net/

Other Weed Management Resources

- **Colorado Natural Areas -** Creating an Integrated Weed Management Plan: A Handbook for Owners and Managers of Lands with Natural Values at http://parks.state.co.us/NaturalResources/CNAP/Publications/

- **Colorado Weed Management Association** (www.cwma.org)

- **Colorado Department of Agriculture, Noxious Weed Program (Noxious Weed Lists and Photos)** http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928159176

- **IPM – Principles of Landscape Weed Management**
  http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7441.html

- **Solarization for Landscape Weed Management**
  - http://vric.ucdavis.edu/pdf/soil_solarization.pdf (a treatise on soil solarization)
  - http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74145.html (solarization for gardens)
  - http://solar.uckac.edu/new_page1.htm (solarization resource website)
  - http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pni7441-tbl4.html (common garden and landscape weeds controlled by solarization)

- **Invasive Plants:** University of California – Definition of Invasive Plants
  http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74139.html

Review Questions

1. What "makes" a plant a weed, and what problems can weeds cause in the home landscape?
2. List/describe a few of the major types of landscape plantings/settings in which weed problems arise and how they might differ in terms of weed management solutions?
3. What are some plant characteristics that allow certain plants to become landscape weed problems?
4. Describe at 4 ways by which weeds may be introduced into the home landscape.
5. Explain what the "seed bank" is and how it factors into weed management decisions.
6. Give an example of a setting/location in YOUR OWN home landscape where weeds almost never occur – and explain why.
7. How do winter annuals and summer annuals differ? How does understanding this difference affect management strategies for each type?
8. For which type of weeds (life cycle, age) and in which landscape situation is the use of citric acid/acetic acid/botanical oil herbicides most effective? Least effective?
9. For which types of weeds (life cycle and age) is cultivation (hoeing) most effective? Least effective?
10. How can water/irrigation management be used to lessen weed problems in the home landscape?
11. How effective is mowing and string-trimming for weed management?
12. What is solarization? In what garden situations is it most effectively used?
13. How effective is landscape fabric for controlling weeds?
14. Why is mulch effective for weed control? Which types of mulch are 1) most and 2) least effective for weed control?
15. Why are biological control weed control products not used more often for landscape and garden weed management?
16. What is the difference between systemic and contact herbicides – and in which landscape situations (or on what types of weeds) would each be used most effectively?
17. How do preemergent herbicides work – and for which types of weeds (think life cycle) are they most effectively and commonly used?
18. What is the difference between selective and non-selective herbicides? Give examples of where each might be most effectively used.
19. What are some reasons that herbicides do not always control weeds as expected?
20. How would strategies for the management of BINDWEED and PURSLANE in a vegetable bed differ?

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CMG GardenNotes #351

Weed Management

Outline:

What Makes a Plant a "Landscape Weed"?

A weed is any plant that becomes undesirable in the landscape because of the following:

- It is growing in a place where it is unwanted (lawn grass in a flowerbed, tree seedlings in a lawn, purslane growing between patio pavers, spearmint invading a raised vegetable bed).
- It is visually unattractive (color, texture, growth habit, growth rate makes it aesthetically unappealing to the eye).
- It poses a health or safety hazard (poisonous plants, thorny plants, fuel for fires).

- It out-competes more desirable plants in the home landscape (competes for water, nutrients, light) or when it escapes into native landscapes (creating biodiversity problems).
- It acts as a host or shelter for other pests (alternate host for rust, attractive to injurious insects, food/shelter for damaging wildlife).

What Characteristics Make Weeds Successful?

Characteristics that make weeds successful where they become a problem include the following:

- Rapid growth rate.
- Prolific seed producer.
- Long longevity of seed.
- Deep roots, stolons, tubers, etc. making them tolerant of adverse growing conditions.
- More "ecologically fit" than other plants in the landscape.
- Adapted to readily spread (wind, animal manure, water, and human activities).
- Often adapted to disturbed soil/sites.
- May not have insects and diseases to keep them in check.
- May be better competitors for light, nutrients, or sun.

Seed Bank

A seed bank builds up as a weed drops seed into the soil over many years –seed can remain viable for years. Persistence and vigilance to keep weeds from going to seed are keys to depleting seed bank [Tables 1 & 2]

Weeds tend to be very competitive and are capable of taking advantage of disturbed areas. They often produce large amounts of seeds or are capable of quick reproduction. Weeds are generally a problem where the desired crop is doing poorly or the soil has been disturbed.

Table 1. Seeds per Plant

Weed	Number of Seeds Produced Per Plant
Dandelion	15,000
Canada thistle	680
Curly dock	29,500
Lamb's quarter	72,450
Mullein	223,200
Pigweed	117,400
Purslane	52,300

Table 2. Viability of Buried Seed

Weed	Viability of Buried Seed
Black mustard	50 years
Curly dock	80 years
Foxtail	30 years
Mallow	20 years
Plantain	40 years
Shepherd's purse	35 years

How Do Weeds Get Into Our Landscapes?

Major sources of landscape weeds include the following:

- Weeds going to seed (seed bank)
- Brought into garden in manure and soil amendments or with soils
- Disseminated from neighboring property's plants and weeds
- Deliberate introduction

Minor sources of landscape weeds include the following:

- Brought into garden with plant materials
- Brought into garden in irrigation water
- Brought into garden by humans or animals
- Using poor quality seed (weed content in seed)

Noxious Weeds

Common weeds refer to weeds commonly found in various cropping situations, such as the lawn, vegetable garden, flowerbeds, or naturalized areas.

Noxious weeds refer to weed species declared by state or local statues as a threat to agriculture and naturalized areas. Some designations require control under the law.

Legal Designations for Noxious Weeds

List A: All populations of List A species in Colorado are designated for eradication because they are not widespread (myrtle spurge, purple loosestrife)

List B: These weeds have discrete populations and will be managed to stop their continued spread, or eradicated in certain areas (Chinese clematis, oxeye daisy)

List C: These weeds are already very widespread, and not required to be controlled; however, education and research continue on these species. (downy brome, field bindweed)

For additional information on Colorado's noxious weed laws, refer to the Colorado Department of Agriculture Noxious Weed Management Program at **www.colorado.gov/ag/weeds**

Weed Life Cycle

To control weeds, the gardener needs to know their life cycles.

Annuals

Summer Annual – The seed germinates in the spring, the plant develops and produces seed during the summer, and the plant dies with killing frost in the fall. Examples include crabgrass and puncture vine.

Winter Annual – The seed germinates in late summer or fall; and lives over winter as small tufts or rosettes of leaves. It resumes growth in spring, matures seed early in the summer, and dies in summer heat. Examples include downy brome and shepherd's purse.

Keys to controlling annuals are preventing seed production, depleting the seed bank, and preventing germination.

- Timing is important.
- Winter annuals must be controlled before seed set in early summer.
- Summer annuals must be controlled before seed set in middle to late summer or early fall.
- The use of herbicides at the end of an annual's life cycle is often ineffective and does not make sense!
- Competition (from other plants and mulch) to prevent seed germination and seedling development.

Biennials

Requires two seasons to complete growth cycle. Seeds germinate in spring; the following season, the plant flowers and matures seeds in summer and fall before dying. An example is dame's rocket.

Keys to control are preventing seed production and depleting the seed bank, and preventing germination and seedling establishment.

Perennials

Simple Perennials have a root crown that produces new shoots every year. It depends upon seed production to spread. Examples include foxtail barley and dandelion.

Creeping Perennials propagate by seed, creeping above ground stems (stolons), and/or creeping underground stems (rhizomes). Examples include quackgrass and Canada thistle.

Keys to control are to prevent seed production and to kill the plant. Creeping perennials have a more extensive root system, and are harder to control.

IPM: Integrated Weed Management

"Integrated Pest Management, IPM, is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks." - the National IPM Network

The best weed control is prevention!

- Plant weed-free seed, sod, nursery stock
- Avoid using plant species known to be invasive
- Use weed-free amendments, topdressing
- Uses mulch where appropriate
- Maintain healthy, competitive plants
- Irrigate and fertilize appropriately

Methods of Control

Cultural Methods

Irrigation

Irrigation methods and frequency have a direct influence on weeds. Infrequent, deep irrigation droughts out many shallow rooted weeds. Sprinkler irrigation (wetting the entire soil surface) encourages weeds. Drip irrigation (keeping most of the soil surface dry) discourages weeds. Keep non-irrigated areas dry to help suppress weeds.

Lawn Mowing

Many common garden weeds will not survive the frequent mowing of a lawn. However, mowing the lawn too short (less than 2 inches for Kentucky bluegrass) encourage weeds as it reduces vigor of the grass.

Mulching

If maintained at adequate depths, mulching has many benefits including preventing weed seed germination. For wood/bark chips, a depth of three inches is best for weed control. Less is ineffective. Mulching may not effectively control established perennials growing from root.

Landscape Fabrics

In landscape management, landscape fabric with wood/bark chips or rock mulch above is common. However, it prevents soil improvement by organic breakdown, decreasing plant vigor. Weed seeds that germinate above the fabric layer will be difficult to pull and must be removed with herbicides. Use of landscape fabric should be considered as a deferred maintenance technique rather than a low maintenance technique.

Crop Competition

Competition with the crops and weeds for light, water, nutrients, and growing space is an effective weed management tool. For example, mowing a cool season lawn (like Kentucky bluegrass) gives the lawn a growth advantage, shading out many weeds like crabgrass.

Block planting in the vegetable garden and close spacings in a flowerbed, with plants filling the bed space, helps suppress weeds.

Summary: Cultural Methods for Weed Management

Pros: This is the best long-term control as the gardener increases the conditions for desired plants to grow at the same time decrease the conditions for weeds.

Cons: Possibly more expensive and time-consuming; control may be slow.

Mechanical Methods

Tilling / Cultivating

Tilling or cultivating effectively controls 90% of annual and biennial weeds if done before seed set. It also brings a new set of weed seeds to the soil surface ready to germinate. When tilling for weed control, use only shallow cultivation. Deep tilling can damage crop roots. Cultivating/tilling may actually propagate most perennial weeds.

Hand Pulling

Hand pulling is quick when pulled while the weeds are small, and it is effective for small infestations. A few minutes on a weekly basis to keep the garden weed free will be more effective than a long weed pulling session as the weeds get large. For many gardeners, pulling weeds is a great way to vent stress. With hand pulling, most weed species require that they be pulled out by the roots. The weed will readily regrow if just the tops are removed. It is essential that weeds are removed before they go to seed, filling the seed bank. Some weed species, like purslane, must be removed from the garden bed. It can reroot if left in the garden.

Mowing Naturalized and Low Maintenance Areas

Mowing is a common weed management tool in natural areas and lower maintenance sections of a yard, reducing the unsightly appearance of the yard and fire hazard.

String Trimming ("Weed Whacking")

Use of a string trimmer is a form of weed management by mowing. It can be effective in preventing weeds from going to seed. However, it can sow seeds if done on weeds with seeds.

Flame (Propane Torch)

Flaming off weeds with a propane torch is a common practice in production agriculture and has limited application in landscape maintenance due to fire hazards. During the flaming process, heat from the flame is transferred to the plant tissues, increasing the thermal energy of the plant cells and resulting in coagulation of cell proteins if the temperature is above 50°C. Exposing plant tissue to a temperature of about 100°C for a split second (0.1 second) can result in cell membrane rupture, resulting in loss of water and plant death. Thus, the weeds do not need to be burned up, but rather just scorched. Flaming works best on very young weeds.

It is rather expensive and many not be cost effective in some production agriculture situations. It presents a fire and explosion hazard; use with caution. Fire prevention measures prohibit the use of flaming in many communities.

Burning

Burning of fields and ditch banks is a weed management tool in production agriculture. Generally, a permit is required. Most communities prohibit burning of weeds inside city limits.

Solarization

Solarization is a method of heating the soil to kill roots, weed seeds, and soil borne insects and diseases near the soil surface. In regions with hot summer temperatures, it is effective in open areas will full sun. However, do not solarize the soil in the rooting area of trees, shrubs, and other desired plants. Steps include the following:

1. Remove vegetation and cultivate the soil to a six inch depth.
2. Sprinkle irrigate the area.
3. Cover the area with 4 mil clear plastic. Bury the edges of the plastic all the way around the plot.
4. Leave in place for three weeks during the summer heat of July and August.
5. After removing the plastic, avoid deep cultivation what would bring up weed seeds, insects, and disease pathogens from deeper soils.

Summary: Mechanical Method

<u>Pros:</u> Mechanical methods can be quick, inexpensive, environmentally friendly, and effective on small weed seedlings.

Cons: Mechanical methods have limited effectiveness on many established perennials, and could be detrimental at wrong time.

Biological Methods

Biological methods include the use of carefully screened insects to attack portions of the weed (i.e., stems, seeds, flowers, etc.). Development of biological methods with insects is rather complex and must be used with caution. The introduced insects must survive and become established in the new ecosystem. The insects need to reduce the weed population, but cannot entirely eliminate it as the weeds as that would eliminate the insect's food supply. The insects must not attach beneficial plants. The insects must not become insect pest. A great example of biological methods that failed is earwigs. They were intentionally introduced into the United States as a biological control agent and have since become a pest.

Biological methods also include the grazing of sheep, cows, horses, or goats. The purposeful use of grazing animals to control weed patches can be extremely expensive.

Pros: Biological methods can be an inexpensive, long-term control solution. It can be environmentally friendly and require little labor.

Cons: Biological methods are not always effective, may require a large population of weeds to maintain insect populations (will not work in backyard setting), and does not eradicate weeds. Insects can sometimes attack non-target plants.

Herbicides (Chemical Methods)

The use of herbicides is the use of chemicals that disrupt key physiological processes in plants, leading to plant death. Among the various herbicides, many different modes of action are found.

Pros: Use of herbicides is generally effective (if the correct herbicide is used), cost-effective, and provides quick control.

Cons: Use of herbicides can be environmentally problematic when incorrectly applied. Proper use includes proper selection of the specific herbicide for the weeds and for the growing crops in the area, timing of application, correct application rates, correct application procedures, and application safety measure to protect the application and non-target plants. Some require special licensing and may not be used in a home landscape or garden setting.

Be sure to follow the label, it is the law. Components of the herbicide label include the following:

- Trade Name
- Common name
- Chemical name
- Signal Words (Danger, Warning, Caution)
- Use instructions
    - Weeds controlled
    - Plant tolerances

    - Application rate(s)
    - Application timing
    - Application technique
    - Application restrictions
- Safety
    - Applicator
    - Bystanders, pets
    - Wildlife
    - Non-target plants

How Herbicides Are Applied

- **Broadcast** application refers to a uniform application over a treatment area.
- **Spot treat** refers to application to a specific area, such as directly to individual weeds.
- **Foliar** application refer to application to the leaves
- **Soil incorporation** refers to tilling or watering the herbicide into the soil after application.

Types of Herbicides

- **Systemic or Translocated** herbicides move internally in the plant. They must be applied during period of active growth with adequate water. Systemic herbicides are especially good for many perennials. Examples include glyphosate (Round-up), and 2,4-D.

- **Contact** herbicides only desiccate the portion of the plant that is contacted. Contact herbicides are most effective on annuals. Examples include vinegar and diquat.

- **Pre-emergent** herbicides are applied to soil prior to weed seed germination, killing germinating seeds. They will not kill growing weeds. Application timing is critical. For example, to control crabgrass in lawns, pre-emergent herbicides need to be applied late April to early May before the crabgrass germinates, about the time that common lilac blooms. Most require soil incorporation by irrigation.

  Some desired crops germinating from seeds may also be killed. For example, do not apply pre-emergent herbicides prior to seeding or laying sod. Uniform application and strict adherence to application rate are essential for attaining good weed control and for preventing injury to landscape plants.

- **Post-emergent** herbicides are applied to foliage of actively growing plants. Example include 2,4-D, and glyphosate (Round-up).

- **Selective** herbicides control a limited group of plants, like monocots versus dicots.

- **Non-selective** herbicides are effective on a broad range of plants.

Examples of Common Herbicides Used in the Home Landscape

Selective Herbicides for Broadleaf Weed Control in Lawns

Examples: 2,4-D, MCPP and MCPA, Banvel (dicamba), and Confront

Caution:

- Avoid drift and ground water movement to non-target crops. Tomatoes and grapes are extremely sensitive to 2,4-D products.
- Do not use with temperatures above 85ºF.
- Do not broadcast apply under trees. Spot individual weeds.
- Banvel and Confront have higher toxicity on some shade trees including honeylocust, linden, and Japanese pagoda.
- Keep pets off treated area until lawn dries.
- Low human toxicity. Stay out of area until lawn dries.

Non-Selective Herbicides for Control of Herbaceous Plants

Example: Glyphosate (Round-up). Note: Many Round-up products in the home garden trade have a combination of other herbicides added for quicker kill or longer holding potential.

Caution:

- Requires application to leaf tissue. No soil action. Do not spray the ground.
- Neutralized up contact with soil. Mix only with drinking quality water. The dirt in non-potable water may neutralize the product.
- Effective on most herbaceous plants. May or may not be toxic on woody plants.
- Low human toxicity, but avoid skin contact.
- Extremely toxic to dogs. Keep dogs out of treated area until spray dries.

Pre-Emergent Herbicides to Check Germinating Weeds in the Lawn

Examples: Balan, Betasan (bensulfide), Dacthal (DCPA, Ronstar (oxadiazon), Tipersan (siduron), etc.

Cautions:

- Require soil incorporation by irrigation.
- Do not apply prior to seeding or sodding. (Refer to label direction.)

Approach to Clients Having Weed Problems

- The weed must be correctly identified.
- What is the landscape setting (lawn, vegetable garden, flowerbed, shrub border, hardscape)?
- What is the health of the plants where the weeds are growing?
- What is the degree of weed infestation (by numbers, area, time, nearby sources of weeds)?

- What management has been done to date?
- Cultural issues: How is the area being managed (water, mowing, etc.)?
- Indicator species: Certain weeds "indicate" overwatering, too much/too little fertilizer, etc.
- Do they use mulch, where appropriate?

Authors: Tony Koski, Ph.D., Irene Shonle, Ph.D., David Whiting, and Kurt Jones, CSU Extension

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CMG GardenNotes #352

Weed Descriptions

INDEX

Summer Annuals

Common Mallow, *Malva neglecta*

- Most frequent in cultivated ground, gardens, newly seeded lawns, or stressed lawns that lack density; found at 4,500 to 7,000 feet in elevation
- Prostrate, low-spreading annual, biennial, or perennial; deep taproot; foliage similar to geranium, pinkish-white flowers, fruits look like small round wheels of cheese
- Increase turf density
- Pull plants from moist soil
- Pre-emergent herbicides are effective
- Post-emergent herbicides can be effective

Common Purslane, *Portulaca oleracea*

- Summer annual, found in newly seeded or thinning, non-vigorous lawns and also in cultivated garden sites; up to 8,500 feet in elevation
- Smooth, thick, succulent, alternate (to sub-opposite) edible leaves; small yellow flowers in leaf axils; stems are smooth and reddish; plant is sprawling, prostrate, forming dense vegetative mats from shallow fibrous root system
- Increase turf density
- Pulls easily when soil is moist; easily re-roots after cultivation—remove and dispose of plant
- Pre-emergent herbicides may be helpful
- Post-emergent herbicide use is more effective when plants are young; difficult to kill with an herbicide when larger

Crabgrass, *Digitaria sanguinalis*

- Low-growing, prostrate, summer annual grass; leaf blades wider and lighter green color than Kentucky bluegrass with leaf sheaths with long stiff hairs
- Base of stems are often reddish-purple in color; plant spreads by rooting at the lower stem nodes as well as by seed; forms seedheads below mowing height; seedheads are composed of slender, finger-like spikes
- Crabgrass is less prevalent when turf has good density; mowing too low promotes crabgrass seed germination; maintain mowing height at 2.5 to 3 inches.
- A pre-emergent herbicide applied correctly and at the proper time should provide control; do not use a pre-emergent herbicide on a newly-seeded or sodded lawn or when overseeding a lawn
- Post-emergent "crabgrass killer" sprays are not effective unless crabgrass plants are at the young seedling stage

Green Foxtail, *Setaria viridis*

- A summer annual grass with wider blades and a lighter green color than Kentucky bluegrass
- Faster growing than Kentucky bluegrass; seedheads (known as spikes) have bristles that give it a fuzzy appearance; may form a seedhead despite regular mowing
- Foxtail is much less prevalent when turf has good density; resod or reseed bare spots

- A pre-emergent herbicide applied correctly and at the proper time should provide control; do not use a pre-emergent herbicide on a newly-seeded or sodded lawn or when overseeding a lawn
- Post-emergent herbicides will kill foxtail seedlings (but not mature plants)

Kochia, *Kochia scoparia*

- Very prevalent in disturbed soils, cultivated fields, gardens
- In spring, seedlings have alternate leaves; lower leaves often wider than upper leaves; underside of leaves hairy, margins hairy
- Flowers are yellow, inconspicuous; seed production occurs from July to October
- Stems are 1 to 6 feet tall
- In fall, entire plant first becomes reddish-brown, then brown, becomes "tumbleweed"
- Germinates early; use pre-emergent herbicides before soil temps reach 38°F
- Post-emergent herbicides can be effective
- Mulch inhibits seedling development

Netseed Lambsquarters, *Chenopodium berlandieri*

- Summer annuals prevalent in disturbed soils, gardens, cultivated fields, waste areas
- Extremely variable in appearance; stems 1 to 6 feet tall, grooved, often reddish tinged; undersides of leaves whitish, mealy (mottled, granular appearance)
- Flowers inconspicuous, greenish, at tips of stems and leaf axils; seed production occurs from July to September
- Edible when plant is young and tender
- Competitive weed with rapid growth and high water use
- Can be hoed or pulled when young
- Pre-emergent herbicides applied at the right time in spring can provide good control
- Post-emergent herbicides can be effective
- Mulch inhibits seedling development

Prostrate Knotweed, *Polygonum aviculare*

- Prostrate summer annual from a thin taproot; tough, durable plant common along sidewalks, in turf that is stressed and less vigorous, and in gardens; found to 9,500 feet in elevation
- Thrives in dry, compacted soils or wherever there is excessive foot traffic
- Forms a tough, wiry mat of stems that are enlarged at each joint as well as a papery sheath at each leaf node; to differentiate from spurge, broken stem does not produce a milky sap; leaves and stems are not hairy, and leaves are alternate
- Flowers small, white, inconspicuous; found where leaf meets stem; produces many seeds
- Annual core aeration spring and/or fall will reduce knotweed infestation
- Apply pre-emergent herbicides in late fall/winter (knotweed can germinate in February or March)
- Post-emergent herbicides are mostly ineffective after plants become larger

Prostrate Spurge, *Chamaesyce maculate*

- Prostrate summer annual forming dense mats; found in thinning, less vigorous turf
- Leaves are opposite and each leaf has a reddish-purple spot in the center; small pinkish flowers in leaf axils; stems and leaves are both hairy; sap is milky latex; some people develop a rash after skin contact with sap
- Increase turf density
- Plants can be pulled and bagged if soil is moist; wear gloves because of the sap
- Post-emergent herbicides can be effective

Redroot Pigweed, *Amaranthus retroflexus*

- Coarse, summer annual; fast growing to 12 to 36 or more inches tall; dependent on moisture received
- Alternate leaves vary in appearance, but have prominent veins and midrib
- Lower stem reddish or red-striped; roots pink-red even down the taproot
- Flowers/seedheads at top of plant; prickly; produces many small black seeds
- Very toxic to cattle and swine
- Found in waste areas, gardens, disturbed soils, and in turf if thin and patchy in quality
- Hoe or pull from moist soil before seedheads mature; bag plants if pulled later
- Easy to kill with most herbicides, but apply according to label directions well before seedheads mature; herbicides suggested only where large numbers of plants exist or where large areas are infested

Scentless chamomile, *Matricaria perforata*

- Noxious weed in Colorado List B
- Annual forb that can persist as a biennial or shortlived perennial
- Stems of the plant are green, erect, often branched, glabrous, or slightly pubescent, and can range in height from 6 to 20 inches tall
- Leaves are alternate, 1 to 2 inches long, slightly pubescent or glabrous, and are finely divided into several short thread-like segments
- Terminal flowers are 0.75 to 1.25 inch in diameter, with a daisy-like appearance consisting of white petals surrounding a central yellow core
- Key to control is reducing seed production; hand pulling is effective, but may not be practical in larger patches; mowing conducted early in the growing season before plants flower and prior to seed production will reduce populations
- Maintaining healthy stands of desirable vegetation can also be an effective control measure because scentless chamomile seedlings cannot tolerate intense competition
- Post-emergent herbicides can be effective

Winter Annuals

Downy Brome/Cheat Grass, *Bromus tectorum*

- Noxious weed in Colorado (List C)
- Winter annual, extremely abundant in intermountain west; after maturity can become a fire hazard, especially when dry; found at 4,000 to 9,000 feet in elevation
- Leaf sheaths and blades are covered by dense soft hairs

- Droopy seedheads develop in spring; long awns; prolific seed producer; plants turn reddish brown in early summer (mid to late June), and then fade to a blond color
- Competes vigorously with other perennial grasses for moisture because of its winter and early spring growth habit; root growth during winter can occur until soil temperature goes below 37°F
- Hand-pulling effective for small infestations—repeat pulling over the season is necessary, as seeds will germinate irregularly; extract as much root as possible to prevent re-growth
- Infrequent in mowed turf; in the landscape, glyphosate (Round-up and others) works well in early spring prior to seedhead appearance; best when non-target species are dormant

Shepherd's Purse, *Capsella bursa-pastoris*

- Small winter annual with small white flowers early in spring; common in cultivated gardens and roadsides; common up to 9,000 feet in elevation
- Slender stems from basal rosettes; leaves are hairy below, smooth above, and often deeply lobed; seed pods are heart-shaped (or purse-shaped); seed production from April to September
- Hand-pulling or hoeing before seed set is very effective—get on it early!
- Post-emergent herbicides should be labeled for use in turf grass

Biennials

Dame's Rocket, *Hesperis matronalis*

- Noxious weed in Colorado (List B)
- Can be a short-lived perennial
- Was introduced as an ornamental
- Flowers have four petals, are purple or white, clustered in loose stalks, and fragrant
- Mature plants range from 1 to 3 feet tall
- Can be aggressive in the landscape
- Pulling or cutting flower heads before seed set will control the plant, but this will need to be repeated for several years to exhaust seed bank
- For larger infestations, post-emergent herbicides can be effective
- Do not buy seed mixes that contain this plant

Diffuse Knapweed, *Centaurea diffusa*

- Noxious weed in Colorado (List B)
- A biennial, short-lived perennial, or occasionally an annual
- The plant develops a single shoot (stem), 1 to 2 feet tall that is branched toward the top; first year rosette leaves and lower shoot leaves are finely divided; leaves become smaller toward the top of the shoot and have smooth margins
- Many solitary flowering heads occur on shoot tips; they are about one-eighth inch in diameter and 0.5 to 0.66 inch long; flowers usually are white but may be purplish; involucre bracts are divided like teeth on a comb and tipped with a slender spine that makes them sharp to the touch; sometimes the bracts are dark-tipped or spotted like spotted knapweed; the long terminal spine differentiates diffuse from spotted knapweed
- It reproduces and spreads from seed—keep from going to seed; hoeing or hand pulling before the plant goes to seed can accomplish this
- For larger areas, post-emergent herbicides can be effective

- Cultural controls include revegetating with desirable grasses
- Biological controls include the seedhead flies *Urophora affinis* and *U. quadrifasciata* and root-feeding insects such as the diffuse knapweed root beetle (*Sphenoptera jugoslavica*), the yellow-winged knapweed moth (*Agapeta zoegana*), and the knapweed root weevil (*Cyphocleonus achates*)

Musk Thistle, *Carduus nutans*

- Noxious weed in Colorado (List B)
- Musk thistle is a biennial or winter annual that can grow up to 8 feet tall
- Leaves are up to 10 inches long, dark green with a light green midrib, spiny, and deeply lobed; often have a white margin
- Solitary, lightly spiny, and nodding flower heads develop at the stem tips in midsummer and grow to a diameter of 1.5 to 3 inches and are deep rose to violet
- The key to control is not to let the plant go to seed; herbicides and hand pulling the rosette are both effective
- Applications should be made in late spring/early summer and again in the fall

Prickly Lettuce, *Lactuca serriola*

- Biennial or winter annual to 48 inches tall from a large taproot; invades disturbed garden soils
- Cut stems/leaves exude a "milky juice"; more common in areas from 4,500 to 6,000 feet
- Upper leaves lobed like oak leaves and are often twisted to lie in a vertical plane, also known as "compassplant" because leaves may "point" to north and south; lower leaves often not as lobed; leaves have prominent spines on back side of midrib
- Small yellow daisy-like flowers on elongated stems; seedheads are like those of dandelion
- Hoe or pull from moist soil before yellow flowers mature
- Easy to kill with most herbicides, especially when younger; apply according to label directions well before seedheads mature; herbicides suggested only where large numbers of plants exist or where large areas are infested

Yellow Sweet Clover, *Melilotus officinalis*

- Biennial herbaceous plants; second year plants grow 3 to 5 feet high and are bush-like; sweet clovers are very fragrant
- Leaves are alternate, divided into three finely toothed leaflets; middle leaflet grows on a short stalk
- Flowers are crowded densely at the top 4 inches along a central stem; each flower is attached by a minute stalk
- There are one or two hard small seeds per flower; they stay viable in the soil for 30 years
- Strong taproot
- Can be good forage; however, moldy hay made from yellow sweet clover (or hay made from drought stressed or frost-damaged plants) is toxic to livestock (contains coumarin which converts to dicoumarin, a blood thinner)
- The key to controlling sweet clovers is to keep them from flowering and then concentrate on depleting viable seeds in the soil
- Hoe, hand pull, or spray with post-emergent herbicide when young

Simple Perennials

Curly Dock, *Rumex crispus*

- Leaves emerge from stout taproot in spring
- Elongated leaves have wavy (curly) margins.; leaves mostly basal, with long petioles
- Stems 2 to 4 feet tall, reddish, ridged; nodes sheathed with clear membrane
- Flowers greenish, May
- Winged fruits on flowering stems, reddish-brown
- Habitat—Fields, roadsides, railroads, waste ground, disturbed sites, turf/landscape
- Dig taproot, must remove at least 75% of the taproot to control
- Post-emergent herbicides can be effective

Myrtle Spurge, *Euphorbia myrsinites*

- Noxious weed in Colorado (List A)
- Mat-forming perennial to 9 inches tall
- Escaped ornamental; formerly sold as a drought-tolerant ground cover
- Blue-green succulent leaves form a "donkey tail"; has chartreuse bracts ("flowers")
- For small infestations, dig or pull out clumps with caution; white latex sap from stems and leaves can cause severe dermal reactions—always wear gloves if hand pulling
- For larger infestations, use an herbicide; the best time to treat myrtle spurge with herbicide is during late fall
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Spotted Knapweed, *Centaurea maculosa*

- Noxious weed in Colorado (List B)
- A short-lived, noncreeping perennial that reproduces from seed (primary means of spread)
- Produces one or more shoots that are branched and 1 to 3 feet tall; rosette leaves can be 6 inches long and deeply lobed
- Leaves are similar to diffuse knapweed
- Lavender to purple flowers are solitary on shoot tips and about the same size as diffuse knapweed flowers; involucre bracts are stiff and black-tipped; the tip and upper bract margin have a soft, spine-like fringe and the center spine is shorter than others
- For control measures, see diffuse knapweed

Creeping Perennials

Bouncingbet, *Saponaria officinalis*

- Noxious weed in Colorado (List B)
- An escaped ornamental, aggressive in landscapes and wild areas
- Spreads aggressively through rhizomes and seeds
- White to pink five-petaled flowers are clustered at the ends of branches
- Leaves are opposite, smooth, and have three veins from base
- Mature plants are up to 3 feet tall

- Saponins in plant are toxic to livestock
- Can be controlled by mowing or pulling several times a year—before seed production
- Post emergent herbicides can be effective

Canada Thistle, *Cirsium arvense*

- Noxious weed in Colorado (List B)
- Colony-forming creeping perennial spreading primarily by horizontal roots (can grow as much as 18 feet in one season!) and to a lesser degree by seed; found from 4,000 to 9,500 feet in elevation
- Flowers are purple and are borne in clusters; spiny foliage with variable leaf shapes; when mowed in a lawn, will not develop full height and flower
- Highly invasive species; control is difficult because of its extensive root system; pulling generally is not effective due to the tremendous reserves in the root system; *regular, persistent* pulling may gradually starve root system; shoots should be pulled as they are noticed, as all shoots (leaves) are producing food reserves
- Increase density and competitiveness of turf
- Post-emergent herbicides can be effective
- Vinegar is a contact herbicide and will only brown leaves; these will be replaced by new shoots; frequent applications may be effective
- Biocontrol insects include a seed head weevil, a stem-mining weevil, and a gall-forming fly; these may not be significantly effective alone but can provide good results when combined with other control methods; biocontrol insect releases are best suited to large acreage infestations; backyard releases are generally impractical

Common Tansy, *Tanacetum vulgare*

- Noxious weed in Colorado (List B)
- Introduced from Europe as an ornamental and medicinal herb
- Found in yards, along roadsides, stream banks, and in waste places
- Spreads by rhizomes, can reach 3 to 4 feet tall
- Flowers are button-shaped and yellow in flat-topped clusters
- Leaves are deeply divided into narrow leaflets and rank smelling
- Is toxic to livestock, although unpalatable
- Mowing before seed production can limit spread, although it may have to be repeated several times in a season to prevent regrowth from rootstocks
- Hand pulling in damp soil can remove small infestations; wear gloves; will readily regrow from fragments in soils
- For larger infestations, post-emergent herbicides can be effective

Creeping Woodsorrel/Oxalis, *Oxalis corniculata*

- Prostrate, creeping perennial from slender taproot; stems root where they touch the ground
- Leaves have a shamrock appearance; plants often mistaken for a clover; leaves may "fold up" at night or on cloudy days; leaves turn purplish with the arrival of cooler weather in fall; some plants may have purplish leaves year-round
- Small yellow flowers
- Fruits "explode" when mature, scattering seed often more than 10 feet
- More common in thin, less vigorous turf given too frequent, light irrigation; increase turf density
- Pre-emergent herbicides may be helpful

- Post emergent herbicides can be effective

Field Bindweed, *Convolvulus arvensis*

- Noxious weed in Colorado (List C)
- Creeping perennial; found as high as 10,000 feet in elevation; general range 4,000 to 8,000 feet
- Vining, sprawling, prostrate growth habit; may climb by twining around fence wire or around stems of other plants; not shade tolerant but drought tolerant due to large roots; leaves are arrowhead-shaped; attractive, white or pink bell-shaped flowers that resemble morning glory from late June until frost
- Increase density and competitiveness of turf
- Control is difficult because of its extensive root system, which can penetrate the soil profile to a depth of 20 feet; seeds also can remain viable for 20 to 50 years; pulling generally is not effective due to the tremendous reserves in the root system; *regular, persistent* pulling may gradually starve root system; shoots should be pulled as they are noticed, as all shoots (leaves) produce food reserves
- Post-emergent herbicides can be effective
- The bindweed mite has been used as a biological control with some success; initial impact is reduction of growth and limited flower and seed production; mowing moves mites around and stimulates plant growth for mites to feed on; survival is better in drier settings; excessive moisture may limit establishment; contact your local Colorado State University Extension office for information

Hoary Cress (White Top), *Cardaria draba*

- Noxious weed in Colorado (List B)
- A creeping perennial that reproduces by seed and creeping roots; one of the earliest perennial weeds to emerge in the spring
- It grows erect from 10 to 18 inches high and has a white color
- The alternate leaves clasp the stem and are oval or oblong with toothed or almost smooth margins; the leaves are often covered with very fine white hairs; each leaf is 0.5 to 2 inches long with blunt ends
- The flowers are white, one-eighth inch across, and numerous in compact flat-top clusters, which give the plant its name; each heart-shaped seed pod contains two oval, finely pitted, red-brown seeds each about one-twelfth inch long
- Due to the rhizomes of this perennial weed, mechanical control provides minimal control; diligent digging can provide control of very small infestations; hand pulling of above-ground plant parts is ineffective; successful digging requires complete plant removal within 10 days after weed emergence throughout the growing season for 2 to 4 years; cultivation 6 inches deep must be repeated within 10 days of weed emergence throughout the growing season for 2 to 4 years
- Revegetate with desirable vegetation
- Post-emergent herbicides can be effective

Leafy Spurge, *Euphorbia esula*

- Noxious weed in Colorado (List B)
- An erect plant that grows 1 to 3 feet tall
- Leaves are bluish-green with smooth margins, 0.25 inch to 0.5 inch wide, and 1 inch to 4 inches long
- Umbel flowers are surrounded by heart-shaped, showy, yellow-green bracts (an umbel looks like the stays of an umbrella if it is held upside down); flowers occur in many clusters toward the top of the plant; seeds are round to oblong, about one- twelfthinch long, gray or mottled brown with a dark line on one side
- Leafy spurge contains a white milky latex in all plant parts; latex distinguishes leafy spurge from some other weeds (e.g., yellow toadflax), particularly when plants are in a vegetative growth stage
- Leafy spurge has an extensive root system that is abundant in the top foot of soil, and it may grow 15 feet deep or more; roots contain substantial nutrient reserves that allow the weed to recover from stress, including control efforts; many vegetative buds along roots grow into new shoots
- Use a combination of methods to control leafy spurge; vigorous grass helps weaken leafy spurge through competition
- Post-emergent herbicides can be effective

Orange Hawkweed, *Hieracium aurantiacum*

- Noxious weed in Colorado (List A)
- Shallow, fibrous roots
- Leaves are hairy, spatula shaped, up to 5 inches long, and basal
- Extensive stolons create a dense mat that practically eliminates other vegetation—makes mechanical control very difficult once established
- Stems and leaves exude a milky latex when cut or broken
- Up to 30 half-inch red to orange flowers appear in late May or June
- Post-emergent herbicides can be effective
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Oxeye Daisy, *Chrysanthemum leucanthemum* or *Leucanthemum vulgare*

- Noxious weed in Colorado (List B)
- A perennial from rhizomes with characteristic “daisy-like” flowers
- Plants initially develop as a basal rosette; lower rosette leaves occur on petioles and are from 1.5 to 6 inches long; leaves are lobed
- Flowers are white with a yellow center and range from 1.25 to 2 inches
- Oxeye daisy should be mowed as soon as flowers appear to reduce seed production; root systems are shallow and the plant can be dug up and removed; hand removal will have to be continued for several years because seeds may remain viable in the soil for a long time
- Post-emergent herbicides can be effective
- Native daisies are a good, non-invasive garden alternative

Purple Loosestrife, *Lythrum salicaria*

- Noxious weed in Colorado (List A)
- Escaped ornamental, aggressive in riparian areas
- Square stem, whorled leaves
- Purple-magenta flowers with five to seven petals in long racemes
- If left unchecked, a wetland may become a monoculture of loosestrife
- Control of small infestations can be managed through digging all the plants and roots—this will need to be monitored for a few years
- Large infestations should be controlled with an aquatic-labeled herbicide
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Quackgrass, *Elytrigia repens*

- Noxious weed in Colorado (List B)
- Very aggressive creeping perennial grass especially in moist soils; found from 4,500 to 9,000 feet in elevation; spreads by seeds and invasive rhizomes (underground stems)
- Rhizomes are yellow-white, with brown sections; rhizome ends are sharp-pointed and can penetrate hard soils; base of leaf blade with claw-like appendage that clasps the stem
- Believed to be allelopathic (release of a chemical that inhibits growth of nearby plants)
- Mechanical control is difficult as any rhizome segment produces new plants
- A few quackgrass plants can be spot-sprayed with glyphosate, or individual blades can be painted with glyphosate; note that glyphosate will kill any bluegrass it contacts; repeat applications will likely be needed
- Renovate severely infested lawn areas—spray area with glyphosate; repeat applications will likely be needed; ensure that quackgrass is killed before areas are resodded or reseeded

Russian Knapweed, *Centaurea maculosa*

- Noxious weed in Colorado (List B)
- Creeping perennial that reproduces from seed and vegetative root buds
- Emerges in early spring, bolts in May to June, and flowers through the summer into fall
- Shoots or stems are erect, 18 to 36 inches tall, with many branches; lower leaves are 2 to 4 inches long and deeply lobed; upper leaves are smaller, generally with smooth margins, but can be slightly lobed; shoots and leaves are covered with dense gray hairs
- The solitary, urn-shaped flower heads occur on shoot tips and generally are 0.25 to 0.5 inch in diameter with smooth papery bracts; flowers can be pink, lavender, or white
- Has vertical and horizontal roots that have a brown to black, scaly appearance, especially apparent near the crown
- Toxic to horses; allelopathic to other plants
- The key to Russian knapweed control is to stress the weed and cause it to expend nutrient stores in its root system
- An herbicide alone will usually not effectively manage Russian knapweed; combine treatment with perennial grasses sown in late fall; tillage is necessary to overcome the residual allelopathic effects of Russian knapweed

White Clover, *Trifolium repens*

- Creeping perennial that forms runners that root at nodes

- Many people like clover in lawns, while others find white flowers and the bees they attract objectionable
- A legume that fixes nitrogen, so it is often found in lawns having low fertility
- Increase turf density with proper watering, mowing, and fertilization
- Post-emergent herbicides can be effective

Wild Violet, *Viola* spp.

- Heart-shaped leaves on long petioles, purple flowers in spring; may also spread by rhizomes
- Difficult to control due to resistance to many herbicides
- Improve light penetration to shaded areas by pruning trees and shrubs
- Mow lawn higher to increase competition from grass
- Best control may be to pull plants when ground is moist
- Post-emergent herbicides can be effective

Yellow Toadflax, *Linaria vulgaris*

- Noxious weed in Colorado (List B)
- Yellow toadflax is a perennial that spreads sideways by underground rhizomes and by seeds
- Flowers are small, yellow, look like snapdragons, and bloom mid-late summer; leaves are linear
- Some people confuse a native plant, golden banner, with toadflax, but golden banner blooms very early and has three leaves, like a clover
- Yellow toadflax is difficult to control; its extensive root system lets it recover from control attempts
- Yellow toadflax is very variable, genetically; therefore the effectiveness of herbicides is also variable
- Hand pulling can be effective on small patches, especially in gravelly soils when you can pull a large part of the root; it will need to be pulled for several years; pull *before* it goes to seed
- Post-emergent herbicides can be effective

Woody Plants

Russian Olive, *Elaeagnus angustifolia*

- Noxious weed in Colorado (List B)
- Small tree 10 to 25 feet tall originally planted as an ornamental and for windbreaks
- Leaves are narrow and appear silvery
- Branches have long thorns 1 to 2 inches in length
- Small sweet smelling yellow flowers are followed by a berry-like fruit which is spread by birds
- Has become a serious weed in low-lying pastures, meadows, and waterways
- The most effective control is to cut the tree and immediately paint the stump with a herbicide
- Silver buffalo berry is an excellent native alternative plant

Tamarisk, *Tamarix ramosissima*

- Noxious weed in Colorado (List B)
- Tamarisk was sold as an ornamental plant for gardens during the 1800 and 1900s; tamarisk has now spread to most of the western United States, displacing the native cottonwoods and other plants
- Plants can grow to 6 inches tall during the first 2 months and can grow over 18 feet tall; the taproot can reach 100 feet down with a root spread of up to 150 feet; adventitious roots can produce new trees when buried!
- Mature tamarisk trees can produce millions of pollen-size seeds dispersed through wind and water; seeds can germinate while floating and establish themselves on wet banks within 2 weeks; newly formed sand banks are particularly susceptible; trees may reproduce in the first year, but typically they reproduce during the second year
- It is very "thirsty"—one tree can use up to 300 gallons per day, and it alters hydrologic conditions in riparian areas
- Salt glands on the leaves release salt, increasing salinity of soil
- Tamarisk is difficult to control; single treatment approaches to control tamarisk have not proven feasible because no method completely eliminates tamarisk or its regeneration; use revegetation in conjunction with other methods
- The saltcedar leaf beetle, *Diorhabda elongaa*, has been released on some stands, and has shown to be fairly effective

Authors: Irene Shonle, Ph.D. with Kurt Jones and Tony Koski,Ph.D., CSU Extension

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CMG GardenNotes #353

Weed Associations with Specific Environments and Cultural Conditions

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Compacted Soils

annual bluegrass (*Poa annua*)
common chickweed (*Stellaria media*)
goosegrass (*Eleusine indica*)
knotweed (*Polygonum aviculare*)
mouse-ear chickweed (*Cerastium vulgatum*)
prostrate spurge (*Euphorbia supina*)

Dry Soil

black medic (*Medicago lupulina*)
dandelion (*Taraxacum officinale*)
bindweed (*Convolvulus spp.)*
kochia (*Kochia scoparia*)
stinkgrass (*Eragrostis cilianensis*)

Dry, Infertile Soils

black medic (*Medicago lupulina*)
yarrow (*Achillea millefolium*)

Moist or Poorly Drained Soils

annual bluegrass (*Poa annua*)
bentgrasses (*Agrostis spp.)*
common chickweed (*Stellaria media*)
crabgrasses (*Digitaria spp*.)
goosegrass (*Eleusine indica*)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
violets (*Viola spp*.)
yellow nutsedge (*Cyperus esculentus*)

Moist, Fertile Soils

annual bluegrass (*Poa annua*)
curled dock (*Rumex crispus*)
henbit (*Lamium amplexicaule*)
yellow woodsorrel (*Oxalis stricta*)

Moist, Infertile (Low N) Soils

black medic (*Medicago lupulina*)
plantains (*Plantago spp*.)
white clover (*Trifolium repens*)

Low Mowing Height

annual bluegrass (*Poa annua*)
crabgrasses (*Digitaria spp.)*
yellow woodsorrel (*Oxalis stricta*)
white clover (*Trifolium repens*)

New Seedings (Spring/Summer)

annual bluegrass (*Poa annua*)
barnyardgrass (*Echinochloa crusgalli*)
crabgrasses (*Digitaria spp.)*
purslane (*Portulaca oleracea*)
foxtail (*Setaria spp.)*

New Seedings (Fall)

henbit (*Lamium amplexicaule*)
storksbill (*Erodium cicutariuim*)
shepardspurse (*Capsella bursa-pastoris*)
annual mustards (many)

Old Lawns (25-30+ years)

bentgrasses, redtop (*Agrostis spp*.)
orchardgrass (*Dactylis glomerata*)

Shady Lawns

annual bluegrass (*Poa annua*)
common chickweed (*Stellaria media*)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
nimblewill (*Muhlenbergia shreberi*)
violets (*Viola spp*.)

Formerly Agricultural/Farm Land

barnyardgrass (*Echinochloa crusgalli*)
bindweed (*Convolvulus spp.)*
Canada thistle (*Cirsium arvense*)
foxtail (*Setaria spp.)*
quackgrass (E*lytrigia repens*)
smooth bromegrass (*Bromus inermis*)

Author: Dr. Tony Koski, Extension Turf Specialist, Department of Horticulture & LA, Colorado State University

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Useful Weed ID Books, Keys, and Apps for Use in Colorado

Keys (online, web-based)

University of Missouri Weed ID

- Web-based key: https://weedid.missouri.edu/
- Apps (free) also available for iPhone/iPad and Android devices
- 400+ weeds in database
- Agriculture orientation, but works for landscape weeds and turf/weedy grass ID

Virginia Tech Weed Identification

- Web-based: https://weedid.cals.vt.edu/
- 740+ weeds in database

Apps

PlantNet Plant Identification

- plantnet.project.org
- Choose “USA” or “Canada” for location (but many international regions can also be selected)
- Take a photo, or load an existing photo that you’ve taken (and is stored on your phone), of a weed
- Works very well for dicot weeds (especially when flowering), but also does well with grasses
- Free

LeafSnap

- Image matching app (take a photo with your phone, or load an existing image)
- Works very well for dicot weeds (especially with flowers); does fairly well with grasses
- Free (but premium version available for purchase)

ID Weeds

- The is the University of Missouri phone/tablet app
- A true key (not image-matching)
- Over 400 weeds
- Agricultural orientation, but can work well for urban landscape plants
- Dicot and grassy weeds; also sedges and rushes
- Useful for turfgrass and weedy grass ID
- Free

iNaturalist

- Search in Itunes or Google Play stores for “iNaturalist”
- Image-recognition; take a photo or load an existing one stored on your device
- Not as intuitive as LeafSnap or PlantNet (click on “What did you see?” under your pic)
- Works very well for dicot weeds, with or without flowers; works well on grassy weeds
- Free

Montana Grasses

- A guide to over 200 native and introduced grasses commonly found in the Rocky Mountain region
- For both Android and IOS devices
- Cost is $4.99

Idaho Grasses

- Field guide to 60 grasses (range, native) found in Idaho and the Rocky Mountain region
- For both Android and IOS devices
- Cost is $7.99

Colorado Wildflowers Guide

- More than 500 common flowering plants found in Colorado
- DOESN'T have many/most plants considered to be weeds in Colorado lawns and gardens
- Search by flower color, bloom time, or location
- Can also search using photo recognition
- For both Android and IOS devices
- FREE
- Web site has search capacity (no photo recognition) http://www.easterncoloradowildflowers.com/

Books

Wildflower identification books can be useful; they won't be listed here. The following are weed ID books.

Weeds of California and other Western States (2007)

- Very useful for most of the western and midwestern U.S.
- 2 volumes; 1,760 pages total (comes with a CD of all weed photos)
- ISBN-13: 978-1-879906-69-3
- Has a dichotomous key
- Both volumes together cost $65 (new); https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3488

Weeds of the Northeast (1997)

- Very useful for east and northeast (west to Wisconsin – so complements Weeds of California)
- 408 pages; has a dichotomous key
- ISBN-13: 978-0801483349
- $30 (new) https://www.amazon.com/Weeds-Northeast-Richard-H-Uva/dp/0801483344/

Identifying Turf and Weedy Grasses of the Northern United States (2005)

- Useful for ID of turfgrasses and weedy grass of northern, midwestern, northeast, eastern, and western U.S. lawns (not useful for southeastern U.S. or Hawaii)
- Has a dichotomous key
- 64 pages; from University of Illinois Extension

Cost new is $11.75 with shipping; https://pubsplus.illinois.edu/product/commercial-horticulture/identifying-turf-and-weedy-grasses-of-the-northern-united-states

Weed Management in the Home Lawn

Dr. Tony Koski, Extension Turf Specialist

COLORADO STATE UNIVERSITY EXTENSION

Weeds occur in every lawn, but they seldom become problems in well-managed, vigorously growing turfgrass. Proper site preparation and turfgrass selection before planting are essential to give a new lawn a healthy start. Once a lawn is established, poor maintenance practices that weaken it - such as improper irrigation, fertilization, or mowing - are the primary factors likely to predispose it to weed invasion. Activities that lead to compaction also contribute significantly to turfgrass stress, making it easier for weeds to invade.

An integrated weed management program can reduce most weed populations to tolerable levels and prevent large, unsightly weed patches. Total eradication of weeds is not a realistic or necessary goal for most lawns. With proper maintenance a lawn can be practically free of weeds without the extensive use of chemicals.

WEED IDENTIFICATION

Identifying weeds and knowing their life cycles are essential to management. Three general categories of weeds may be found in lawns: broadleaves, grasses, and sedges. Take care to distinguish annual weedy grasses (crabgrass, foxtail, barnyardgrass) from similar-looking perennial weedy grasses (quackgrass, bromegrass, bermudagrass) because the approaches to their management (both cultural and if using herbicides) are often quite different. Broadleaf weeds can be annual (purslane, spurge) or perennial in their growth habits, which might require a different approach to their management (type and timing of herbicide applications, for example).

The life cycle of weeds may be annual, biennial, or perennial. Annual weeds are commonly identified as either winter (cool-season) or summer (warm- season) annuals and survive only one season. If not controlled before they flower, they can produce seed that will sprout the following year or sometimes in the same growing season. In mild climates or in lawns that are influenced by microclimates, cool-season annuals may be found growing in summer or year-round (chickweed, for example). Perennial weeds survive for many years, and though they produce seeds, most survive and reproduce vegetatively by creeping stems (stolons and rhizomes), tubers, or roots. Perennial weeds are the most difficult to control once established because they often have deep, extensive root and rhizome systems that store energy – enabling them to re-grow if pulled or treated with herbicides.

WEED MANAGEMENT IN ESTABLISHED LAWNS

Weeds often invade turfgrass that is over- or under-watered, improperly fertilized, mowed incorrectly, or highly compacted. Lawns that have been weakened by plant diseases or insect pests are also likely to become weedy because there is more open space for a weed to establish. Many weed problems can be prevented with proper lawn maintenance – or good maintenance can prevent the problem weed(s) from becoming worse. The most troublesome weed species that invade turfgrass are often associated with specific conditions (compaction, low fertility, too dry, too wet, shady, salty, etc.). Identifying the weed species present may give an indication of the underlying problem responsible for the occurrence of the problematic weeds.

Irrigation

Many lawns are watered incorrectly. Poor irrigation practices can weaken turfgrass, allowing weeds to invade. To maintain a healthy lawn, uniform water coverage is needed. Sprinkler heads that are broken, obstructed, or set too low or too high may not reach all areas of the lawn and can result in dry or dead spots in an otherwise healthy turfgrass.

In general, deep, infrequent irrigation will encourage healthier root growth, dense turf, and can reduce weed seed germination. Light, frequent watering is only required when the turfgrass has just been planted and the root system is developing. Watering established turfgrass lightly and frequently creates a shallow-rooted lawn, making it less durable and allowing shallow-rooted weeds such as crabgrass grow more easily – even if a preemergence herbicide is used. Allowing the soil surface to partially dry out between watering events can be useful for reducing weed pressure.

Mowing

Mowing some grasses too short and/or not frequently enough can weaken the turf and increase the potential for weed invasion. In general, bluegrass, ryegrass, fescue and buffalograss lawns should be mowed at a height of 2.5 to 4 inches. Mow grasses more frequently when they are actively growing. A standard guide is to remove no more than 1/3 of the leaf blade at each mowing. If too much is removed at one time, it can take some time for the grass to recover, giving weeds a chance to invade.

Fertilizing

Most bluegrass and tall fescue lawns need to be fertilized 2-4 times a year while they are actively growing, with no more than 1 pound of actual nitrogen per 1,000 square feet per application. Lawns that are older 10+ years or older require less fertilizer (1-2 times yearly) than newer lawns. Recycling grass clippings into the lawn when mowing can also reduce the need for fertilizer application significantly.

Thatch and Compaction Management

Regular thatch and compaction management will help keep your turfgrass healthy, easier to water and fertilize, and more competitive against weeds. Thatch is a layer of organic matter (stems, stolons, roots) that develops between the turfgrass blades and the soil surface on some lawns (bluegrass especially). A thin layer of thatch (1/2 inch is OK) is normal and even beneficial; it can help provide wear/traffic tolerance if you have dogs and/or children that play in the lawn. Some people prefer to use a thatching machine (aka “power-rake”) to remove thatch, while others use core cultivation (aka “aeration”) to manage thatch. The advantage to using aeration is that you will also help reduce soil compaction – which is sometimes a contributing factors towards excessive thatch accumulation (roots don’t grow deeply into soil that is too compacted and/or wet). Lawns on heavy clay soils or lawns with heavy foot or equipment traffic may need to be aerated twice yearly (spring and fall) while lawns with little activity may only need to be aerated once a year or less. Aerate when the turfgrass is actively growing, in the spring or fall (avoid the hottest months of summer). Power-raking is best done in the spring before the grass begins active growth – allowing time for it to regrow in the spring and early summer.

Herbicides for Broadleaf Weeds

The easiest weeds to control in grass lawns are YOUNG (small) annual broadleaf and grassy weeds, like crabgrass, foxtail, spurge and purslane. Generally these herbicides are postemergence, systemic herbicides containing combinations of two or three active ingredients, such as dicamba, mecoprop, or 2,4-D, and are very effective in controlling numerous broadleaf weeds without damaging the grass. Triclopyr is also an effective broadleaf herbicide that is found in products for more difficult-to-control weeds. Newer herbicides carfentrazone, sulfentrazone, and quinclorac also have broadleaf weed activity and are often formulated with the other broadleaf herbicides to increase the speed or spectrum of weed control (and they may provide control of some grassy weeds and sedges). If crabgrass or other annual grassy weeds are present, it’s essential the quinclorac be listed on the herbicide label.

Broadleaf herbicides are also effective against perennial broadleaf weeds, although more than one application may be necessary. Be aware that many postemergence broadleaf herbicides are prone to drift in the air and may contact desirable plants, especially when applications are made in windy conditions or when temperatures exceed 80-85 F. Also be aware that certain broadleaf herbicides, such as dicamba and triclopyr, can be absorbed by tree roots growing in lawns and may cause tree injury if applied too many times during the growing season (more than twice) or at excessively high rates. Always consult the herbicide label for recommended rate usage and application frequency to avoid injury to non-target landscape plants.

Herbicides for Grass Weeds

Annual grasses such as crabgrass, foxtail, and barnyardgrass can be effectively controlled in established lawns with preemergence herbicides such as benefin, bensulide, dithiopyr, pendimethalin, and prodiamine. The key to success for all preemergence herbicides is to apply the herbicide 2 to 4 weeks prior to weed germination. Pre-emergence herbicides must be thoroughly watered into the lawn as soon as possible after application, and cultural practices that encourage annual grassy weeds must be modified to favor the turfgrass (most importantly, mow at 2.5-4 inches). Be aware that overseeding or reseeding lawns may not be possible for several weeks or months after applying a preemergence herbicide. It is more difficult to control annual weedy grasses growing in established lawns with postemergence herbicides. Products containing quinclorac are available to control crabgrass, foxtails, and barnyardgrass infestation.

Herbicides for Newly Seeded Lawns

Special care should be taken when applying herbicides on newly seeded lawns because of the sensitivity of seedling plants. Among the preemergence herbicides, only mesotrione can be used on newly seeded or established cool-season turfgrass for control of broadleaf seedlings and warm-season grassy weeds such as crabgrass, foxtails, and barnyardgrass. Mesotrione is combined with a starter fertilizer to be used at planting and is available to home gardeners as Scotts Turf Builder Starter Food For New Grass Plus Weed Preventer. Postemergence herbicides selective for broadleaf weeds can be used once the turfgrass has produced several tillers and has been mowed two or three times.

Weed and Feed Products

Some fertilizer products contain either preemergence or postemergence herbicides (or both) for weed control (usually crabgrass prevention or broadleaf weed control). Use these combination products only when the lawn has a known weed problem and not every time you fertilize. Be sure the active ingredient in the product is one that will control the weed species causing your problems and also that the timing of the application is right. There is no point in applying preemergence herbicides after the majority of target weeds have emerged. Weed and feed products for existing weeds (dandelion, clover, thistle, etc) must be applied to wet grass and weeds; follow all label instructions in order to get good weed control and to avoid turf injury.

Corn Gluten Meal for Organic Weed Control

This is a waste product left over from the processing of corn and is often marketed for weed control. It has high nitrogen content (9-10 percent nitrogen by weight) and makes for a good organic nitrogen fertilizer. Research conducted at a number of universities across the U.S. suggests that the use of corn gluten meal as an organic weed control product provides little to no reliable control of crabgrass and other weeds. However, corn gluten meal may help in weed management because its fertilizer effect makes the turfgrass more competitive against weed invasion. Corn gluten meal has no effect on already emerged weeds.

Herbicide Success Tips

Lawn and garden companies market their own brand names of herbicides. These trade names are so numerous and change so often that they cannot all be listed in this publication. Shop for herbicides by looking for the common name or active ingredient that appears on the label in small print under the title "Ingredients." Unlike brand names, common names for active ingredients do not change from company to company. Different products will vary in the percentages of active ingredients they contain. Some products are formulated as ready-to- use to allow for the convenience of no mixing, others as granules, and many others as higher-concentration liquid sprays that require mixing with water.

Follow all label directions carefully and only apply herbicides at the time of year and at the rates recommended. Be sure the herbicide is effective against the weed you are trying to control and that it is recommended for your type of lawn. Improper use could injure or kill desirable turfgrass or other plants in the landscape.

Remember that many broadleaf weed herbicides are prone to drift, volatilization (forming a gas at temperatures greater than 80 F), or can be injurious to shallow tree and shrub roots growing in the lawn. Do not apply herbicides under hot, dry, or windy conditions as they could injure turfgrass or nearby ornamentals.

Selective Preemergence Herbicides *(Herbicides applied before weeds emerge)*

Common Name	Sample trade name(s)	Comments
benefin + trifluralin	Team 2G	Controls grasses and some broadleaves; has extended grass control; has some turfgrass species restrictions
dithiopyr	Crabgrass & weed preventer (many brands – often combined with fertilizer)	Controls many grasses and broadleaves (e.g., oxalis, spurge); (has postemergence activity on young crabgrass); safe for most turfgrass species
isoxaben	Bayer Season Long Weed Control for Lawns; Gallery	Controls broadleaves (e.g., oxalis, spurge) and has very minimal activity on grasses; has some turfgrass species restrictions
mesotrione	Scotts Turf Builder Starter Food for New Grass Plus Weed Preventer; also Tenacity	Controls grass weeds and yellow nutsedge in newly seeded lawns; several turfgrass species restrictions
pendimethalin	Scotts Halts Crabgrass Preventer	Controls grasses (very effective on crabgrass) and some broadleaves; has some turfgrass species restrictions; often included with fertilizers
prodiamine	Sta-Green Crab-ExPlus with Lawn Fertilizer	Controls grasses (very effective on annual bluegrass and crabgrass) and some broadleaves (spurge)

Selective Postemergence Herbicides *(Herbicides applied after weeds emerge)*		
Common Name	**Sample trade name(s)**	**Comments**
Mixtures of 2,4-D, dicamba, and mecoprop (MCPP)	Trimec Lawn Weed Killer Spectracide Weed Stop Ortho Weed B Gon Weed Killer for Lawns products	Many brand names and formulations available; combines 3 active ingredients and controls most broadleaves (weak on oxalis); dicamba products may harm ornamentals if roots are in lawn or drift occurs
mixtures of 2,4-D, 2,4-DP, dicamba, MCPP, carfentrazone, quinclorac	Bayer All in One Weed & Crabgrass Killer Gordon's Speed-Zone Lawn Weed Killer Monterey Crab-E-Rad Plus Ortho Weed B Gon Weed Killer products Spectracide Weed Stop for Lawns plus Crabgrass Killer	Many brand names and formulations available; combines 2-4 active ingredients and controls most broadleaves and some weedy grasses; dicamba products may harm ornamentals if roots are in lawn or drift occurs
Mixture of 2,4-D, dicamba, MCPP, sulfentrazone, quinclorac	Roundup for Lawns	Very broad spectrum weed control: broadleaf weeds, annual grassy weeds, yellow nutsedge.
halosulfuron	Sedgehammer, Monterey Nutgrass Killer II	Effective on sedges
mesotrione	Tenacity	Safe for use on both seedling and established turf. Do not use on bermudagrass or fine fescue lawns unless damage can be tolerated. Provides good control of annual grassy weeds (crabgrass, foxtail, barnyardgrass) and some perennial grassy weeds (bentgrass, windmillgrass, nimblewill).
quinclorac	available combined with other broadleaf weed herbicides Drive XLR8, Quinclorac	Selectively removes some weedy grasses and broadleaves from many established turfgrasses; some turfgrass species restrictions. Will control fountaingrass in cool-season lawns.
sulfentrazone	Ortho Nutsedge Killer for Lawns	Effective on yellow and purple nutsedge, green kyllinga, and several hard to control broadleaves such as curly dock, knotweed, plantain, spurge, wild garlic, wild onion, woodsorrel (oxalis)
triclopyr	Monterey Turflon Ester Turflon	Controls broadleaves (especially clover, oxalis) and suppresses bermudagrass in cool-season lawns; not for use on warm-season turfgrass species
triclopyr + MCPA + dicamba	Monterey Spurge Power Ortho Weed B Gon Weed Killer for Lawns products	Controls a broader spectrum of broadleaves (e.g., spurge, wild violet, dandelion); not for use on warm-season turfgrass species

Inclusion of product names does not imply any endorsement or that the products will work effectively, nor does exclusion of any product names imply criticism of the product. Please contact author with corrections, or to have additional products added to these lists.

Tony Koski tony.koski@colostate.edu

Draft version 2
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Indicator Weeds

Compacted Soils
annual bluegrass (*Poa annua*)
common chickweed (*Stellaria media*)
goosegrass (*Eleusine indica*)
knotweed (*Polygonum aviculare*)
mouse-ear chickweed (*Cerastium vulgatum*)
prostrate spurge (*Euphorbia supina*)

Dry Soil
black medic (*Medicago lupulina*)
dandelion (*Taraxacum officinale*)
bindweed (*Convolvulus spp.)*
kochia (*Kochia scoparia*)
stinkgrass (*Eragrostis cilianensis*)

Dry, Infertile Soils
black medic (*Medicago lupulina*)
yarrow (*Achillea millefolium*)

Moist or Poorly Drained Soils
annual bluegrass (*Poa annua*)
roughstalk bluegrass (*Poa trivialis*)
barnyardgrass (*Echinochloa crusgalli*)
bentgrasses (*Agrostis spp.)*
common chickweed (*Stellaria media*)
crabgrasses (*Digitaria spp*.)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
violets (*Viola spp*.)
yellow nutsedge (*Cyperus esculentus*)

Moist, Fertile Soils
annual bluegrass (*Poa annua*)
curled dock (*Rumex crispus*)
henbit (*Lamium amplexicaule*)
yellow woodsorrel (*Oxalis stricta*)

Moist, Infertile (Low N) Soils
black medic (*Medicago lupulina*)
plantains (*Plantago spp*.)
white clover (*Trifolium repens*)

Low Mowing Height
annual bluegrass (*Poa annua*)
crabgrasses (*Digitaria spp.)* y
ellow woodsorrel (*Oxalis stricta*)
white clover (*Trifolium repens*)

New Seedings (Spring/Summer)
annual bluegrass (*Poa annua*)
barnyardgrass (*Echinochloa crusgalli*)
crabgrasses (*Digitaria spp.)*
purslane (*Portulaca oleracea*)
foxtail (*Setaria spp.)*

New Lawn Seedings (Fall; winter annuals)
henbit (*Lamium amplexicaule*)
storksbill, red-stem filaree (*Erodium cicutariuim*)
shepardspurse (*Capsella bursa-pastoris*)
annual mustards (many)

Old Lawns (25-30+ years)
Bentgrasses, redtop (*Agrostis spp*.)
Orchardgrass (*Dactylis glomerata*)

Shady Lawns
annual bluegrass (*Poa annua*)
roughstalk bluegrass (*Poa trivialis*)
bentgrasses (*Agrostis spp.)*
common chickweed (*Stellaria media*)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
nimblewill (*Muhlenbergia shreberi*)
violets (*Viola spp*.)

Formerly Agricultural/Farm Land
barnyardgrass (*Echinochloa crusgalli*)
bindweed (*Convolvulus spp.)*
Canada thistle (*Cirsium arvense*)
foxtail (*Setaria spp.)*
quackgrass (*Elytrigia repens*)
smooth bromegrass (*Bromus inermis*)

Vegetable Garden Weed Management

Tony Koski, Extension Turf Specialist

Weeds compete with vegetables for light, water and nutrients, can interfere with harvesting and may increase the potential for vegetable disease problems. Complete elimination of weeds in the vegetable garden is neither realistic nor necessary. Effective weed management can employ several strategies, depending on weed species involved and personal preferences regarding use of pesticides and other weed management tools.

Understand the Sources of Weeds

- Weed seed exists in all garden soils
- Manure, compost, and other soil amendments often contain weed seed
- Imported topsoil will always contain weed seed (no matter claims to the contrary), and may contain rhizomes, bulbs and other plant parts that may grow into a weed
- Plant-based mulch materials (straw, hay, grass clippings) may contain weed seed
- Weed seed can be moved into gardens by wind, water, humans or animals
- Weeds may move from other areas of your landscape, adjacent fields, neighboring landscapes by above- (stolons, runners) or below-ground (rhizomes) laterally growing stems
- It is impossible to prevent or eliminate weeds – but persistent, proper management can result in a nearly weed-free vegetable garden
- Soil disturbance (tilling, digging, hoeing, pulling weeds, foot traffic) encourages weed seed germination

Preventing Weed Growth

Weed prevention is always preferable to (and easier than) having to manage weeds after they have begun growing. Prevention involves a combination of practices – cultural and chemical (optional) – which create conditions unfavorable for weed growth.

Cultivation Practices

- Soil disturbance encourages weed seed germination by exposing buried seed to light – a stimulus for seed germination (buried seeds don't germinate)
- Consider preparing soil (tillage, amendment incorporation) for planting 3-4 weeks prior to planting and control emerging weeds ("fallowing")
    - As weeds emerge, but prior to planting, cultivate SHALLOWLY to kill seedling weeds
    - Kill emerging weed seedlings with synthetic or "natural" herbicides (see below)
    - Kill emerging weed seedlings by flaming (see below)
- If herbicides or flaming aren't options, mulch immediately following tillage
- If soil doesn't require amendment prior to planting, consider use of a broadfork to loosen soil (this reduces weed seed movement to the surface of the soil)

Written 6/2014; revised 3/2018.

Plant Spacing

- Use recommended plant spacing to create competition for weeds
- Consider the use of block planting to increase competition against weeds
- The critical weed-free period for most warm-season vegetables is about 45 days after planting, after which time plant canopy will be big enough to shade the weeds and inhibit their growth. Thus, early-season weed control is critical
- Squash, corn, potatoes, cabbage, broccoli, tomatoes are strong competitors against weeds
- Lettuce, carrots, peppers, onions, peas, radish are poor competitors against weeds

Mulch

- Will smother existing weeds and/or prevent germination of weed seeds
- Grass clippings are ideal mulch for vegetable gardens
- Hay and straw can be effective mulch, but may introduce weed seeds to the garden
- Wood chips and sawdust should be used sparingly; their decomposition can increase the need for nitrogen
- Newspaper and cardboard can be used between rows (must be weighed down)
- Plastic mulch can be used to increase soil temperature for warm-season crops
- All mulches will reduce water loss and irrigation needs (especially plastic mulch)

Irrigation Practices

- Overhead sprinkler irrigation, which also applies water to soil where plants are not growing, will encourage weed growth
- Drip irrigation wets a lesser amount of soil and encourages less weed growth
- When drip irrigation and mulch are used together, weed problems in the vegetable garden are significantly reduced
- Use of drip irrigation will reduce the potential for disease occurrence and spreading of disease pathogen by splashing
- Drip irrigation will produce equivalent yields but uses less water than overhead irrigation

Thermal Weeding (flaming, steam, boiling water)

- Used on fallowed seedbeds before vegetable seedlings emerge
- Can be used between rows after vegetable emergence
- Burning and/or fire hazard is an obvious concern
- Most effective on seedling broadleaf weeds; less effective on grasses and sedges
- Not effective on perennial weeds unless repeated

Solarization

- Soil is covered with clear plastic (gets hotter than black plastic) for 4-6 weeks to kill weeds, weed seeds, and some plant pathogens
- Can be very effective if done during warmest time of the year
- Garden can't be used during solarization process
- Any subsequent tillage will bring weed seeds to surface (only seeds in surface 2-3 inches will be killed)

Herbicides for Use in Vegetable Gardens

Synthetic

- Glyphosate (Roundup, Kleenup, many other names)
  - Non-selective; postemergence
  - Systemic; good for perennial weed control
  - No root activity; no soil residual
  - No activity on seeds
- Trifluralin (Preen)
  - Preemergence
  - Kills germinating seeds
  - Will not control weeds you can see
  - Short residual (6-8 weeks)
  - Soil disturbance will reduce effectiveness

"Natural"/Organic

- Corn gluten meal (CGM)
  - VERY limited preemergence activity – if any
  - Short residual (4-6 weeks), if any
  - Contain 10% nitrogen
  - Rates and application frequency recommended for weed control may encourage excessive vegetable growth
- Soaps, essential oils, acetic acid, iron sulfate
  - Non-selective (can damage desirable plants)
  - Disrupt leaf cuticle; burns leaves
  - Not systemic; full coverage of weed is essential
  - Most effective on seedlings; **PERENNIALS WILL GROW BACK**
  - Must be reapplied for control of larger/perennial weeds

Managing Difficult Perennial Weeds in the Home Landscape

The four most difficult weeds encountered in the home landscape – lawns, vegetable gardens, flower and shrub beds – include four perennial weeds: bindweed, Canada thistle, quackgrass and bermudagrass. Though these are very different species, they behave similarly as weeds in the landscape. All are non-native, deep-rooted perennials that spread by underground rhizomes (bermudagrass also spreads above-ground by stolons or runners). While all can produce seed, the main way that they spread in the landscape is by their laterally growing stems. They all can survive – and even thrive – without any supplemental irrigation and will persist through the longest and most severe droughts because all four produce extremely deep roots (as deep as 6 feet or more). **The key to eradicating these perennial weeds is to interrupt/prevent photosynthesis and depleting stored energy by forcing the plant to continuously produce new shoots, leaves, and roots.** By reducing the plant's ability to re-supply underground energy reserves via photosynthesis, it uses up energy by constantly re-growing new leaves, stems, and roots.

MULCHING prevents photosynthesis and forces the plant to use energy to push leaves and stems through the mulch layer
- Deeper mulch (3-6 inches) is more effective
- Sheet mulching (using newspaper or cardboard) under a layer of soil or other mulch can be very effective – but weeds will grow laterally and emerge at the borders of the sheet mulched area
- Pull/cut plant tops (or spray with appropriate herbicide) as soon as they grow through the mulch
- Persistent, diligent removal of new growth that emerges through and at the borders of the mulch will result in successful control – but this may take years (especially if herbicides are not used)

CULTIVATION (plowing, tillage, hoeing, pulling) can be effective if performed diligently and persistently through consecutive growing seasons
- Will be more effective if done in conjunction with herbicides
- Cultivation will disturb the weed seed bank and may lead to other weed problems

SOLARIZATION can be an effective tool for managing these perennial weeds
- Subsequent tillage of a solarized area may result in germination of buried, unkilled seeds
- Weeds can still infest the solarized area from its borders

BIOCONTROLS
- Biocontrols never result in total eradication of the weed; rate of weed population reduction can be slow
- There are no biocontrols for quackgrass or bermudagrass
- Bindweed mite (*Aceria malherbae*) can be effective where bindweed receives no irrigation
- For more information on using bindweed mites go to: http://www.colostate.edu/Dept/CoopExt/Adams/weed/bindweed_mite.html

HERBICIDES can be effective when used with the above management tools
- Glyphosate (Roundup, Kleenup, many other product names) is the only synthetic POSTEMERGENT herbicide that can legally be applied to vegetable gardens by the home gardener for control of these perennial weeds
- Glyphosate can provide excellent perennial weed control when used with mulching and cultivation practices
- Corn gluten meal will be ineffective for managing perennial weeds, and may increase their aggressiveness because nitrogen in CGM may stimulate weed growth
- Use of acetic acid/vinegar and other "natural"/organic weed control products will only be effective if used repeatedly and in conjunction with other management tools described above

Natural Herbicides for Landscape Weed Management

Tony Koski, Extension Turf Specialist
Colorado State University

Increasing demand for alternatives to traditional, synthetic weed control products like glyphosate and 2,4-D has resulted in the development and sales of many “natural” or “organic” products for controlling lawn, garden and landscape weeds. Relatively little research has been conducted to evaluate their efficacy (compared to traditional herbicides), and how these new herbicide alternatives can be used most effectively. More and more shelf space is being dedicated by retailers to herbicides that are considered by some to be less-toxic alternatives.

The alternative weed-control products contain oils (clove oil, eugenol, and d-limonene), soaps (pelargonic acid), acids (acetic, citric) or iron compounds (chelates). All of them function in essentially the same way: they destroy the leaf cuticle and the integrity of leaf cells, causing cell leakage that can lead to rapid leaf death. These are often referred to as “burn-down) herbicides. While very fast-acting (symptoms often appear within a few hours of application), effectiveness is dependent on good coverage. All of these are contact herbicides that kill only green parts of the plant they contact. The lack of systemic activity limits their effectiveness for the control of weeds having extensive root systems or underground storage structures such as rhizomes, tubers, or bulbs; perennial broadleaf and grassy weeds like thistle, bindweed, quackgrass, and bermudagrass are not controlled easily using these products. These herbicides work most effectively on small weeds (seedlings) and annuals that haven’t grown too large.

Users of these alternative herbicides should also be aware of the fact that many of these products have the potential to cause skin irritation, and eye or lung problems if not used with caution. Minimally, eye protection and gloves should be worn when using these natural herbicides, even if they are listed as exempt products. Horticultural vinegar (20% acetic acid) products can be quite hazardous to handle.

Effectiveness of the alternative, contact herbicides can be increased by:

- ensuring good spray coverage
- applying in warm/hot weather (at least 75° to 80°F), and with minimal cloud cover
- adding surfactants to improve coverage and to reduce “beading” of droplets on leaves
- treating when weeds are small/young
- repeating applications (especially important for larger and/or perennial weed20

Essential oil herbicides

WeedZap (45% clove oil + 45% cinnamon oil)

Bioganic Broadleaf Killer (2% clove and thyme oil; 1% sodium laurel sulfate; 10% acetic acid)

Burnout II (12% clove oil, 8% sodium laurel sulfate, vinegar, citric acid)

EcoSmart Weed and Grass Killer (sodium laurel sulfate and eugenol; 2-phenethyl propionate)

GreenMatch EX (50% lemon grass oil)

Repellex Weed-A-Tak (8% clove oil; 8% cinnamon oil; 4% citric acid)

Citrus oil-based herbicides

Avenger

GreenMatch (55% d-limonene)

Worry Free Weed and Grass Killer (70% citrus oil)

Acid-based herbicides

WeedPharm (20% acetic acid)

AllDown (23% acetic acid; 14% citric acid)

C-Cide (vitamin C-based product)

Natural Guard (citric acid and soybean oil)

The acetic acid concentration for herbicidal use should be about 10 to 20%. Household/culinary vinegar is about 5% acetic acid and isn't effective for controlling most weeds.

Fatty acid-based herbicides (aka herbicidal soaps)

Scythe

Safer Moss and Algae Killer

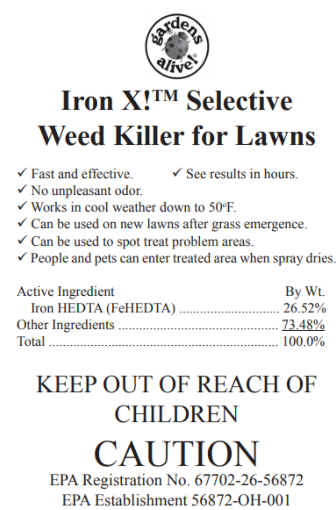
Safer Fast Acting Weed and Grass Killer

Monterey Herbicidal Soap

Natria Weed and Grass Killer

Iron HEDTA herbicides

Bayer Advanced Natria Lawn Weed Control	26.5% (concentrate)
Fiesta Turf Weed Killer	26.5% (concentrate)
Iron-X Selective Weed Killer for Lawns	26.5% (ready to use)
Ortho Elementals Lawn Weed Killer	1.5% (ready to use)
Whitney Farms Lawn Weed Killer	1.5% (ready to use)



Inclusion of product names neither implies effectiveness, nor endorsement by the author or Colorado State University. Not all products described may be commercially available, and the active ingredient content may be changed by manufacturers. Read CAREFULLY and follow all label instructions whenever using any pesticides. 7/2015 ver 2

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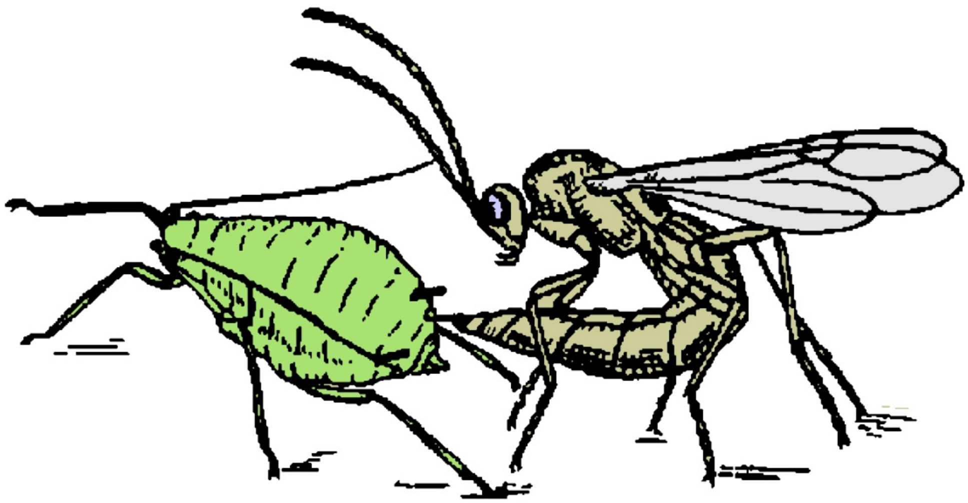

Identifying Insects

Reference

CMG GardenNotes

Books

- ***Garden Insects of North America*** by Whitney Cranshaw. Princeton University Press. 2004.
- ***Insects and Diseases of Woody Plants of the Central Rockies*** by Dr. Whitney Cranshaw, Colorado State University Extension # 506A. 2004.
- ***Pests of the West*** by Dr. Whitney Cranshaw. Fulcrum Publishing. 1998. ISBN: 1-55591-401-2

Curriuclum developed by David E Whiting, Extension Consumer Horticulture Specialist (retired), Colorado State University. Revised by Mary Small, Colorado State University Extension.

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Learning Objectives

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

- Identify common insects to taxonomic orders.

Review Questions

1. Describe the identifying characteristics of the following orders:

    a. *Coleoptera* (beetles)
        1) Adults
        2) Typical *grubs*
        3) Some borer larva in trees

    b. *Diptera* (flies)
        1) Adults
        2) Larva: *maggot*

    c. *Hemiptera*, *Suborder Heteroptera*,(true bugs)

    d. *Hemiptera, suborder Homoptera*
        1) Aphids
        2) Scale

    e. *Hymenoptera* (bees, wasps, sawflies, etc.)
        1) Adults
        2) Sawfly larva

    f. *Lepidoptera*
        1) Adults (butterflies, moths)
        2) Larva: *caterpillars*

    g. *Orthoptera* (Grasshoppers, katydids, and crickets)

2. How do you quickly tell the following orders of insects apart?

    a. Caterpillars (*Lepidoptera* larva) from sawfly larva (*Hymenoptera*)
    b. *Diptera* adults (flies) from *Hymenoptera* adults (bees, sawflies, hornets etc.)
    c. Hemiptera, *Homoptera* suborder nymphs from *Heteroptera* suborder nymphs
    d. Hemiptera, *Homoptera* suborder adults and *Hemiptera* suborder adults
    e. *Beetles* (Coleoptera) from true bugs (*Hemiptera, suborder Heteroptera*), and cockroaches (*Blattaria*)

3. What orders and families have maggot or maggot-like larva?

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CMG GardenNotes #311

Taxonomy of Arthropods
(Insects and Insect Relatives)

Outline:

Introduction

Insects and Mankind

Insects are the most abundant and diverse form of life found on earth. Over three-quarters-of a million species are known to exist, more than the number of all kinds of animals and plants put together. Insects are a vital part of the world's ecosystem.

Insects are a major link in the world food chain. Insects like bees, wasps, flies, bugs, and beetles pollinate crops. Insects destroy various weeds in the same manner that they can injure crops. Insects improve the physical conditions of the soil, and promote its fertility by decomposing plant residues and aerating the soil. Insects help control insect pests as predators and parasites. Only a few of the thousands of species are pests of mankind or his crops.

Most books list insect pests according to host plants, or by orders (beetles, bugs, flies, etc.) and families (aphids, scales, leaf beetles, etc.). When gardeners can identify insects to order, they will be able to identify the majority of pests by the process of elimination. Most routine garden pests are readily identifiable to order, some to families. However, there are always a few insects, with atypical appearances, that do not fit standard descriptions.

Insect Orders

"Order" is one of the levels of taxonomy. Most common names for insects describe the insect *orders*. For example, "beetle" is the common name for members of the *Coleoptera* order, and "butterflies" and "moths" for the *Lepidoptera* order.

Insect Identification

Identifying an insect is easy when:

- The insect is large enough to see.
- The insect is associated with plant damage.
- The insect has typical characteristics for the order and family.

Insect identification is more difficult when:

- The insect is too small to see characteristics.
- The insect is not associated with plant damage.
- The insect has atypical characteristics for the order or family.
- The insect has moved on, leaving only damage symptoms.

Taxonomy of *Arthropoda* (Insects and Insect Relatives)

The phylum *Arthropoda* includes insects, plus spiders, mites, tick, sowbugs, centipedes, millipedes, and more. They are characterized by chitinous exoskeletons, segmented bodies and jointed appendages.

Class

- ***Arachnida*** — Spiders, mites, ticks, scorpions, and daddy-long-legs
- ***Chipoda*** — Centipedes
- ***Crustacae*** — Lobsters, crabs, shrimp, sowbugs, and pillbugs
- ***Diplopoda*** — Millipedes
- ***Symphyla*** — Garden centipedes
- ***Hexapoda*** (or *Insecta*) — Insects

Orders of Hexapoda

- ***Coleoptera*** — Beetles
- ***Diptera*** — Flies
- ***Lepidoptera*** — Butterflies and moths
- ***Hemiptera*** — True bugs
- ***Homoptera*** — Aphids, cicadas, leafhoppers, scales
- ***Hymenoptera*** — Ants, bees, hornets, sawflies, wasps
- etc.

Family

Some insects, such as beetles, are easy to identify to family, while others, like flies, are more difficult.

<u>Genus and species</u>

Actual identification of an insect to genus and species requires a very high level of expertise.

Insect Relatives

Class: *Arachnida*
Spiders, Mites, Ticks, Scorpions, Daddy-Long-Legs

Arachnids (spiders, mites, and ticks) have four pair of legs and two body regions, the ***cephalothorax*** (a fusion of head and thorax) and the abdomen. [Figure 1]

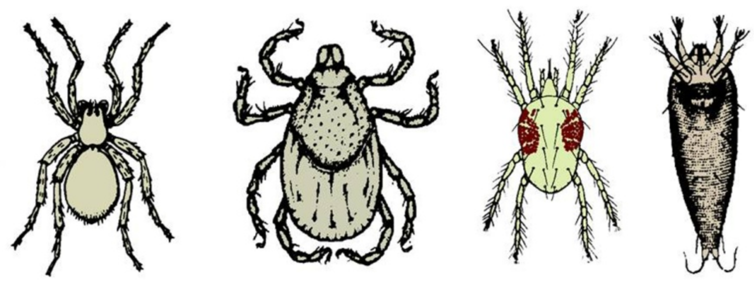


Figure 1. Arachnids (left to right): spider, dog tick, two-spotted mite, eriophyid mite

Class: *Crustacea*
Sowbugs, Pillbugs, Shrimp, Lobster, and Crayfish

Pillbugs and sowbugs are land crustaceans that usually have 5-7 pair of legs. They have two pair antennae and two body regions. The pillbug will roll into a ball, the sowbug cannot. [Figure 2]

Pillbugs and sowbugs are organic matter feeders, occasionally feeding on tender roots. Pillbugs and sowbugs can become a pest when numbers become very high or when they invade a home.

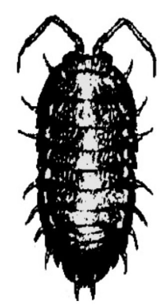


Figure 2. Sowbug

Class: *Diplopoda*
Millipedes

Millipedes have <u>two pair of legs per body segment</u> (except the first three). The body is usually cylindrical, 1 to 1 1/2 inches long, with short antennae. They may have 15 to 150 body segments, with 30 being common. [Figure 3]

Millipedes are usually found in damp and dark places, such as under leaves, under stones or boards, in rotting wood and in soils high in organic materials. If touched or picked up when crawling, they will curl up. They frequently invade homes, especially after a heavy rainstorm. They are not known to bite people. However, some species will give off an ill-smelling fluid. Most are scavengers and feed on decaying plant materials and overripe fruit. A few species attack living plants.

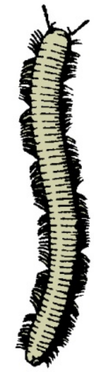


Figure 3. Millipede

Class: *Chilopoda*
Centipedes

Centipedes have flattened bodies with typically 40-50 body segments and one pair of legs per body segment. [Figure 4]

They are predatory, feeding on small spiders, carpet beetles, sowbugs, millipedes, and other small insets.

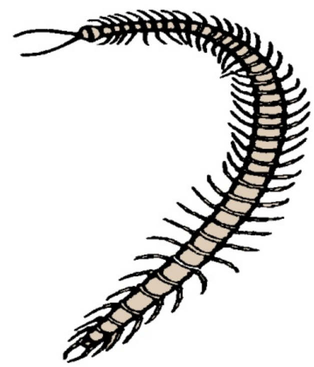


Figure 4. Centipede

Class: *Symphyla*
Garden Centipede

Garden centipedes are small (1/4" long), translucent relatives of centipedes. They have 12 pairs of legs at maturity and are usually found in the upper 6 inches of soil. They feed on germinating seeds and underground parts of plants. Centipedes, predatory mites and predaceous ground beetles are predators of symphylans.

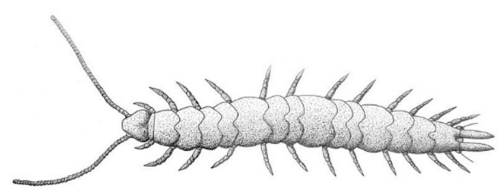


Fig 5. Garden Symphylan

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings: USDA; Symphyla: Wikimedia Commons. Revised by Mary Small, CSU Extension.

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #312

Insect Anatomy and Growth

Identification and classification of insects is based on their structure and physiology. A basic understanding of insect physiology will enable the gardener to identify most insects to order and some to family.

External Structure

The exterior body wall, called an ***exoskeleton***, provides the structural support for the insect. It is composed of five distinct layers made of waxy lipoproteins and *chitin* (a cellulose like polymerized glucosamine). The acid resistant exoskeleton protects the insect from excessive dryness, humidity, and disease organisms.

This external skeleton is somewhat cylindrical and typically made up of 21 hardened, ring-like *segments*. These segments are arranged in three groups or body regions, the ***head***, ***thorax*** and ***abdomen***. The body may be covered by ***setae*** (hairs*)* and may have external protuberances, such as horns, spines, or spurs. [Figure 1]

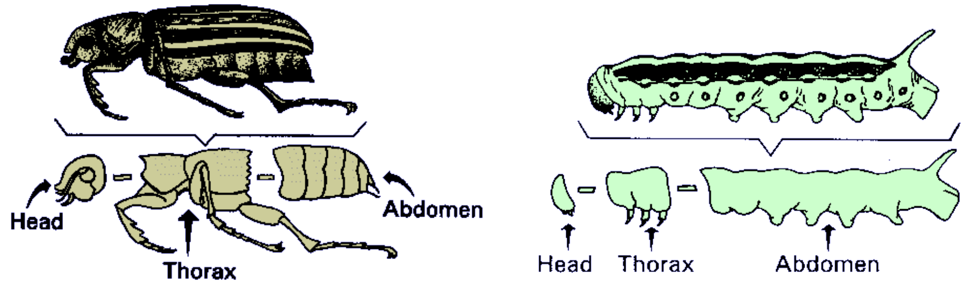


Figure 1. Body regions of beetle (left) and caterpillar (right).
[Line drawing: Colorado State University Extension]

Head

The head serves as a sensory center and for the intake of food. Main features of an insect's head include the eyes, antennae, and mouthparts.

Eyes

Insects have two types of eyes. To detect movement, most adult insects have a pair of lateral **compound eyes** comprised of multiple *ommatidium* (cornea). The number of ommatidia in the eye determines how well insects see. For example, dragonflies have approximately 50,000 per eye, house flies about 4,000 and ants about 50. These large compound eyes often occupy the greater portion of the insect head. Insects with large compound eyes are often predators, while insects with small compound eyes are often the prey. [Figure 2]

The ***ocelli*** or simple eyes are used for light responsiveness. Two or three are typically located between the larger compound eyes on most insect adults. Some immatures may have one to eight lateral ocelli. [Figure 2]

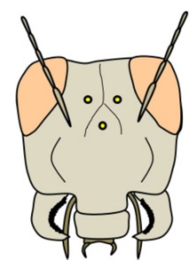


Figure 2. Grasshopper head; note large eyes, three ocelli between eyes, and large mandibles (chewing mouthparts). [Line drawing: David Whiting]

Antennae

All adult insects and many immature stages have a pair of segmented antennae, used for sensory function. Many modifications in form occur and these variations are often used in identification.

Mouthparts

The most remarkably complicated structural feature of insects is the mouth. Mouthparts are modified for various types of feeding, chewing, or sucking.

The ***mandibles*** or ***chewing mouthparts*** move horizontally on insects. Insects with chewing mouthparts consume the plant or insect they are feeding upon. [Figure 3]

Figure 3. Chewing mouthparts of a beetle. [Photograph by David Whiting]

Sucking-type mouthparts vary greatly for different feeding habits. ***Piercing-sucking*** mouthparts are typical of the *Hemiptera* (true bugs), *Homoptera* (aphids, scales) and blood sucking lice, fleas, mosquitoes, and the so-called biting flies. These are designed to punch and suck on the plant's sap, victim's blood, or in the case of predatory insects to suck out the insides of the victims. [Figures 4 & 5]

Figure 4. **Piercing-sucking mouthparts of a cicada** — Insects with piercing-sucking mouthparts feed on plant sap, blood, or in the case of predators, their victim's insides. They do not consume the plant or insect tissues. [Photograph by David Whiting]

Figure 5. **Lapping mouthparts** — Flies are an example of an insects with lapping mouthparts. . [Line drawing: Colorado State University Extension]

The **siphoning** type found in butterflies and moths is a long coiled tube designed to suck up nectar. It looks like a cinnamon roll coiled up under the head. [Figure 6]

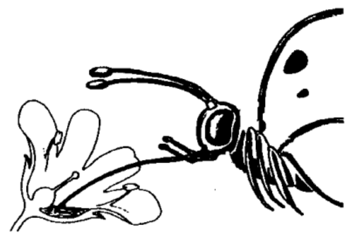


Figure 6. **Siphoning mouthparts** — Butterflies and moths have a coiled siphoning tube. To reach the nectar in flowers, the uncoiled tube may be longer than the butterfly's body. [Line drawing: Colorado State University Extension]

Intermediate types of mouthparts include the ***rasping-sucking*** type found in thrips, and the ***chewing-lapping*** types found in honey bees, wasps, and bumble bees.

Thorax

The **thorax** is made up of three segments (*prothorax, mesothorax and metathorax*).

Legs – A pair of legs is attached on each thorax segment. The insect's leg consists of five independent movable parts. Legs may be specially adapted for leaping, walking, digging, grasping, swimming, etc.

Wings – Insects may have one or two pairs of wings or no wings. The wings are attached to the latter two thorax segments. The wing ***venation*** (arrangement of the veins) is different for each species of insect and is often a means of identification. Wing surfaces are covered with fine hairs, scales or may be bare. On beetles, the thickened front wing, call ***elytra***, serves for protection when not in flight.

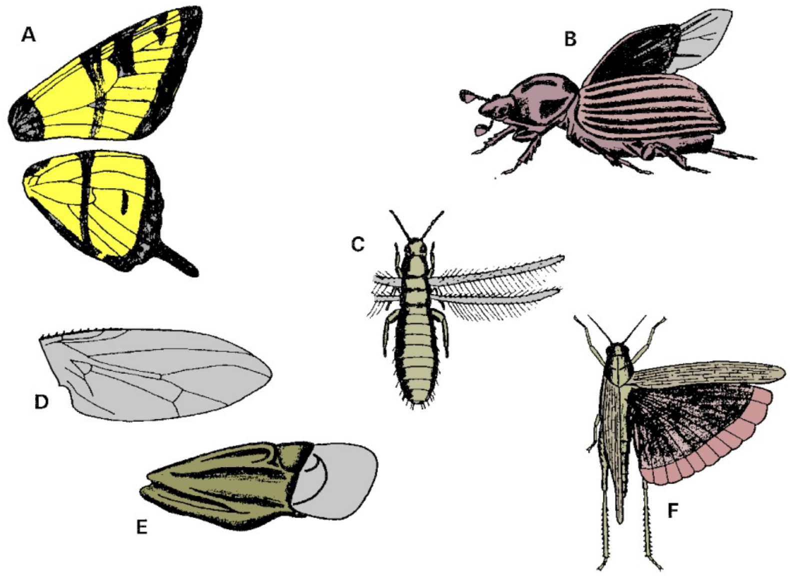


Figure 7. Types of insect wings: (A) scaly wing of moths and butterflies, (B) armor-like (elytron) and membranous wings of beetles, (C) feather wings of thrips, (D) membranous wing of a fly, (E) half-leathery/half-membranous wings (memelytron) of true bugs, and (F) wings of grasshoppers. Line drawing: Colorado State University Extension]

Abdomen

The **abdomen** may have eleven or twelve segments, but in most cases they are difficult to distinguish.

Prolegs (fleshy leg-like projections) occur on some larva such as caterpillars and sawfly larva. Prolegs, with tiny crochet-type hooks on the bottoms help the insect cling to plants. [Figure 8]

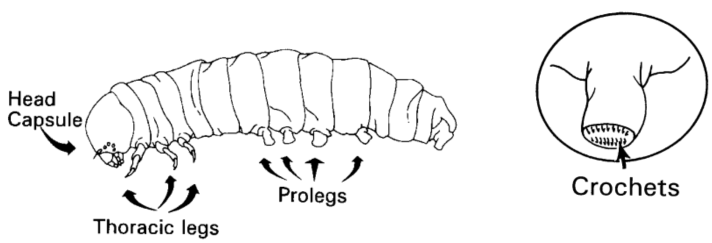


Figure 8. **Prolegs** (leg-like appendages on the abdomen of caterpillars and sawfly larvae) have small crochet-like hooks that help the insect cling to plants. [Line drawing: Colorado State University Extension]

Some insects have a pair of appendages called ***cerci*** at the tip of the abdomen. The pinchers on earwigs are the best-known example of cerci. Cerci may be short, as in grasshoppers, termites and cockroaches, extremely long as in mayflies, or curved as in the earwigs. They are sensory structures and may be used for defense or capturing prey. [Figure 9]

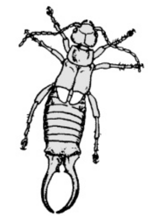


Figure 9. Earwig with cerci (pinchers) on end of abdomen.

Some groups have additional long segmented ***filaments***, which appear like antennae. [Figure 10]

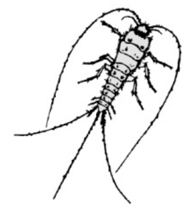


Figure 10. Silverfish with three filaments on end of abdomen.

The females of some insects have a prominent structure for depositing eggs, called an ovipositor. In bees, wasps, and ants the ovipositor is modified into a stinger. [Figure 11]

Figure 11. Horntail with large ovipositor on end of abdomen

The ***spiracles***, external openings used for respiration, are also present on the abdomen. Digestion, respiration, excretion, and reproduction are the main functions of the abdomen.

Internal Structure and Physiology

The muscular, digestive, circulatory, respiratory, nervous, and reproductive systems of insects are highly efficient. The insect's skeletal system has already been discussed as part of the external structure.

While insect **muscles** are very small, they are very strong and often capable of extremely rapid contractions. Grasshoppers are said to have over 900 distinct muscles and some caterpillars over 4,000. In comparison to humans, insect muscle tissues are very strong.

The **circulatory system** of insects is an open type. The blood is pumped by the heart from the abdomen toward the head, bathing the organs in the body cavity. Blood functions to transport nutritive materials to the tissues and to carry away certain wastes. With a few exceptions, the blood of insects contains no red corpuscles, and plays no part in respiration.

The **respiratory system** consists of a series of slender branching tubes or *tracheae*, which divide and subdivide throughout the body. Movement of oxygen and carbon dioxide is primarily by diffusion. Breathing-like movements help to ventilate the tracheae.

Insects have a two-part **nervous system**. The sympathetic nervous system controls functions of the heart, digestion, respiration, and possibly other systems. The peripheral nervous system controls sensory stimulations from the external environment.

Most insect **reproduction** is sexual, (the union of an egg cell from the female with the sperm cell from the male). Some species are capable of producing young without fertilization (***parthenogenesis***). A few species carry the eggs internally, giving birth to live young (***ovoviviparous***). Glands of the insect reproductive systems are similar to that found in higher animals.

Growth and Metamorphosis

The series of events from egg to adulthood constitutes the insect's ***life cycle***. The life cycle varies for each insect species. For example, mosquitoes under optimum environmental conditions may develop from egg to adult in 10 days, whereas the periodical cicadas require 13 to 17 years to complete their life cycle.

<u>An understanding of an insects' life cycle is a critical element in insect management practices</u>.

Because the *exoskeleton* cannot expand sufficiently to accommodate an increase in size, it is cast off during the process called ***molting***. The number of moltings varies considerably in the insect world. The form of an insect between successive molts is called an ***instar***.

The ***pupa*** is a non-feeding stage during which the larval structures are transformed into adult structures. ***Cocoon*** refers to pupal cases made of silk from the modified salivary glands of the larva. ***Chrysalis*** is a term that denotes the pupa of a butterfly.

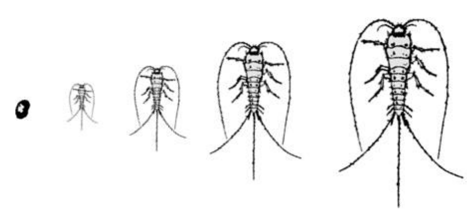
<u>Metamorphosis</u>

One of the most distinctive features of the insect world is ***metamorphosis***, the marked or abrupt change in form, structure, and habit. Four basic types of metamorphosis are observed in the insect world.

No Metamorphosis

Upon hatching from the egg, the young insect with "no metamorphosis" development looks exactly like the adult except for size and minor differences in spines and setae (hairs). Size is the major change between each instar. Some species may molt after sexual maturity. The young and adults live in the same environment, and have the same types of mouthparts and feeding habits. These groups of very primitive, wingless insects include the *Thysanura* (silverfish) and *Collembola* (springtails). [Figure 12]

Figure 12. No Metamorphosis of silverfish: from egg (left), nymphs, and adult (right)



Simple Metamorphosis

In simple metamorphosis, the insect goes through three basic changes, egg, nymph, and adult. The nymphs typically go through three to five instars. Some books further divide simple metamorphosis into gradual and incomplete types.

In **gradual metamorphosis**, the newly hatched insect resembles the adult in general body form, but lacks wings and external genital appendages. With each successive molt, the nymph resembles the adult more than it did in the previous instar. Both nymphs and adults have the same type of mouthparts and food habits. Grasshoppers, squash bugs, and aphids are examples of insects with gradual metamorphosis. [Figure 13]

Figure 13. Simple-Gradual Metamorphosis of stink bug: from left to right: egg, nymphs, and adult.

Incomplete metamorphosis is characteristic of some orders with aquatic nymphs, such as *Emphemeroptera* (mayflies), *Odonata* (dragonflies), and *Plecoptera* (stoneflies). The changes that occur during the immature instar stages are more pronounced than in the case of insects with gradual metamorphosis, but not nearly so dramatic as in complete metamorphosis. The young, called *nymphs* or *naiads*, are aquatic insects found in rivers and streams, while the strikingly different fly-like adult is aerial. [Figure 14]

Figure 14. Simple-Incomplete Metamorphosis of Dragonfly from egg (left), naiads, and adult (right)

Complete Metamorphosis

Insects with complete metamorphosis have four developmental stages; **eggs**, **larva**, **pupa**, and **adult**. The insect may have several instars and molts as a larva, but it does not pick-up the characteristics of the adult with each molting. The larval stage is primarily an eating and growing state. All larvae have chewing or modified chewing mouthparts. [Figure 15]

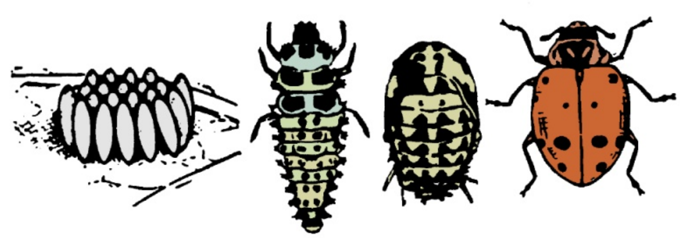


Figure 15. Complete metamorphosis of beetle from left to right: egg, larva (grub), pupa, and adult.

Various names apply to the larvae of insects from different orders. Beetle larvae are known as ***grubs***, butterfly and moth larvae are called ***caterpillars***, and the larvae of flies are known as ***maggots***. Grubs typically have three pair of legs on the thoracic segment and no prolegs on the abdomen. Caterpillars have three pair of legs on the thoracic segment and up to five pair of prolegs (fleshy leg-like structures on the abdomen). By comparison, sawfly larvae have more than five pair of prolegs. Maggots are typically legless.

When the larvae have attained maturity, they cease to feed and following a period of inactivity transform into the pupa stage. In the pupa stage the insect usually remains inactive and does not feed, but undergoes marked physiological and morphological changes. The insect emerges from the pupa stage as a functional adult.

In the case of many insects, provisions are made by nature to protect the helpless pupa. Some seek protection in the ground, while others hide under the bark of trees. Some spin cocoons of silk (moths) or pupate in the last larval skin (flies).

The primary function of the adult insect is reproduction. In many insect groups, the adults die soon after mating and laying eggs. Some adults do little or no feeding.

Insects with complete metamorphosis may have entirely different types of mouthparts and food habits in the larval and adult stages. For example, caterpillars (larva of butterflies and moths) have chewing mouthparts and feed on a variety of materials, while the adults have siphoning mouthparts and normally feed on plant nectar. Flea larvae feed on inert organic materials with their chewing mouthparts, while the adults suck the blood of their hosts.

Diapause is defined as a state or period of suspended activity in any stage of the life cycle. This state is initiated or terminated by environmental stimuli, such as photoperiod (length of the daylight), temperature, moisture, nutrition, or a combination of these. Diapause should not be confused with the cycles in metamorphosis.

Because eggs and pupa are non-feeding stages, they are resistant to insecticides. This is important point to remember when dealing with insect management.

Insect Names

All insects are classified into order, family, genus and species using scientific Latinized names. Scientific names are unique for that insect throughout the world. Genus names always begin with a capital letter, and species names are written entirely in lower case. Scientific names are printed in italics or underlined. In technical papers, the first entry of an insect name is followed with the name of the author whom first described the species. For example the honey bee, first described by Linnaeus is written *Apis mellifera* Linnaeus.

Common names, generally used by the public, often refer the insect to its groups such as orders, suborders, families or subfamilies, rather than individual species.

For example, "beetle" applies to all species in the order *Coleoptera*; "leaf beetle" applies to species in the family *Chrysomelidae*.

Generally, only the insect species commonly known by the public have common names. Most insect species occurring in the world do not have a common name.

Most common names of insects that consist of a single word (i.e., beetles, earwigs, thrips, or termites) refer to an entire order. Most common names applied to families consist of two or more words, the last being the name of the larger groups. For example, Carrion beetles, lady beetles, bark beetles, and blow flies.

Some common names are used for insects in more than one order, such as "fly" and "bug". The correct use and spelling of these words will help you identify orders. When a "bug" belongs to the *Hemiptera* order (often referred to as the "true bugs") it is written as two words (bed bugs, stink bugs, water bugs). When it does not belong to this order, it is written as one word (sowbugs, pillbugs, ladybugs). The same principle applies to "flies" and the fly order *Diptera*. Insects in the Diptera (fly) order are written as two words (house fly, deer fly, flower fly). When the fly-like insect is of another order, it is written as one word (dragonfly, stonefly, Mayfly).

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings from USDA. Photographs by David Whiting. Reviewed by Mary Small, Colorado State University Extension.

Reviewed July 2017

CMG GardenNotes #313

Insect Orders

Anoplura
Sucking Lice

- Feeds by sucking blood from mammals.
- Some species (head lice and crabs lice) feed on humans.

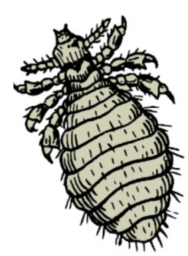


Figure 1. Sucking lice

Metamorphosis: Simple/Gradual

Features: [Figure 1]

- Wingless
- Mouthparts: Piercing/sucking, designed to feed on blood.
- Body: Small head with larger, pear-shaped thorax and nine segmented abdomen.

Blattaria (Subclass of *Dictyoptera*)
Cockroaches and Woodroaches

- Most species are found in warmer subtropical to tropical climates.
- The German, Oriental and American cockroach are indoor pests.
- Woodroaches live outdoors feeding on decaying bark and other debris.

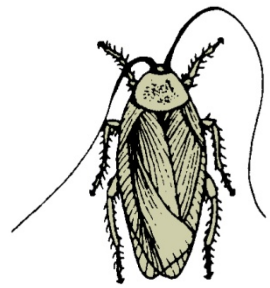


Figure 2. American cockroach

Metamorphosis: Simple/Gradual

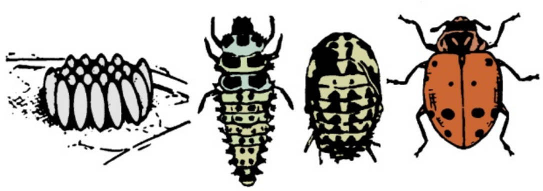
Features: [Figure 2]
- o <u>Body:</u> Flattened
- o <u>Antennae</u>: Long, thread-like
- o <u>Mouthparts:</u> Chewing
- o <u>Wings:</u> If present, are thickened, semi-transparent with distinct veins and lay flat.

Coleoptera
Beetles and Weevils

- *Coleoptera* is the largest order of insects with 290,000 species worldwide and some 24,000 species in North America.
- Many species are plant feeders; some are predaceous (ground and lady beetles), scavengers (scarab and hide beetles), or aquatic.
- The term *weevil* refers to a snout beetle.

Metamorphosis: Complete [Figure 3]

Figure 3. Coleoptera metamorphosis (left to right): egg, grub, pupa, and adult



Adults:
- o <u>Wings</u>: two pair
  - ▪ Front pair, called ***elytra***, are greatly thickened and shell-like (form fitting) and make a straight line down the back when at rest.
  - ▪ Hind wings are membranous and protected by the front pair.
  - ▪ A few beetles are wingless, or have only the front pair.
- o <u>Mouthparts:</u> Chewing
- o <u>Antennae:</u> Noticeable, generally quite stout
- o <u>Cerci</u> (tail-like appendage): None

Larva:
- o <u>Legs</u>:
  - ▪ Larva that feed externally on plants are the typical "grub" with head capsule, three pair of legs on thorax, and no prolegs on the abdomen. [Figure 4]

    - Some larva that feed internally in plants (e.g., bark beetles, and wood borers) may be maggot-like with no head capsule and no legs.
- Mouthparts: Chewing

Figure 4. Grub with head capsule, three pair of legs on the thorax, and no prolegs on abdomen.

Beneficial families include:
- Blister beetles, *Meloidae*
- Carrion beetles, *Silphidae*
- Checkered beetles, *Eleridae*
- Darkling beetles, *Tenebrionidae*
- Fireflies, *Lampyridae*
- Ground beetles, *Carabidae*
- Lady beetles, *Coccinellidae*
- Rove beetles, *Staphylinidae*
- Scarab beetles, *Scarabaeidae*
- Soldier beetles, *Cantharidae*
- Tiger beetles, *Cicindelidae*

Pest families include:
- Bark and ambrosia beetles, *Scolytidae*
- Blister beetles, *Meloidae*
- Carpet beetles, *Dermestidae*
- Click beetles or wireworms, *Elateridae*
- Ground beetles, *Carabidae*
- Leaf beetles, *Chrysomelidae*
- Longhorned beetles or roundheaded borers, C*erambycidae*
- Metallic wood beetles or flatheaded borers, *Buprestidae*
- Sap beetles, *Nitidulidae*
- Scarab beetles including rose chafer, *Scarabaeidae*
- Seed beetles, *Bruchidae*
- Weevils, *Curculionidae*

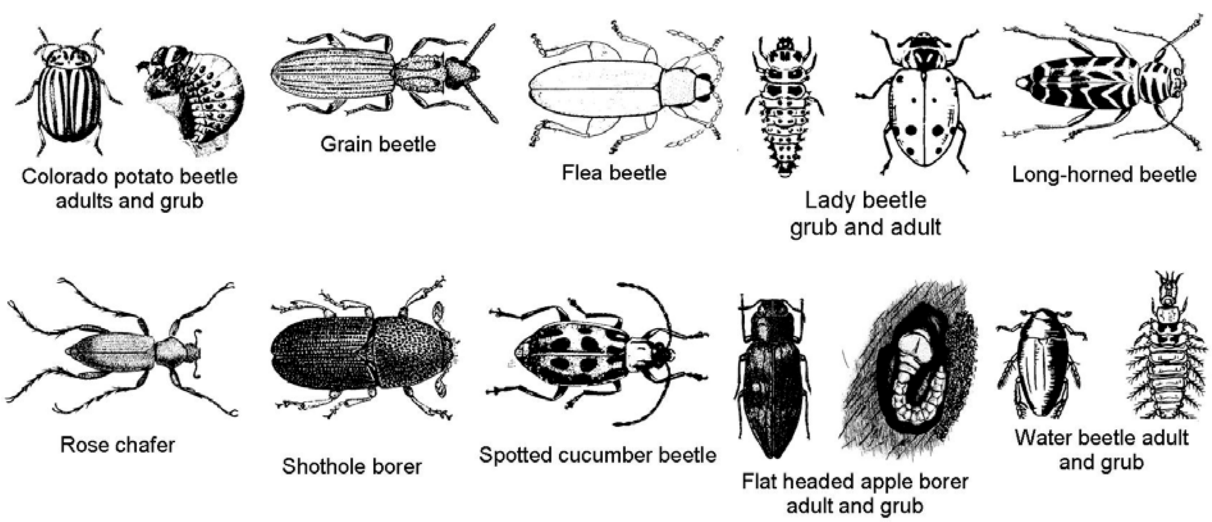


Figure 5. Examples of common beetles

Collembola
Springtails

- Very tiny (1-2 mm) soft-bodied insect almost always associated with soil.
- Very common but rarely observed due to tiny size.
- Most feed on algae, fungi, and other organic matter. Some are predators of other insects and mites found in the soil.

Metamorphosis: None

Features: [Figure 6]
- o <u>Wingless</u>
- o <u>Mouthparts:</u> Chewing
- o <u>"Springtail"</u>: (furcula) often present, used to jump.

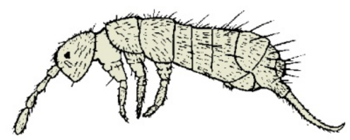


Figure 6. Springtail

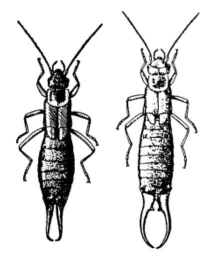
Dermaptera
Earwigs

- Introduced from Europe as a biological control.

Metamorphosis: Simple/Gradual

Features: [Figure 7]
- o <u>Mouthparts:</u> Chewing; generally feed on decaying organic matter, occasionally on plants and insects.
- o <u>Wings:</u> 2 pair
  - Front wings are short, leathery, without venation and meet in a straight line down the back when at rest.
  - Hind wings are membranous, broad, with veins radiating from a center, folded both lengthwise and crosswise when at rest.
  - Note: Wings can be confused with those of beetles, but beetles do not have forceps-like cerci (tail-like appendage).
- o <u>Body:</u> Elongated, flattened insects
- o <u>Cerci:</u> Strong moveable forceps-like cerci on the abdomen end. Cerci cannot produce a painful pinch, but the mouthparts can.
- o <u>Habit</u>: Over-winters as adults. During the day, earwigs hide in dark, moist areas. They are often assumed to cause a plant problem when they may simply be hiding on or near the plant.

Figure 7. Earwigs: Female (left) has straight cerci, male (right) has curved cerci.

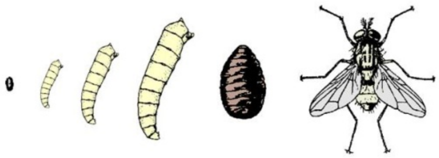


Diptera
Flies, Gnats, Midges, and Mosquitoes

- Around 99,000 species worldwide, with some 17,000 in North America.
- Feeding habits vary widely, for example
    - Scavenger (house fly, blow fly)
    - Blood sucking (mosquitoes)
    - Plant galls (gall midges)
    - Predators (flower flies, robber flies)
    - Aquatic

Metamorphosis: Complete [Figure 8]

Figure 8. Complete metamorphosis of flies.



Adults [Figures 8-10]
- Wings: One pair, membranous
    - One pair is a quick identifcation for *Diptera*.
    - Note: Count the wings! Some *Diptera* look like bees or wasps. Some *Hymenoptera* (bees and wasps) look like flies. *Diptera* has one pair. *Hymenoptera* have two pair, the hind pair is typically smaller and hidden under the front pair.
- Mouthparts: Highly variable
    - Sponging (house fly)
    - Cutting-lapping (horse fly)
    - Piercing-sucking (mosquito)
- Body: Typically soft bodied and often hairy.

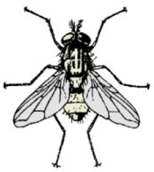


Figure 9. House fly.

Larva [Figures 8 and 10]
- Vary greatly in appearance.
- Larva of advanced forms, like the house fly, are ***maggot*** type
    - No head capsule
    - Mouth hooks
    - Legless
- Lower forms, such as mosquitoes, have a head capsule.

Pupa: Typically pupate in last skin of larva.

Beneficial families include:
- Bee flies, *Bombyliidae*
- Crane flies, *Tipulidae*
- Gall gnats *Cecidomylidae*
- Robber flies, *Asilidae*
- Syrphid or flower flies, *Syrphidae*
- Tachinid flies, *Tachinidae*

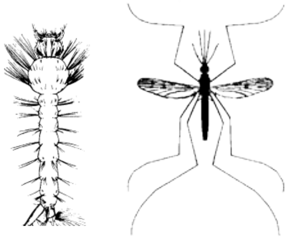


Figure 10. Mosquito maggot and adult.

Pest families include:

- Cabbage, onion, and seed corn maggots, beet leaf miner, *Anthomyiids*
- Biting midges, *Certopogonidae*
- Black flies, *Simuliidae*
- Blow flies, *Calliphoridae*
- Crane flies, *Tipulidae*
- Fruit flies, *Tephritidae*
- Gall gnats *Cecidomylidae*
- Horse and deer flies, *Tabanidae*
- Horse bot flies, *Hippoboscidae*
- Leafminer flies, *Agromyzidae*
- Mosquitoes, *Culicidae*
- Muscids (house flies), *Muscidae*
- Sand flies (no-see-ums), *Psychodidae*
- Syrphid or flower flies, *Syrphidae*
- Vinegar flies, *Drosophilidae*

Ephemeroptera
Mayflies

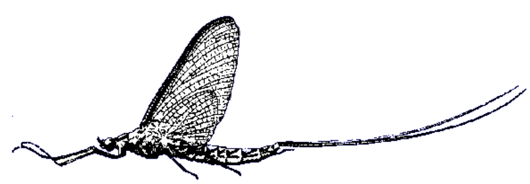
- Small aquatic naiads found in the bottom of streams and lakes. Serves as a source of food for fish.
- No interaction with gardening activities.

Metamorphosis: Simple/Incomplete

Adults: [Figure 11]

- Wings: two pair
  - Front wings large and triangular shaped.
  - Hind wings small and rounded.
  - Wings held vertically over body.
- Antennae: Small, bristle-like
- Filaments: Two very long tail-like filaments.
- Mouthparts: Adults do not feed and only live a few days.

Figure 11. Mayfly adult



Naiads: [Figure 12]

- Body: Aquatic naiads vary in shape, most are broad, and have functional gills along the sides of the abdomen.
- Mouthparts: Chewing.
- Molting: Frequent; 20 to 60 times

Figure 12. Mayfly naiad .

Hemiptera Order, Suborder: Heteroptera
TRUE BUGS: Plant Bugs, Squash Bugs, Stink Bugs

Note: Research has led to the re-ordering of insects. True bugs are the Hemiptera order, but now have their own suborder. In older references you will still find Hemiptera without the suborders.

- This order includes many important insect predators.

Metamorphosis: Simple/Gradual [Figure 13]

Figure 13. Metamorphosis of stink bugs.

Features: [Figure 14]
- Mouthparts: Piercing-sucking
  - Jointed beak is typically visible, and originates from top of head in front of eyes.
- Wings: two pair
  - Front wings (called *hemielytra*) are thickened at base and membranous at end.
  - Hind wings are membranous.
  - When at rest, the wings overlap at the tips forming a large triangular plate (the *scutellum*) on the back.
- Body: Usually broad and somewhat flattened

Beneficial families include:
- Ambush bugs, *Phymatidae*
- Assassin bugs, *Reduvlidae*
- Coreids, *Coreidae*
- Damsel bugs, *Nabidae*
- Flower or minute pirate bugs, *Antocoridae*
- Leaf or plant bugs, *Miridae*
- Stink bugs, *Pentatomidae*

Pest families include:
- Chinch and lygus bugs, *Lygaeidae*
- Coreids, squash bugs, *Coreidae*
- Lace bugs, *Tingidae*
- Stink bugs, *Pentatomidae*

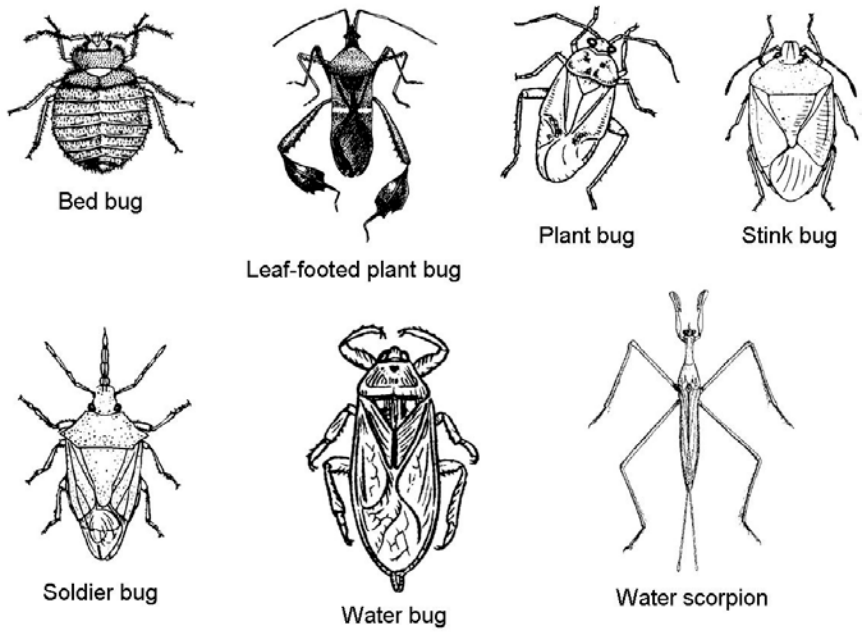


Figure 14. Examples of common *Hemiptera* (true bugs)

Hemiptera Order, Suborder: Auchenorrhyncha
Hemiptera Order, Suborder: Sternorrhynca
Aphids, Cicadas, Leafhoppers, Mealybugs, Scale and Whiteflies

Note: Research has led to the re-ordering of insects. These insects used to be in their own order, Homoptera, but are now a sub-order of Hemiptera. You will still find references to Homoptera. You may also still find references to Hemiptera without the suborders.

- All species are plant feeders, often feeding on phloem sap.
- Excretion of honeydew is common to many members of the order.
- Insects of this order are carriers of several plant pathogens.

Metamorphosis: Simple/Gradual
- Nymphs and adults similar in appearance (except male scales and whiteflies).

Features: [Figure 15]
- Mouthparts: Piercing-sucking
  - *Auchenorrhyncha* mouthparts arise from under the head; *Sternorrhyncha* mouthparts arise from between the forelegs.The jointed beak-like mouthparts not easily visible.

  Note: In contrast, in the *Heteroptera* suborder, mouthparts are more visible and originate from top of head, in front of eyes.
- Wings: two pair
  - Membranous
  - Typically held roof-like at rest
  - Many forms are wingless

- Nymphs have no wings, but wing pads may be observed on some older nymphs.

Pest families include:
Suborder Auchenorrhyncha:

- Cicadas, *Cicadidae*
- Leafhoppers, *Cicadellidae*
- Planthoppers, superfamily *Fulgoroidea*
- Spittlebugs, *Cercopidae*
- Treehoppers, *Membracidae*

Suborder Sternorrhyncha:

- Adelgids, *Phylloxeridae*
- Aphids, *Aphididae*
- Armored scales, *Diaspididae*
- Mealybugs, *Pseudococcidae*
- Psyllids (many gall insects), *Psyllidae*
- Soft scale, *Coccidae*
- Whiteflies, *Aleyrodidae*

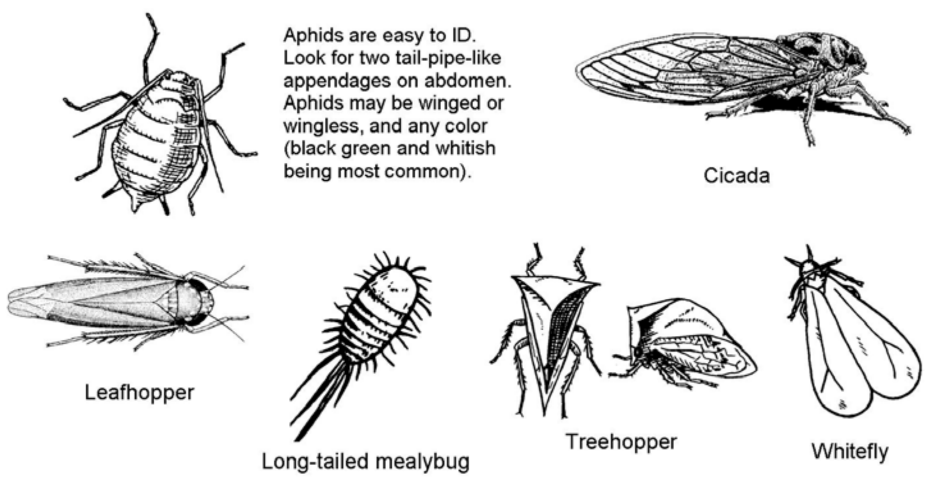


Figure 15. Examples of common *Hemiptera in either Auchenorrhyncha or Sternorrhyncha*

Hymenoptera
Ants, Bees, Horntails, Sawflies, and Wasps

- Large order with some 103,000 species worldwide and 18,000 in North America.
- Order includes many important parasites and predators.
- This order has the most highly developed insect behaviors and social patterns.
- Most species live in nests.

Metamorphosis: Complete

Adults [Figure 16]

- Wings: 2 pair, membranous
  - Hind wing is usually smaller and often hidden under front wing.
  - Front and hind wings may be attached.
- Mouthparts: Typically chewing or chewing-sucking
- Body: Most species have a distinct constriction between the thorax and abdomen (wasp waist). The sawfly/horntail group does not have a "wasp waist").
- Antennae: Jointed, sometimes elbowed
- Stinger: Female abdomen usually provided with a saw, piercing organ, or stinger.

Larva

- Larvae of most species are rarely observed, often developing in a nest or as an internal parasite.
- Head: Distinct head capsule
- Legs: None (except sawfly larva)
  - Sawfly larva look like caterpillars but have six-plus pair of prolegs.
  - Note: Caterpillars (*Lepidoptera)* have five or fewer pair prolegs.
  - Some sawfly larva are legless and slug-like.
- Mouthparts: Chewing

Wasp or Bee?

Wasps have a slender and thin body, a narrow waist, slender, cylindrical legs and a skin that generally lacks much hair. Yellow jackets, bald-faced hornets, and paper wasps are the most common wasps encountered by people.

Wasps are predators, feeding on insects and other arthropods. During late summer and autumn when insect prey becomes more scarce, many wasps become scavengers and are especially attracted to sweets and other carbohydrates.

Bees are robust-bodied and very hairy compared with wasps. The hair on bees is branched giving them a fuzzy or soft appearance. Their hind legs are flattened, with bristle-fringed areas for collecting and transporting pollen. Bees laden with pollen will appear to have yellow hind legs because of the pollen loads. Bees are vegetarians, feeding on nectar and pollen.

Beneficial families include:

- Ants and parasitic wasps, superfamily *Scolioidea*
- Bees, superfamily *Apoidea*
- Chalcid wasps, *Chalcidoidea*
- Digger wasps, superfamily *Sphecoidea*
- Ichneumon and braconid wasps, superfamily *Ichneumonoidea*
- Social wasps, superfamily *Vespoidea*

Pest families include:

- Ants, superfamily *Scolioidea*
- Gall wasps, superfamily *Cynipoidea*

- Horntails, superfamily *Siricoidea*
- Sawflies, *Tenthredinoidae*
- Social wasps, superfamily *Vespoidea*

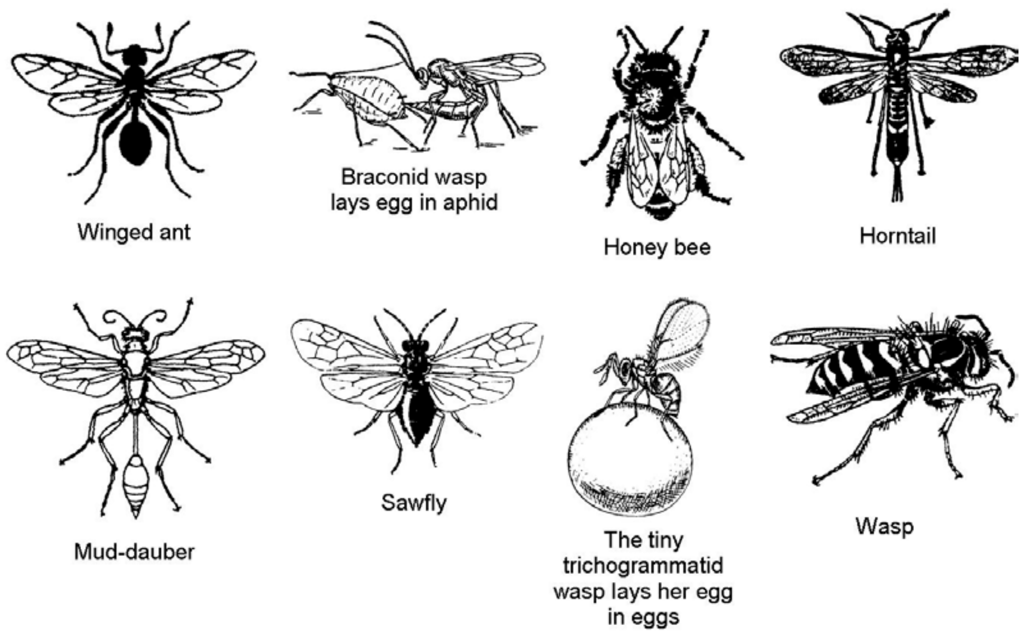


Figure 16. Examples of common *Hymenoptera*

Isoptera
Termites

- Termites are social insects living in colonies. Colorado species live below ground.
- Workers avoid exposure and are rarely seen except when disturbed. Only the winged reproductive adults leave the colony.

Metamorphosis: Simple/Gradual

Features: [Figure 17]
- Color: Creamy white
- Wings: two pair that are the same size and longer than the body.
- Body: rectangular-shaped with NO constriction (wasp waist) between thorax and abdomen.
- Antennae: Straight and beaded
- Mouthparts: Chewing

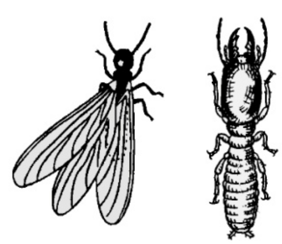
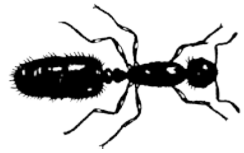


Figure 17. Winged adult termite (left), and worker termite (right)

Ant or Termite?

	Ant	Termite
		
Color	Black, red, yellowish, etc.	Creamy white
Waistline	"Wasp waist"	No constriction
Antennae	Jointed, sometimes elbowed	Straight and bead-like
Wings on adult	Front wing larger and hind wing smaller; wings may be attached.	Front and hind wings same size, longer than body.
Worker's body	Typical "ant" shape	Rectangular body with large chewing mouthparts
Observed	Commonly seen crawling around	Worker termite rarely seen except when disturbed.

Lepidoptera
Butterflies and Moths

Metamorphosis: Complete

Adults [Figure 18]
- Wings: Two pair
  - Typically covered with small overlapping scales.
  - Often but not always highly colored.
- Mouthparts: Coiled sucking tube designed to siphon fluids like nectar.
  - Some adults do not feed.

Figure 18. The wings of butterflies and moths are generally covered with colorful scales.

Larva: *Caterpillars* [Figure 19]
- Legs: Three pair on thorax
- Prolegs: Up to five pair of prolegs (fleshy leg-like appendage with crochet-like hooks on the end which helps hold the insect to plants).
  - Note: Sawfly larva look like caterpillars but typically have six or more pair prolegs.
- Decorations: Often highly colored or decorated with spines or other appendages.
- Mouthparts: Chewing, with voracious appetites.

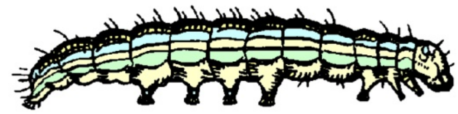


Figure 19. Caterpillars (larval stage of Lepidoptera) have three pair of jointed legs on the thorax plus up to five pair of prolegs on the abdomen.

Pupa

- Cocoon, made of silk spun from saliva glands

Families of interest include:

- Bagworm moths, *Psychidae*
- Carpenterworm moths, *Cossidae*
- Clearwing moths (squash vine borer, lilac borer), *Sesiidae*
- Giant silkworm moths, *Saturniidae*
- Leafrollers, Tortricidae
- Measuringworms, *Geometridae*
- Monarch, viceroy, red admiral, morningcloak and angelwings butterflies, *Nymphalidae*
- Noctuids (cutworms, armyworms, fruitworms, corn earworm, cabbage loopers), *Noctuidae*
- Olethreutid moths, *Olethreutidae*
- Prominents (redhumped caterpillars), *Notodontidae*
- Pyralids (corn borer, sod webworm, meal moths), *Pyralidae*
- Royal moths, *Citheroniidae*
- Silkworm moths, *Bombycidae*
- Sphinx or hawk moth, hornworms, *Sphingidae*
- Swallowtail or parsleyworm, *Papilionidae*
- Tent caterpillars, *Lasiocampidae*
- Tineids, (cloths moths), *Tineidae*
- Tussock moths, *Lymantriidae*
- White or yellow butterflies (imported cabbageworm), *Pieridae*

Mallophaga
Chewing or Biting Lice

- Tiny parasite of birds and some mammals.
- Feeds on blood, feathers, hair, skin, or sebaceous fluids.

Metamorphosis: Simple/Gradual

Features: [Figure 20]

- Flattened, oval
- Head larger than thorax
- Antenna short
- Eyes very small or absent
- No wings
- Legs short and modified to hold to feathers or fur
- Lives only on hosts

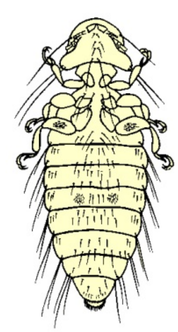


Figure 20. Chewing lice.

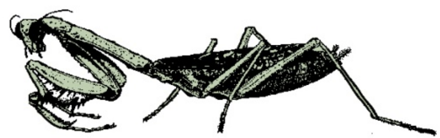
Mantodea
Mantids

- Predators of other insects, which they capture with front legs and eat.
- Winter is spent in the egg mass covered with a tough polystyrene-like coat.

Metamorphosis: Simple/Gradual

Features: [Figure 21]
- o <u>Legs</u>: Foreleg designed for grasping and holding prey
- o <u>Body</u>: Elongated
- o <u>Mouthparts</u>: Chewing
- o <u>Antennae</u>: Long, thread-like
- o <u>Wings</u>: If present, are leathery and over abdomen. Absent in nymphs.

Figure 21. Mantid



Neuroptera
Antlion, Lacewing, Snakeflies, and Dobsonflies

- Order includes many important predators.
- No harmful species are known.
- The antlion is the larva of the common lacewing. Some forms are aquatic.

Metamorphosis: Complete

Adults [Figure 22]
- o <u>Wings</u>: Two pairs
  - Membranous, similar in size and texture
  - Large membranous wing, usually with many veins and cross veins.
  - Held roof-like over body when at rest.
- o <u>Mouthparts:</u> Chewing; some are predators, while others feed on nectar or pollen.
- o <u>Cerci:</u> None
- o <u>Tarsus</u> (foot): Five segments

Figure 22. Lacewings: Left: adult, Right: Antlion (lacewing larva)

Larva [Figure 23]
- o <u>Mouthparts:</u> Forward-projecting curved pointed jaws designed to grasp prey, which they crush and suck out the insides.

- Body: Often elongated
- Legs: Three pair

Figure 23. Antlion (lacewing larva)

Odonata
Dragonflies and Damselflies

Metamorphosis: Simple/Incomplete

Adults [Figure 24]
- Eyes: Very large eyes that may cover much of head.
- Wings: Two pair
  - Large, elongated, highly veined.
  - Dragonflies hold wings horizontally when at rest. Damselflies project wings back over body when at rest.
- Mouthparts: Chewing, prominent, used to capture and consume winged prey in flight.
- Antennae: Small, bristle-like

Figure 24. Dragonfly adult

Naiads [Figure 25]
- Aquatic insect that feeds on mosquito larva and other aquatic life
- Eyes: Large
- Mouthparts: Uniquely hinged jaw that can project forward to capture prey.
- Gills: Three leaf-like gills at end of abdomen (damselfly only.)

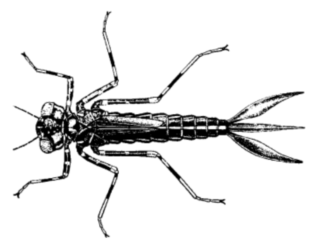


Figure 25. Dragonfly naiad

Orthoptera
Crickets, Grasshoppers, and Katydids

- Note: Older books place mantids (*Mantode*a), walking sticks (*Phasmida*) and roaches (*Blattaria*) in the order *Orthoptera*.
- Most are plant feeders. A few are predators or scavengers.

Metamorphosis: Simple/Gradual

Features [Figure 26]
- Mouthparts: Chewing
- Wings: Two pair
  - Front wings more or less parchment-like with distinct venations.
  - Hind wings membranous and folded fan-like when at rest.
  - Wings may be used to make sounds.
- Legs: Hind legs enlarged for jumping.
- Cerci (tail-like appendages): 1 pair on most adults

Pest families include:

- Crickets, *Gryliidae*
- Short-horned grasshoppers, *Acrididae*
- Long-horned grasshoppers (katydids, meadow grasshoppers, and Mormon crickets), *Tettigoniidae*

Figure 26. Orthoptera (left to right): grasshopper, cricket, and katydid.

Phasmida
Walking Stick

- Feeds on plant leaves.
- Stick-like form provides camouflage.

Metamorphosis: Simple/Gradual

Features: [Figure 27]
- Body: Very elongated, stick-like
- Mouthparts: Chewing
- Wings: typically none

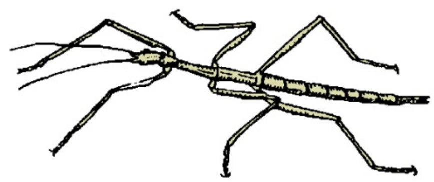


Figure 27. Walking stick

Plecoptera
Stoneflies

- Aquatic naiads cling to stones in streams and serve as food for other aquatic insects and fish.
- There is no direct interaction with gardening activities.

Metamorphosis: Simple/Incomplete

Adults [Figure 28]
- Wings: Two pair, elongated wings fold flat over body when at rest.
- Antennae: Long, filament-like
- Filament: (tail-like): Two

Figure 28 Stonefly adult

Naiads [Figure 29]
- Aquatic naiad typically found under stones in rivers and lake shores.

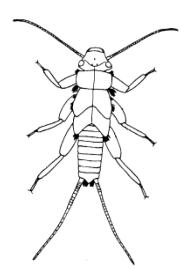


Figure 29. Stonefly naiad.

Psocoptera
Psocids or Booklice

- Common but inconspicuous insect rarely observed due to tiny size.
- Found in warm, damp places feeding on molds, fungi, cereals, pollen, etc.
- Occasionally invade the home.

Metamorphosis: Simple/Gradual

Features: [Figure 30]
- Size: Tiny, less than 1/8 inch
- Wings: Two pair on some adults
  - Held roof-like over body when at rest
  - Front pair larger
  - Veins prominent
  - Non-winged specimens common
- Mouthparts: Chewing
- Antennae: Slender and as long or longer than body

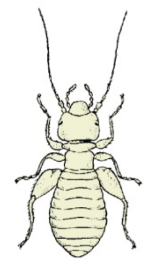


Figure 30. Booklice

Siphonaptera
Fleas

- Household pest of pets and people.

Metamorphosis: Complete

Adults [Figure 31]
- Size: Less than 1/8 inch
- Wingless
- Body: Flattened sideways, dark colored, covered with bristles that project backwards
- Mouthparts: Piercing/sucking, designed to suck blood.

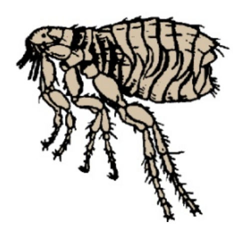


Figure 31. Flea

Thysanoptera
Thrips

- It is a very common insect, but due to tiny size is rarely observed.
- Feeding leaves the plant looking scarred, as they rasp the leaf or flower surface and suck the fluids.

Metamorphosis: Simple/Gradual

Features: [Figure 32]
- Wings: Two pair
  - Slender wings fringed with hairs

        - Often absent.
    - Mouthparts: Rasping-sucking; typically feed on flowers and leaves.
    - Tarsi (feet): One or two segmented, each with a balloon-like structure on the end.
    - Size: Minute, less than 1/8 inch long.

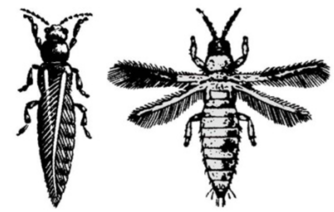


Figure 32. Thrips

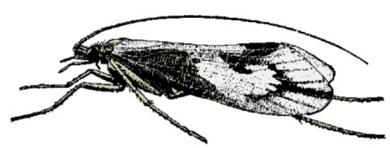
Trichoptera
Caddisflies

- Aquatic naiad.
- Not associated with gardening activities.

Metamorphosis: Simple/Incomplete

Adults [Figure 33]
- Wings: Two pair
    - Covered with fine hairs
    - Held roof-like over body at rest
    - Resemble moths with hairy wings.
- Antennae: Extended back over body

Figure 33. Caddisfly



Naiads
- Aquatic naiad
- Some live in cases constructed of silk, pebbles, sticks, and leaves. Others construct silken nests.
- Some are free-living and actively hunt other insects.

Zygentomaa
Silverfish and Firebrats

- Found in cool, moist, dark places.
- General feeder on starches and carbohydrates, including paper, wall paper, vegetables and grain products.

Metamorphosis: None

Features: [Figure 34]
- Size: Small, ¼” to ½”
- Wingless
- Mouthparts: Chewing
- Cerci: Pair, long tail-like
- Active, fast moving

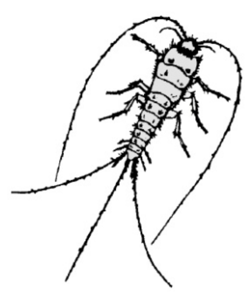


Figure 34. Silverfish

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings from USDA. Revised by Mary Small, Colorado State University.

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CMG GardenNotes #330-331

Plant Pathology

Bean Leaf with Necrotic Spots
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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #330

Plant Pathology
References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #331, *Plant Pathology*.

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #2.800, *Backyard Orchard: Apples and Pears* [pest management].
- #2.804, *Backyard Orchard: Stone Fruits* [pest management].
- #2.900, *Necrotic Ring Spot of Kentucky Bluegrass*.
- #2.902, *Powdery Mildew*.
- #2.903, *Non-Chemical Disease Control*.
- #2.904, *Juniper-Hawthorn Rust*.
- #2.907-1, *Fire Blight in Fruit Trees*.
- #2.907-2, *Fireblight in Ornamental Trees and Shrubs.*
- #2.910, *Bacterial Wetwood*.
- #2.920, *Aspen and Poplar Leaf Spots*.
- #2.925, *Mistletoes in Colorado Conifers*.
- #2.930, *Sycamore Anthracnose*.
- #2.931, *Strawberry Diseases*.
- #2.937, *Cytospora Canker*.
- #2.939, *Honeylocust Diseases*.
- #2.946, *Diseases of Roses in Colorado*.
- #2.947, *Greenhouse Plant Viruses* (TSWV-INSV).
- #2.948, *Pinyon Pine Insects and Diseases*.

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.
- #1400-21, *Fairy Rings*.
- #1411, *Fireblight*.
- #1423, *Dutch Elm Disease*.
- #1433, *Rose Diseases*.
- #1450, *Juniper-hawthorn Rust.*

- #1522, *Dollar Spot Disease of Turfgrass*.
- #1524, *Leaf Spot and Melting Out*.

Other

- *Insects and Diseases of Woody Plants of The Central Rockies* – Extension Bulletin 506A.
- *A Systematic Approach to Diagnosing Plant Damage*, Green, Malloy, Capizzi, Oregon State University, 1990, https://agsci.oregonstate.edu/sites/agscid7/files/horticulture/osu-nursery-greenhouse-and-christmas-trees/onn130601.pdf.
- *The 20 Questions of Plant Problem Diagnostics,* https://ohioline.osu.edu/factsheet/plpath-gen-3.
- *Abiotic Disorders of Landscape Plants*, Costello, Perry, Matheny, Henry, Geisel, University of California Agriculture and Natural Resources Publication 3420, 2003. ISBN-13: 978-1-879906-58-7.
- *Diseases of Annuals and Perennials – A Ball Guide: Identification and Control*, Chase, Daughtrey, Simone, APS Publishing, 1995.
- *Diseases of Trees and Shrubs*, 2nd edition, Sinclair, Lyon and Johnson, Comstock Publishing Associates, 2005. ISBN-13: 978-0801443718.
- *Diseases of Woody Ornamentals and Trees in Nurseries*, Jones and Benson, American Phytopathological Society (APS) Press, 2001.
- *Essential Plant Pathology*, 2nd edition, Gail Schuman and Cleora J. D'Arcy, APS Press, 2009.
- *Landscape Plant Problems*, Byther, Foss, Antonelli, Maleike, Bobbitt, and Glass. Washington State University Extension, MISC0194. 2006.
- *The Disease Compendia* series, APS Press. Booklets covering diseases of various crops including apple/pear, conifers, corn, cucurbits, foliage plants, peppers, potatoes, potted plants, raspberry, rose, stone fruits, strawberries, tomatoes, and turf. Available at https://my.apsnet.org/APSStore/.

Learning Objectives

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

- Define disease as it relates to plants.
- Describe the difference between a sign and a symptom.
- Identify the four components of the plant disease pyramid.
- Identify examples of biotic and abiotic causes of disease.
- Describe how to manage common leaf spot and canker diseases using Integrated Pest Management techniques.
- Describe and use the plant diagnostic process.

Review Questions

1. Define a plant disease.
2. What four components must be present for biotic disease development?
3. What is another name for a living cause of disease?
4. What is another name for a non-living cause of disease?
5. How do fungal pathogens spread? Bacteria? Phytoplasmas? Viruses?
6. Define the following terms:
    - Chlorosis.
    - Canker.
    - Mycelium.
    - Ooze.

7. List four ways to manage foliar diseases.
8. A client brings you a foot long branch of a chokecherry tree. The leaves on the branch tips are dark brown and wilted. The branch tip is bending over. Could this be fireblight? Why or why not?
9. What is the recommended pruning procedure for removal of fireblight-infected branches?
10. List two management techniques for tomato spotted wilt virus.
11. List two management techniques for canker diseases.
12. How are leaf scorch and winter desiccation similar?
13. List three characteristics of healthy roots.
14. When diagnosing plant problems, why is it important to know what a “normal” plant looks like?
15. Random patterns of injury point to a/an ________ problem; uniform patterns of injury point to a/an _______ problem.

CMG GardenNotes #331

Plant Pathology

Introduction

A plant disease is usually defined as abnormal growth and/or dysfunction of a plant. Diseases are the result of some disturbance in the normal life process of the plant.

Plants can be damaged by infectious/living organisms (***biotic*** factors) such as fungi, bacteria, viruses, and nematodes. They can also be damaged by noninfectious agents (***abiotic*** factors) such as soil compaction, wind, frost, soil salt damage, and girdling roots. Biotic factors cause ***biotic diseases*** while abiotic factors cause ***abiotic disorders*** (also called "abiotic diseases").

Plant Disease Pyramid

Specific conditions must be present for biotic disease to develop. Disease development occurs when there is a susceptible ***host*** plant, a ***pathogen*** (fungi, bacteria, viruses, etc.), and a conducive ***environment*** in a given point in time. These conditions make up what is called the ***Plant Disease Pyramid***. Biotic disease cannot occur if one of these pieces is missing. [**Figure 1**]

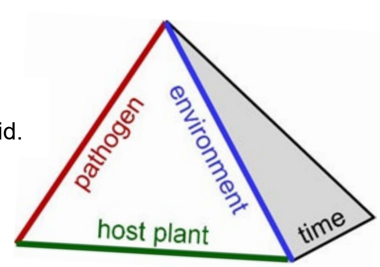


Figure 1.
Plant Disease Pyramid.

Symptoms

Symptoms of disease are the plant's reaction to the causal agent. In other words, symptoms are changes in the plant's growth or appearance in response to causal factors. Plant symptoms include:

- **Blight** – A rapid discoloration and death of twigs, foliage, or flowers.

- **Canker** – Dead area on bark or stem, often sunken or raised.
- **Chlorosis** – Yellowing or loss of green color on foliage. Chlorosis is so generic that without additional details diagnosis is impossible.
- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch, or root starting at the tip.
- **Distortion** – Malformed plant tissue.
- **Gall or gall-like** – Abnormal localized swelling or enlargement of plant part. It could be caused by insects, mites, diseases, or abiotic disorders.
- **Gummosis** – Exudation of gum or sap.
- **Leaf distortion** – The leaf could be twisted, cupped, rolled, or otherwise deformed.
- **Leaf scorch** – Burning along the leaf margin and into the leaf from the margin.
- **Leaf spot** – A spot or lesion on the leaf.
- **Mosaic** – Varying patterns of light and dark plant tissue.
- **Necrosis** – Dead tissue. Necrotic areas are also so generic that without additional details diagnosis is impossible.
- **Stunting** – Lack of growth.
- **Wilt** – General wilting of the plant or plant part.
- **Witches broom** – Abnormal broom-like growth of many weak shoots.
- **Insect feeding injury** – A symptom used in diagnosis, but not a symptom of disease.

Even though a plant has symptoms on a specific part, it does not necessarily mean the damaged tissue contains the organism causing the symptoms. For example, root rot can cause chlorosis and wilting of stems and leaves, but the disease causal organism is in the roots. It is *imperative* to examine as much of the plant as possible to determine exactly where the problem originates.

Signs

Signs are the actual organisms causing the disease. Signs include:

- **Conks** – Woody reproductive structures of fungi.
- **Fruiting bodies** – Reproductive structures of fungi; could be in the form of mushrooms, puffballs, pycnidia, rusts, or conks.
- **Mildew** – Whitish growth produced by fungi, composed of mycelium.
- **Mushrooms** – Fleshy reproductive structures of fungi.
- **Mycelium** – Thread-like vegetative growth of fungi.
- **Rhizomorphs** – Shoestring-like fungal threads found under the bark of stressed and dying trees caused by the *Armillaria* fungi. They may glow!
- **Slime Flux or Ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.
- **Spore masses** – Masses of spores, the “seeds” of a fungus.
- **Insects** and/or their **frass** – Excrement are also signs, although not signs of disease.

Biotic Disease

Biotic causes of disease include fungi, bacteria, viruses, phytoplasmas, nematodes, oomycetes, and parasitic plants.

Fungi

Fungi are organisms that are classified in the kingdom “Fungi.” They lack chlorophyll and conductive tissue. Until a few years ago, fungi were considered lower forms of plants, but today they are classified as a group by themselves. Because fungi cannot manufacture their own food (due to lack of chlorophyll), they must obtain it from another source as either a **saprophyte** or **parasite**. Most fungi encountered are saprophytic (feed on decaying organic matter). The parasitic fungi, those that derive their sustenance from living plants, are the group of interest in plant health.

Weather plays a large role in fungal disease development. Most fungi require free water or specific levels of humidity or moisture for prolonged periods of time to develop. Dry climates are not conducive to their survival. The Rocky Mountain region has fewer fungal diseases than many other parts of the United States due to climatic differences. However, fungi are the most frequent causes of plant diseases in Colorado because gardens and other microclimates may have conditions ideal for disease development due to poor air circulation, shade, high humidity, and high moisture.

A fungus "body" is a branched filamentous structure known as ***mycelium***. One single thread is called a hypha (hyphae, plural). Most fungi reproduce by spores, which are structures that contain little stored food (unlike seed). Spores are the main dispersal mechanism of fungi and can remain dormant until germination conditions are appropriate. Many fungi over-winter as fruiting structures embedded in dead plant tissue.

When a spore comes into contact with a susceptible plant, it will germinate and enter the host if the proper environmental conditions are present. Hyphae develop from the germinated spore and begin to extract nutrients from host plant cells. The hyphae secrete enzymes to aid in the breakdown of organic materials that are absorbed through their cell walls. Fungi damage plants by killing cells and/or causing plant stress.

Fungi are spread by wind, water, soil, animals, equipment, and in plant material. They enter plants through natural openings such as stomata and lenticels and through wounds from pruning, hail, and other mechanical damage. Fungi can also produce enzymes that break down the cuticle (the outer protective covering of plants).

Fungi cause a variety of symptoms including leaf spots, leaf curling, galls, rots, wilts, cankers, and stem and root rots. Fungi may be responsible for "damping off" symptoms associated with seedlings.

Damping Off

Damping off may be a symptom of fungal infection of seeds or seedlings that leads to death. (Oomycetes, fugal-like organisms, also cause damping off symptoms). When infected with damping off, seeds may fail to germinate. In other situations, seedlings develop but eventually fall over and die. An examination of stems at the soil line reveals a discolored, "pinched in" appearance. Most plants are susceptible to damping off because of the soft immature nature of seedling tissue that is more susceptible to infection.

The best method to manage damping off is to avoid it in the first place. For starting seeds indoors, use pasteurized soil or planting mix and ensure that plants receive optimum light, water, and heat for rapid germination and growth. In home situations, damping off frequently develops due to poor lighting and overwatering. These conditions stress plants and make conditions optimal for the development of the soil-borne organisms that cause damping off.

In the garden, plant seeds at appropriate times (correct soil temperature for rapid germination) for the crop and avoid overwatering for optimal germination and growth. A strong healthy plant is better equipped to fight off infection.

Scientists continue to study the role of hyperparasites (parasites of parasites) in disease management. Several biological pesticides have been developed from naturally occurring hyperparasitic fungi and bacteria. The organisms protect plant roots against invasion by harmful soil pathogens. These biological pesticides must be applied prior to the development of damping off so the beneficial organisms have time to grow and colonize roots. They cannot be used as “rescue” treatments.

Leaf Spots

One of the most common fungal plant symptoms is leaf spotting. Leaf spot symptoms are caused by many different fungi. Fungal leaf spots possess a distinct dark brown or red margin between the interior (dead) and exterior (healthy green) tissue called a *border* or *margin*. [**Figure 2**]

Figure 2. Cedar knot gall rust is a common leaf spot with a colorful border.

Fungal fruiting structures (reproductive structures) are usually embedded in the dead interior. Frequently, a “halo” of yellow or red color develops around the border. A halo indicates recently killed tissue that will eventually die. Because of the cycle of killing tissue and creating a border, then killing more tissue and creating another border, many fungal leaf spots take on a target-like appearance.

To confuse matters, a series of drought events can cause damage that exhibits alternating light and dark bands. Additionally, fruiting structures may not be obvious in dry climates like Colorado. To positively identify a fungal leaf spot, it is best to either culture tissue from the sample or look for spores under a compound microscope.

Examples of common leaf spot diseases in Colorado include *Marssonia* and *Septoria* leaf spots of cottonwoods and aspen, ink spot of aspen, and early blight of tomatoes and potatoes.

Powdery Mildew

Powdery mildew is one of the most common diseases in dry climates like Colorado. General symptoms include a white or grayish powdery growth on leaves. It thrives in warm dry climates, often explodes in small yards with limited air movement, and in the fall as nighttime humidity rises. [**Figure 3**]

Figure 3. Powdery Mildew.

There are many species of mildew fungi, each being host specific. In Colorado, for example, it is common on ash, lilac, grapes, roses, turfgrass, vine crops (cucumbers, melons, and squash), peas, euonymus, cherry, apple, crabapple, pear, Virginia creeper, and others.

Management is centered on a variety of practices:

- Avoid crowding plants as the lack of air circulation favors powdery mildew.

- Select resistant varieties where possible.
- Avoid late-summer application of nitrogen fertilizer as it may push growth of tender young leaves that are more prone to mildew.
- Avoid overhead irrigation as it raises relative humidity.
- Remove and destroy infected plant parts.
- Several fungicides found in the personal garden trades are effective against powdery mildew. Look for those specifically labeled to treat powdery mildew in each host. (The label is the law!)

Cankers

Cankers are discolored, sunken areas found on plant stems, branches, and trunks. They damage plants by killing the conductive tissue and girdling the plant. Cankers may be caused by fungi, bacteria, viruses, and abiotic disorders such as sunscald and hail. [**Figure 4**]

Figure 4. Canker at base of honeylocust.

Fungal cankers contain fruiting structures embedded in the discolored canker. Plants with cankers may exhibit branch dieback, leaf loss, and/or poor growth above the damaged area. Common fungal cankers in Colorado are *Cytospora* (*Cytospora* sp.) and *Thyronectria* (*Thyronectria* sp.). A common bacterial disease which causes cankers in Colorado is fireblight (*Erwinia amylovora).*

Root Rots

Root rots damage plants by stressing or killing root systems. Two common soil-inhabiting fungi that cause root rots include *Fusarium* sp. and *Rhizoctonia* sp.

Root symptoms of these (and other soil-borne) fungi include darkening, limpness, and mushiness. Rotted roots may break off easily. The cortex (the outer protective covering) of roots sloughs off, leaving behind the thread-like root core.

Leaves, stems, and entire plants may wilt, prompting one to think that the plant simply needs more water. Unfortunately, additional water often makes the problem worse.

The lower, interior leaves turn yellow, then brown and drop off. In addition, plants may be stunted. If enough roots are damaged, the plant eventually dies.

There are no root-rot resistant plants. Management strategies include avoiding overwatering and improving soil drainage. Roots stressed from overwatering or oxygen starvation easily succumb to root rots, because the organisms move through moist soil and water.

Sometimes, a plant with root rot may be salvaged by cutting off damaged roots and replanting in well-drained soil. Biological pesticides containing hyperparasites may help protect against root rot. These products are not designed to “rescue” plants from ongoing damage, but function as preventatives.

In the Green Industry, root rots can be managed with a combination of cultural management strategies and through use of fungicides. Because not all fungicides kill all root rot fungi, it is essential to determine which root rot organism is causing the problem through microscopic examination so the correct product can be recommended.

Bacteria

Bacteria are single-celled microorganisms. They do not contain a nucleus protected by a membrane and reproduce by dividing into two equal parts (fission). As a result, they multiply and mutate rapidly. Bacteria function as either parasites or saprophytes.

Bacteria can infect all plant parts. Unlike fungi, bacteria must find a natural opening for entry. Bacterial cells can move from one plant to another in water, soil, and plant material, just as fungi do. However, bacterial pathogens are more dependent on water. Conditions must be very wet and/or humid for them to cause significant and widespread damage. [**Figure 5**]

Bacteria move between plant cells and secrete substances that degrade plant cell walls so the contents can be utilized. Some produce enzymes that break down plant tissue, creating soft rots or water soaking. Like fungi, bacteria cause symptoms such as leaf blights and spots, galls, cankers, wilts, and stem rots.

Figure 5. Fireblight on crabapple.

Bacterial leaf spots appear different from fungal leaf spots due to their intercellular movement. Veins often limit the development of a lesion, so they appear angular or irregular, not round.

Bacterial diseases are *not* common in the Rocky Mountain region due to lack of natural moisture.

Common bacterial diseases in Colorado include bacterial wetwood (slime flux), fireblight (*Erwinia amylovora*), and bacterial leaf spot (*Erwinia* sp.).

It is difficult for beginners to tell fungal and bacterial plant symptoms apart. **Table 1** may be used to help distinguish symptoms caused by these pathogens.

Table 1. Comparison of Fungal and Bacterial Leaf Spots

Symptom Description	Fungal	Bacterial
Water-soaked appearance	No	Yes
Texture	Dry, papery	Slimy, sticky
Smell	No	Yes
Pattern	Circular, target-like	Irregular, angular
Disintegration	No	Yes
Color changes	Red, yellow, purple halos	No
Structures of pathogen	Mycelia, spores, fruiting structures	No

Viruses

Viruses are crystalline particles composed of nucleic acid (ribonucleic acid or deoxyribonucleic acid) and protein. They are obligate parasites, meaning they are unable to survive outside of their host. Small virus particles can be found in all plant parts and cannot be seen without an electron microscope.

To move from plant to plant, the particles must be transmitted by vectors and through a wound. The vector is typically an insect, nematode, or human. Insects and nematodes spread viruses between plants as they feed on them. The feeding injury creates the necessary wound. Usually, a plant virus is spread by only one kind of insect vector. Aphids, leafhoppers, and thrips are examples of virus vectors, but not all aphids, leafhoppers, or thrips spread virus.

Humans may spread plant viruses as they work in the garden. Mechanical abrasion from infected tools or touching and abrading plants with infected hands may be all that is needed. Viruses overwinter in infected perennial plants or overwintering insects. A small portion of viruses can be transmitted through seeds. Some are transmitted through vegetative propagation.

Viruses cause mottling, spots, mosaic-like patterns, crinkling, and other malformations on leaves and fruits, and may stunt plants. Because viruses are *systemic*, infected plants must be rogued or discarded. [**Figure 6**]

Viruses are named according to the first plant on which they were found and the type of symptom they cause (i.e., peony ringspot virus, rose mosaic virus).

For example, common virus diseases in Colorado include curly top virus of tomatoes, cucumber mosaic virus of vine crops and tomatoes, tomato spotted wilt virus of tomato, and a variety of greenhouse plant viruses.

Figure 6. Tomato spotted wilt virus on tomato fruit.

Phytoplasmas

Phytoplasmas are bacteria-like organisms; however, they lack a cell wall and can take on a variety of shapes. They are obligate parasites, meaning they can only survive within their hosts. Phytoplasmas live in the phloem of host plants and are vectored by certain phloem-feeding insects, such as leafhoppers. This pathogen causes distortion, yellowing, wilting, and **"witches' brooms"** (a proliferation of growth). Immature leaf veins may appear clear (called "vein-clearing"). Flower parts may become vegetative and flowers that do develop produce sterile seeds.

Aster Yellows

Aster yellows damage over three hundred species of broad-leafed herbaceous plants nationwide. Commonly affected flowering plants include *Echinacea sp*. (purple coneflower), cosmos, marigolds, asters, chrysanthemums, delphiniums, daisies, coreopsis, and zinnias. Vegetables affected include carrots, lettuce, and potatoes. Weeds such as dandelion, ragweed, plantain, wild lettuce, and thistles may also be infected. [**Figure 7**]

Aster yellows is spread by the aster (or six-spotted) leafhopper. These insects are small (one-eighth inch long), gray-green, and wedge-shaped. They are called leafhoppers because they move or fly away quickly when plants are disturbed. They feed only on plant sap (phloem tissue) and generally on leaf undersides.

Aster leafhoppers do not overwinter in Colorado due to the cold climate but are blown in from the Gulf of Mexico in late spring or early summer. Once a leafhopper feeds on an infected plant, about ten days to three weeks must elapse for the insect to become infective. Plant symptoms appear ten to forty days after infection. Dry weather can cause increased disease occurrence in the home garden as leafhoppers move from plants in prairies and pastures to irrigated yards. Generally, aster yellows symptoms appear in middle to late summer.

Figure 7. Aster yellows on carrot.

Although aster leafhoppers spread the disease, placing infected plants in the yard can also spread it. Management strategies for aster yellows include planting healthy plants, controlling weeds that may harbor the insects, and removing infected plants. Even though only one part of a plant appears infected, one must assume the phytoplasma is throughout the entire plant.

The pathogen can overwinter in plant crowns and roots. Leaves and stems that develop from this tissue will always be infected and provide a source of inoculum for other susceptible plants. Insecticidal control of aster leafhoppers is very difficult as they are constantly moving in and out of the garden, so it is not recommended.

Parasitic Plants

More than 2,500 species of higher plants are known to live parasitically on other plants. Parasitic plants produce flowers and reproduce by seeds like other plants. The main difference is they cannot produce their own chlorophyll or produce only a small amount of chlorophyll. Therefore, they must obtain sustenance from a chlorophyll-producing plant to survive. Parasitic plants are spread in various ways including animals, wind, and forcible ejection of their seeds.
Dwarf mistletoe and dodder are two examples of parasitic plants encountered in Colorado. Dwarf mistletoe has chlorophyll but no roots and depends on its host for water and minerals, although it can produce carbohydrates in its green stems and leaves. Dodder cannot produce its own chlorophyll and completely depends on its host for sustenance.

Plants damaged by parasitic plants appear wilted, stunted, distorted, and chlorotic. Some plants, particularly conifers, develop witches' broom symptoms.

Nematodes

Nematodes are microscopic roundworms that live in soil, water, and plant material. They have a spear-like **stylet** mouthpart, require free water to move about, and reproduce by eggs. They spread in water, infected plant material, soil, and in some cases, insects.

Nematodes cause a variety of symptoms including stunting, yellowing, and wilting of plant tissue. Some infected plants simply appear unthrifty. Some develop strange, knot-like growths on their roots. Many saprophytic and parasitic species exist. Due to cold winters, nematodes as plant pathogens are uncommon problems in Colorado landscape plantings.

Pinewood nematode (*Bursaphelenchus xylophilus*) is a North American native nematode that invades exotic pines such as Austrian, black, and Scots pines.

Pinewood nematode causes pine wilt disease. The symptoms include needle necrosis, branch flagging, and eventual tree death. Trees may decline rapidly; whole tree death can occur in two weeks.

Pinewood nematodes are vectored two ways. The primary transmission is by maturation feeding of adult pine sawyer beetles (*Monochamus* sp.) on susceptible trees. Secondary transmission occurs when adult female pine sawyer beetles oviposit (lay eggs) into phloem of susceptible trees. If this disease is suspected as the cause of pine tree death, samples must be sent to a diagnostic laboratory to accurately diagnose pine wilt disease.

Foliar nematodes are found occasionally in irrigated Colorado landscapes. They have a broad host range and can infect many plant species but especially anemone and chrysanthemums.

General Management of Biotic Plant Disease

Plant disease is best managed through an *integrated* approach, which includes a combination of cultural, mechanical, biological, and chemical practices.

Cultural management includes appropriate plant selection. Utilize plants that perform well in the local climate. Use disease-resistant varieties when possible. Plant certified seed or seed pieces.

Place plants in the appropriate environment for optimum growth. For example, grow shade-loving plants in the shade, not hot sun. Prepare soil before planting to improve root growth, reduce compaction in clay soils, and improve water holding of sandy soils. Apply fertilizer and water according to plant needs. Prune correctly, as needed, and at the correct time of year.

Apply mulch in gardens. Not only does this keep soil moister and cooler (helping roots thrive), but it also creates a splash barrier against soil pathogens or pathogens on plant debris in the soil. Use soil solarization to reduce soil pathogens and weed seeds. Pull weeds and volunteer seedlings that hog precious water but also serve as a reservoir for pathogens and insects.

Rotate crops, when possible, to starve pathogens. For example, avoid planting solanaceous crops in the same area as pathogens specific to this group may build up in soil and infect new crops.

Mechanical management techniques include rototilling in the fall, which exposes pathogens, insect eggs, and weed seeds to cold winter temperatures. This action also speeds the decomposition of crop residues, improving soil organic matter. Clean up or prune out infested plant materials to reduce the source of inoculum on the property. It may also be helpful to core-aerate turf once or twice yearly.

Biological controls include the use of compost, compost teas, and hyperparasite products, which may reduce pathogens by introducing beneficial microbes. Encourage beneficial insects by planting flowering plants attractive to all stages of development. Avoid blanket applications of pesticides, which may kill beneficials in addition to harmful insects. Spot treat pest problems instead.

Chemical control refers to the use of fungicides, insecticides, and herbicides to manage a problem. Always identify the cause of a plant problem first, then select and use a product appropriate for the problem and follow **label directions**. Apply it at the correct time using the recommended method. Always spot treat.

Abiotic Disorders

Abiotic agents are non-living factors such as soil compaction, spring frosts, hail, and lawnmower damage to tree trunks. Abiotic agents are noninfectious and non-transmissible. Plant disorders deriving from these agents have commonly been referred to as ‘physiological diseases’ or ‘environmental diseases.’

Water Management

One of the major causes of abiotic plant disorders is improper water application. Too much water can be just as damaging as not enough water, as both kill roots. Examples of abiotic disorders related to water are leaf scorch, winter desiccation, and oxygen starvation. [**Figure 8**]

To control problems caused by water management issues, identify the likely causes and correct them if possible. This will require some detective work to determine which factor or (usually) combination of factors is causing the problem.

Figure 8.
Water stress on trees often appears from the top down.

Leaf Scorch

Symptoms of leaf scorch include necrosis (browning) of leaf edges and/or between the veins. These parts are the least hydrated areas of a deciduous leaf, so when moisture is lost, symptoms appear there first. Scorch symptoms on needled evergreens appear as necrosis from the needle tips downward in a uniform pattern. The initial reaction to these symptoms is to provide more water, but that may only exacerbate the situation depending on what is causing scorch in the first place. [**Figure 9**]

There are several causes of leaf scorch. For example, there may not be enough water in the soil for root absorption. This phenomenon occurs during drought periods as Colorado experienced in the early 2000s and during winters when soil water is frozen.

Another cause of leaf scorch is when water may be lost faster than it can be replaced. Warm, windy, and sunny weather during winter months causes rapid transpiration at a time when soil moisture may be frozen. During summer, sunny, hot, and windy weather causes such rapid transpiration that roots cannot physically keep up with the water loss.

Figure 9. Leaf scorch on linden caused by hardscaping over the root zone.

Soil water may be available, but roots may not be functioning properly to absorb it. What causes roots to function poorly? Soil may be so compacted that roots cannot adequately explore soil for nutrients and moisture. Roots may be severed or otherwise damaged from construction activities or garden cultivation. Planting too deep limits oxygen availability for roots and stresses or kills them. A thick layer of mulch or black plastic covering root systems also injures them due to oxygen deprivation.

Mechanical damage on lower stems or trunks from mowing equipment, improper planting, improper staking, animal chewing, or boring insects may also prevent or slow uptake of water. ***The bottom line is that more water is lost than can easily be replaced.***

Oxygen Starvation

Oxygen starvation occurs when excess water in the soil drives out oxygen, causing the "suffocation" of roots. Plants respond by dropping lower leaves that are usually yellowed or necrotic. Leaf loss is most noticeable from the inside of the plant out and the bottom up. In addition, leaves may be smaller than normal, growth increments may be small, and the plant may have an overall unthrifty appearance.

While oxygen starvation causes root damage, the first clue that something is wrong appears on the canopy, stems, and branches. These parts are the furthest from the water source, so the symptoms appear there first.

Management strategies are based on good horticultural practices. For example, add organic matter to vegetable and flower gardens before planting to improve drainage as well as water-holding capacity. Cut back on irrigation frequency or adjust the quantity of the water applied. Core aerate turf, which will also benefit tree roots growing in it. Apply and maintain mulch at levels appropriate for the material used. Remove any black plastic in the landscape.

Weather

Winter desiccation is caused by dry winter winds that result in leaf water loss. Water cannot be replaced in the plant because the soil is too cold for root function. Symptoms of winter desiccation include necrotic leaf or needle tissue (typically from the tips inward), discoloration of needle or leaf tissue, and patchy damage distribution on individual plants in windy locations. Plants may not exhibit symptoms until the following summer when droughty summer conditions ensue. [**Figure 10**]

Figure 10. Winter dehydration on pine appears on needle tips.

To deter winter desiccation on woody plants, it is recommended to water plants in the fall even after they go dormant. Roots are still active and can absorb water until soil temperatures drop below 40°F. When the ground is not frozen, additional irrigation may be helpful monthly during the winter in the absence of snow cover or sufficient snowmelt or rainfall.

Temperature

Temperatures below optimal plant growth cause plant damage. The amount and type of damage depends on how quickly temperatures drop, the lowest temperature reached, and how long cold temperatures are sustained. Freeze injury may be caused by frost crystals that form in the freezing water outside of plant tissues or by freezing water inside plant cells. Damage from the latter is much more severe and resembles herbicide phytotoxicity, bacterial blight, and branch flagging due to insect borer activity. [**Figure 11**]

Figure 11. Sunscald or "southwest bark injury" results from rapid winter temperature changes.

Spring freezes damage exterior buds first, as these are the first to de-harden. Fall freezes affect interior buds first as these are the last to harden. Damage to tissues is uniform. For example, newly developing conifer needles may be killed completely or from the tips inward. Temperatures above optimal growth cause plant damage as well. The most severe injury occurs on leaves that are exposed to the sun and tissue that is furthest away from water such as outer branch tips, leaf margins, and between leaf veins.

Chemical Injury

Chemical injury is plant damage caused by pesticides, fertilizers, de-icing salts, and other products.

Herbicides

Herbicides (weed killers) damage plant tissues by causing symptoms such as chlorosis, necrosis, distortion, and elongated growth. Glyphosate, dicamba, and 2,4-D are examples of common herbicides that cause chemical injury to plants when used incorrectly.

Herbicides that behave like plant growth regulators, such as dicamba and 2,4-D, translocate through both the xylem and phloem. They stimulate growth such as cell division, elongation, and fruit and flower production. [**Figure 12**]

Figure 12. Damage on grapes from 2,4-D. Notice the distortion in leaf vein pattern.

Excessive concentrations of these chemicals cause twisting and curling of stems, stem swelling, weakened cell walls, rapid cell growth, and cellular and vascular damage and death. Grasses are not affected by plant growth regulators apparently due to a different arrangement of vascular bundles (xylem and phloem).

Glyphosate

Glyphosate is an amino acid inhibitor that interferes with synthesis of certain amino acids needed to build proteins. Glyphosate moves through the phloem to the new growth of shoots and roots. Injury symptoms include chlorosis, shortened internodes (compact growth or stunting), stem proliferation, and mimics damage caused by 2,4-D and other plant growth regulators, viruses, phytoplasmas, eriophyid mites, and environmental factors.

Fertilizers

An excess or shortage of the seventeen essential elements required for plant growth and development may cause plant damage. Excess amounts of fertilizers can "burn" plants due to the level of salts in fertilizers.
Symptoms of fertilizer damage include leaf margin necrosis (similar to drought stress in appearance), leaf discoloration, soft rapid growth, and vegetative growth at the expense of flower and fruit production.

Nutrient deficiencies include chlorosis, interveinal chlorosis, blossom-end rot, stunting, and purpling. Symptoms of nutrient excesses and deficiencies may be confused with disease, insects, mites, or other environmental problems. If a soil nutritional problem or salt injury is suspected, have the soil tested.

When excess fertilizer has been applied, apply water to leach salts from the root zone. Quick release fertilizers are more prone to "burn" plants. Follow label directions when applying fertilizers to avoid plant damage.

Salts

It is common practice in Colorado to use de-icing salts to remove snow and ice from roadways and sidewalks. Salts injure plants from salt burn on foliage, root burn of salts, or soil buildup that deteriorates soil structure, interfering with drainage and root growth.

Symptoms of salt spray on leaves include stem and leaf deformities, witches' brooms, and twig dieback of deciduous plants. Conifers exhibit needle browning at the tips of branches. Salt spray damage is only noticeable on the plant side adjacent to a road. [**Figure 13**]

Symptoms of salt accumulation in soils are different from salt spray and include marginal leaf scorch, stunting, and twig dieback. Leaf scorch may not appear until later in the season or in following seasons.

To reduce salt burn, avoid de-icing salts, add organic matter and charcoal to the soil, leach with water, or protect plants using a barrier that will keep salt-laden snow away from plant material.

Compost and other soil amendments can be high in salt when made with manure or biosolids. Symptoms of salt burn include marginal burning of leaves, stunting, root dieback, and death of plants. For additional information, refer to CMG GardenNotes #241, *Soil Amendments.*

Figure 13. Salt damage on bean leaf "burns" the margin of the leaf. This was caused by using compost high in salts.

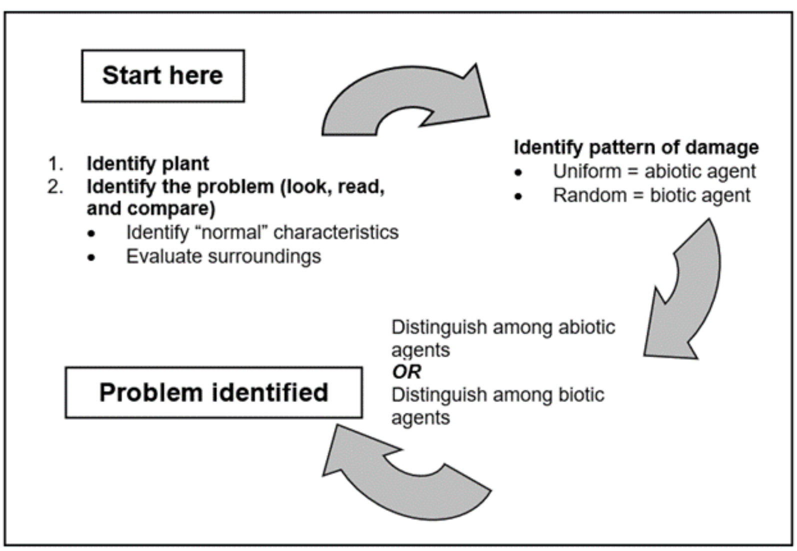
Distinguishing Between Biotic and Abiotic Factors

Determining the causal agent (biotic or abiotic factor) of plant damage can be a tumultuous endeavor, so it is imperative to use the **plant diagnostic process** to obtain an accurate result. For more information on this process, please refer to Garden Notes #102, *Diagnosing Plant Disorders*.

There are certain aspects that can aid in distinguishing between biotic and abiotic plant problems. Some of them involve:

- **Use a systematic approach when diagnosing plant damage.** The probability of correctly diagnosing plant damage based on one or two symptoms is low. In contrast, the probability of correctly diagnosing plant damage based on many symptoms and signs is high. Using investigative skills and asking many questions is imperative to arriving at a correct diagnosis [**Figure 14**].
- **Look for signs of biotic pathogen activity first.** Signs will always be present. It is a matter of whether the sign is observed or not. First, closely study plant damage. Mentally identify possible causal agents. Then, look for signs that would accompany such damage. Signs of disease include fruiting structures, overwintering structures, mycelium, insect frass or carcasses, and ooze. Because some diseases are vectored by insects, signs that the vectors are present are equally as important as finding signs of the disease. In addition, some types of disease symptoms mimic symptoms of insect or vertebrate damage. It is critical, therefore, to distinguish between insect and pathogen damage using observed or unobserved signs of both insects and pathogens.
- **If no signs are observed, abiotic activity should be considered.** Ask questions regarding mechanical, physical, and chemical factors affecting the damaged plant. Mechanical factors include string trimmer damage to tree trunks, improper pruning cuts, injury during transportation of plant material and guy wire damage. Physical factors include temperature extremes, light differentials, and extreme changes in oxygen and moisture levels. Chemical factors include pesticide damage, fertilizer damage, nutritional disorders, and pollutants.
- **Evaluating pattern of damage (uniform versus random).** Uniform damage patterns on individual plants and on many different plants in a specific area are typically characteristic of nonliving or abiotic factors. Random damage patterns on individual plants or on a specific family or genus of plants typically indicate a living or biotic agent of disease. Biotic factors include fungi, bacteria, or nematodes.

Figure 14. Flow Chart Displaying the Systematic Approach to Determining Causal Agents of Plant Damage



Authors: Mary Small, CSU Extension, retired. Figures 2, 3, and 6 by Mary Small; figure 10 by Chris Utley, former CSU Extension employee; artwork by David Whiting CSU Extension, retired. Used with permission. Revised November 2017. Reviewed October 2022 by Mary Ortiz Castro, CSU Extension.

Reviewed October 2022

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

Vegetables

Learning Objectives

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

- Describe block style layout in a raised bed garden design.
- Describe garden planning and planting times.
- Describe soil preparation and fertilization for the vegetable garden.
- Describe routine garden care including mulching, irrigation, and water conservation.
- Describe routine care for tomatoes.
- List hints for growing other vegetables.
- Describe frost protection and microclimate modification.

Vegetables Curriculum developed David Whiting (CSU Extension, retired), Carol O'Meara (CSU Extension, Boulder County) and Carl Wilson (CSU Extension, retired)

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised October 2014

References / Reading

Colorado State University Cooperative Extension

CSU Extension Fact Sheets

- Eggplants – Peppers and Eggplant – #7.616
- Flea Beetle – #5.592
- Grasshopper Control in Yards and Gardens – #5.536
- Herbs – Growing, Preserving and Using Herbs – #9.335
- Horticultural Oils – #5.569
- Insects – Flea Beetle – #5.592
- Insects – Grasshopper Control in Yards and Gardens – #5.536
- Insects – Greenhouse Whitefly – #5.587
- Insects – Potato or Tomato Psyllids – #5.540
- Insects – Squash Bug Management - #5.609

- Peppers and Eggplant – #7.616
- Potatoes Seeds – Saving Seeds – #7.602
- Preventing E. coli From Garden to Plate – #9.369
- Psyllids – Potato or Tomato Psyllids – #5.540
- Seeds – Growing Plants from Seed – #7.409
- Seeds – Home Storage of Vegetable and Flower Seeds – #7.221
- Storage of Home-Grown Vegetables – #7.601
- Tomatoes – Recognizing Tomato Problems – #2.949
- Vine Crops – Cucumbers, Pumpkins, Squash, and Melons – #7.609

<u>Review Questions</u>

1. Describe how adding organic matter improves a <u>sandy</u> garden soil. A <u>clayey</u> garden soil.

2. List techniques to manage soil compaction in the vegetable garden.

3. What are the limitations on using manure and compost made with manure in the vegetable garden?

4. Describe the pros and cons of homemade compost, of commercial compost.

5. Describe the standard application rate for compost. How does it change with incorporation depth and potential for salts in the product?

6. If the soil is low in organic matter, will a routine application of compost and/or manure supply the nitrogen needs for crops? Explain why.

7. How the fertilizer application rate change based on soil organic content?

8. What is the purpose of a starter fertilizer? List examples of common fertilizers that could be used as a starter fertilizer.

9. What is nitrogen side dressing? List examples of common fertilizers that could be used for side-dressing.

10. In Colorado, what types of soils will likely have deficiencies of phosphorus and potassium?

11. Why are the advantages of a block style garden layout? Of raised bed gardens?

12. Describe how to design a garden in block style layout.

13. Describe how to make a raised bed garden. How high should the beds be raised? In routine raised bed gardening, where are the crop's roots?

14. Explain "double digging".

15. Describe how to set up a soaker hose drip irrigation system in a raised bed garden.

16. Describe procedures and limitations on using grass clipping mulch in the vegetable garden.

17. Can wood/bark chip mulch be used in the vegetable garden? Explain.

18. List gardening techniques to conserve water in the vegetable garden. What happens to vegetable quality with inadequate water supplies?

19. What is the critical water period for various vegetables?

20. Describe the ideal tomato transplant. How should tall, leggy transplants be planted?

21. What are the advantages of trellising tomatoes? How far apart should tomatoes be spaced? Give examples of trellising methods.

22. What are the advantage and limitations on using black plastic mulch on tomatoes, peppers, eggplants and vine crops? Describe techniques for using plastic mulch.

23. Tomatoes are often referred to as being a "low nitrogen" crop. More correctly stated, they are fussy about nitrogen levels. Explain the fertilizer needs at planting and as the crop nears harvest.

24. Explain the management option for early blight on tomatoes. Will a fungicide stop the disease when leaves have turned yellow late summer?

25. Why will vine crops bloom but not set fruit?

26. When should beans be planted?

27. Beans have a higher water use than other vegetables. What happens when they get a little dry? How can you tell when bean plants need irrigation?

28. Explain the growing techniques for quality cole crops.

29. *Bacillus thuringiensis, Bt,* is the standard biological control approach for worms in cole crops. Describe the criteria in using *Bt*. (See fact sheet #5.556.)

30. What is isolation required in growing Super Sweet corn varieties?

31. Gardeners often list "poor quality" as the reason most don't grow leafy vegetables. What are the keys to great quality lettuce, spinach, chard, and other leafy vegetables?

32. What cultural practices are needed to compensate for the onion family's poor, inefficient root system?

33. What is the difference between English peas, snow or sugar peas, and snap peas?

34. Describe how to get potatoes off to a great start.

35. What are the different temperature requirements of hardy, semi-hardy, tender, and very tender vegetables?

36. How does a gardener know when to plant various crops?

37. In covering plants for frost protection, what is the heat source, i.e., where is the heat stored?

CMG GardenNotes #711

Vegetable Gardens:

Soil Management and Fertilization

In the garden, managing soils to improve ***tilth*** and garden ***fertilization*** are related but not necessarily the same process. For example, compost or manure may be added as a soil amendment to improve tilth; however, they may add nominal amount of plant nutrients. A manufactured fertilizer may be added to supplement soil fertility levels, but it will not improve a soil's tilth. For optimum yields and quality, gardeners need to pay attention to both soil management for improving tilth and soil fertilization.

Tilth is a term related to the suitability of a soil to support plant growth. Technically speaking, tilth is "the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seeding emergence and root penetration".

Soil Amendment or Fertilizer

The term ***soil amendment*** refers to any material mixed into a soil. By law, soil amendments make no legal claims about nutrient content or other helpful (or harmful) properties. Compost and manure are common soil amendments used to improve soil tilth. They may also supply nominal amounts of plant nutrients. Some of the nutrient effect seen from adding soil amendments is likely due to their effect on soil microorganisms. The organic material in soil amendments is a food source that allows microorganisms to multiply. The larger numbers increase the conversion of nutrients in the soil to plant usable forms.

Mulch refers to a material placed on the soil surface.

By law, the term ***fertilizer*** refers to a material that guarantees a minimum percentage of nutrients of nitrogen, phosphate, and potash. An ***organic fertilizer*** is derived from natural sources and guarantees the minimum percentages of nitrogen, phosphate, and potash.

Soil Amendments

In the vegetable garden, the routine addition of organic soil amendments such as compost will optimize potential yields and quality. The goal in soil management is to increase the organic content to 4-5%, over a period of years.

Common amendments include compost, manure, compost made with manure, fall leaves, straw, and peat moss. Home compost has the advantage that the gardener controls what goes into the compost, reducing problems with salts, weed seeds, and plant diseases.

In climates with long growing seasons, another method to add organic matter is to grow green manure crops in between the vegetable growing season. In some areas, this would be a winter crop, in hot areas of the south this would be a summer heat crop. In areas like Colorado, where the entire growing season is used for vegetable production, a green manure is less practical. For additional information, refer to *CMG GardenNotes* #244, **Cover Crops and Green Manure Crops**.

How Organic Amendments Improve the Soil

On clayey soil, organic matter (over a period of years) glues the tiny soil particles together into larger aggregates, increasing pore space. This increases soil oxygen levels and improves soil drainage, which in-turn increases the rooting depth thereby allowing roots to reach a larger supply of water and nutrients.

On sandy soils, organic matter holds over ten times more water and nutrients than sand.

Organic matter also encourages the beneficial activity of soil organisms and helps remediate soil compaction.

Application

General application rates for compost or other organic soil amendments are based on the salt content of the materials and soil and on the depth to which it is cultivated into the soil. Ideally, cultivate the soil amendment into the top six to eight inches of the soil. On compacted/clayey soils, anything less can lead to a shallow rooting system with reduced plant growth, lower vigor, and lower stress tolerance.

Table 1 gives the standard application rate for compost. Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems, and higher application rates are safe.

Compost, which includes manure or biosolids as a component, has a potential for high salt. Excessive salt levels are common in many commercially available products sold in Colorado. In compost made with manure or biosolids, the application rate is limited unless a soil test on that batch of product shows a low salt level. An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable if incorporated six to eight inches deep in a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable.

Note: dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

<table>
<tr><th colspan="4">Table 1. Routine Application Rates for Compost</th></tr>
<tr><th rowspan="2">Site</th><th rowspan="2">Incorporation Depth[2]</th><th colspan="2">Depth of Compost Before iIncorporation[1]</th></tr>
<tr><th>Plant Base Compost and other compost known to be low in salts[3]</th><th>Compost Made with Manure or Biosolids for which the salt content is unknown[4]</th></tr>
<tr><td rowspan="2">One-time application— such as lawn area</td><td>6-8 inches</td><td>2-3 inches</td><td>1 inch</td></tr>
<tr><td>3-4 inches</td><td>1-1½ inches</td><td>½ inch</td></tr>
<tr><td rowspan="2">Annual application to vegetable and flower gardens – first three years</td><td>6-8 inches</td><td>2-3 inches</td><td>1 inch</td></tr>
<tr><td>3-4 inches</td><td>1-1½ inches</td><td>½ inch</td></tr>
<tr><td rowspan="2">Annual application to vegetable and flower gardens – fourth year and beyond</td><td>6-8 inches</td><td>1-2 inches</td><td>1 inch</td></tr>
<tr><td>3-4 inches</td><td>1 inch</td><td>½ inch</td></tr>
</table>

1 3 cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.
2 Cultivate compost into the top 6-8 inches of the soil. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor and low stress tolerance. The 3-4" inch depth is shown as an illustration of how application rates need to adjust when the deep cultivate is not practiced.
3 Plant based composts are derived solely from plant materials (leaves, grass clippings, wood chips and other wards wastes). Use this application rate also for other compost known, by soil test, to be low in salts.
4 Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado. Based on soil tests of commercially available compost, this application rate may be too high for products extremely high in salts.

Compost needs to be thoroughly mixed into the upper six to eight inches of the soil profile. Do not leave compost in chunks, as this will interfere with root growth and soil water movement.

As the soil's organic content builds in a garden, the application rate should be reduced to prevent ground water contamination issues. A soil test is suggested every four to six years to establish a base line on soil organic matter content.

If using a green manure cover crop, till the cover crop in before it reaches four inches in height.

In the vegetable garden, do not plow in woody materials such as bark or wood chips. They may interfere with seedbed preparation and may result in soil nitrogen depletion.

Precautions When Using Compost and Manure

Manure, compost made from manure, and bio-solids may be high in salts that will interfere with crop growth. Do not add more than one inch per season without conducting a soil test to evaluate potential salt build-up.

Due to a health issue (*E coli* contamination), fresh manure additions should be made at least four months prior to the harvest of any edible crops. In other words, apply fresh manure only in the fall after crops are harvested.

Fresh manure or unfinished compost products may be high in ammonia. Avoid application of products with an ammonia smell; they could burn roots and leaves. Manure and compost may be source of weed seeds.

Nutrient Release Rates from Compost and Manure

Gardeners need to understand that the nutrient release from compost and manure is slow, taking years. Adding compost or manure to improve soil tilth is not the same as fertilizing.

The typical nitrogen release rates from manure is only 30 to 50% the first year (fresh manure), 15 to 25% the second year, 7 to 12% the third year, 3 to 6% the fourth year, and so on. With compost and composted manure, the release rate is even slower, 5 to 25% the first year, 3 to 12% the second year and 1 to 6% the third year.

Because the nitrogen percentage of compost and manure products is typically only 2 to 4%, the amount of actual nitrogen release to support crop growth is very small.

For soil with 4 to 5% organic matter, the mineralization (release) of nitrogen from soil organic matter will likely be sufficient for crop growth.

For soils with 2 to 3% organic matter, the mineralization of nitrogen from soil organic matter will not likely be sufficient for heavy feeding vegetable crops. Supplement with 0.1 pound nitrogen fertilizer per 100 square feet.

For the typical garden soil with 1% organic matter or less, the mineralization of nitrogen for soil organic matter will be minimal. Add 0.2 pounds of nitrogen fertilizer per 100 square feet.

Fertilization

Soil fertilization is the addition of soil nutrients to support crop growth. While some soil amendments add small amounts of nutrients, amending the soil to improve soil tilth is not the same as amending the soil to provide nutrients.

Manufactured fertilizers are popular with gardeners because they are readily available, inexpensive, easy to apply, and generally provide a quick release of nutrients for plant growth. Application rates for any fertilizer depend on the content and the amount of nutrient to be applied. **In products containing multiple nutrients, the application rate is always based on the nitrogen content.**

Nitrogen Applications

Nitrogen is the nutrient needed in largest quantities by plants and the one most frequently applied as fertilizer. It is annually applied in the form of manufactured fertilizer, organic fertilizers, and/or organic soil amendments. **Application rates are critical, because too much or too little directly affects crop growth**.

The standard annual application rate for home vegetable gardens is 2 pounds actual nitrogen per 1,000 square feet (0.2 pound actual nitrogen per 100 square feet). When organic matter is supplied, adjust the rate accordingly to account for nitrogen released by the organic matter. [Table 2]

Table 2. Standard Nitrogen Fertilizer Application Rates for Gardens

	Soil Organic Content		
	Typical garden soil low in organic matter (<2% organic matter)	Moderate level of organic matter (2-3% organic matter)	High level of organic matter (4-5% organic matter)
Nitrogen needed	**0.2 lb. actual N per 100 sq. ft.**	**0.1 lb actual N per 100 sq. ft**	**0**
Fertilizer examples			
Ammonium sulfate 21-0-0	1 lb. fertilizer per 100 sq. ft (approx. 2 cups)	0.5 lb. fertilizer per 100 sq. ft (approx. 1 cup)	0
OR			
Ammonium nitrate 34-0-0	0.6 lb. fertilizer per 100 sq. ft. (approx. 1 1/3 cups)	0.3 lb. fertilizer per 100 sq. ft (approx. 2/3 cup)	0
OR			
Urea, 45-0-0	0.4 lb. fertilizer per 100 sq. ft. (approx. 1 cup)	0.2 lb. fertilizer per 100 sq. ft (approx. ½ cup)	0

Manufactured nitrogen fertilizer can be broadcast and watered in, or broadcast and tilled into the top few inches of soil. It can be banded 3-4" to the side of the seed or plant row. Do not place the fertilizer in the seed row or root injury will occur. Some soluble types are applied in the irrigation water. "Organic" nitrogen fertilizers are typically tilled in or some can be applied in irrigation water.

Starters Fertilizers

In setting out transplants, starter solutions often promote early growth. Because transplants have been hardened-off (growth slowed to prepare the plant for movement to the exposed, windy, outdoor environment), the nitrogen in the starter solution gives the signal to resume active growth. Because phosphorus is less available in cold soils, phosphate may also be helpful in spring and before soils have thoroughly warmed.

A starter fertilizer is any water-soluble fertilizer added to the irrigation water. Common examples include MiracleGro, Peters, Schultz Plant Food, Fertilome Root Simulator, and Plant Starter Solution, etc. They generally contain ammonium nitrate since it is readily usable by the plant. Some products claim that vitamins or hormones promote plant growth. These claims are not supported by research findings.

Nitrogen "Side Dressing"

Plant need for nitrogen varies. Beans, peas, tomatoes, and vine crops (cucumbers, squash, pumpkins, and melons) are examples of vegetables with a lower need for nitrogen. High nitrogen promotes excessive growth of the plant at the expense of fruiting.

Crops such as potatoes, corn, and cole crops (broccoli, cauliflower, cabbage, and kale) use large amounts of nitrogen and need supplemental applications during the growing season (referred to as ***side dressing***). For example, home garden potatoes often show nitrogen deficiency from August into fall. Symptoms start as a yellowing of lower leaves and progress into a general browning and dieback of the vine. When nitrogen stress hits, potatoes become more susceptible to diseases, including early blight and Verticillium wilt. [Table 3]

Fertilizers commonly used in the home garden for side dressing include ammonium sulfate, ammonium nitrate, and water-soluble fertilizers such as MiracleGro, Peters, etc. Phosphate and potash fertilizers are best added in the spring or fall, when they can be cultivated into the soil.

<table>
<tr><th colspan="5">Table 3. Nitrogen Side Dressing of Vegetable Crops</th></tr>
<tr><th rowspan="2">Vegetable</th><th rowspan="2">Timing</th><th colspan="3">Application Rate
(Based on rate of 0.1 lbs. actual N per 100 square feet)</th></tr>
<tr><th>Ammonium sulfate
21-0-0</th><th>Ammonium nitrate
34-0-0</th><th>Water soluble fertilizers</th></tr>
<tr><td>Asparagus</td><td>1) Early spring
2) At end of harvest season</td><td rowspan="6">0.5 lbs. fertilizer per 100 sq. ft. (approximately 1 cup)

Sprinkle over soil and water in, OR place in furrow to side of plant. CAUTION: an over application will burn roots, stunting or killing plants.</td><td rowspan="6">0.3 lbs. fertilizer per 100 sq. ft. (approximately 2/3 cup)

Sprinkle over soil and water in, OR place in furrow to side of plant. CAUTION: an over application will burn roots, stunting or killing plants.</td><td rowspan="6">See label of specific product.

Water soil with fertilizer added to water.
Low burn potential, but significantly more expensive.</td></tr>
<tr><td>Sweet Corn</td><td>1) 12 inches tall
2) One month later</td></tr>
<tr><td>Leafy green vegetables</td><td>3-4 weeks after emergence</td></tr>
<tr><td>Onions</td><td>3-4 weeks after emergence</td></tr>
<tr><td>Potatoes</td><td>Late-July to early-August</td></tr>
<tr><td>Tomatoes, peppers, and eggplants</td><td>First fruits 1” diameter</td></tr>
<tr><td>Cole crops (broccoli, cabbage, cauliflower)</td><td>1) 2-3 weeks after transplanting
2) 4-5 weeks after transplanting</td><td></td><td></td><td>See label for specific product.</td></tr>
</table>

Phosphorus and Potassium Applications

A soil test is the best method to determine the need for phosphate and potash. With a fertilizer containing nitrogen and phosphate and/or potash, the application rate is always based on the nitrogen percentage because nitrogen is most critical to plant growth.

Phosphate and potash fertilizers are best applied in the spring or fall, when they can be tilled into the soil

Phosphorus

Phosphorus levels are adequate in the majority of established Colorado soils. Deficiencies are most likely to occur in new gardens where the organic matter content is low and in soils with a high pH (7.8 to 8.3). Excessive phosphorus fertilizer can aggravate iron and zinc deficiencies and increase soil salt content.

Routine application of compost or manure will supply the phosphorus needs in most Western soils.

Where phosphorus levels are believed to be low, the standard application rate without a soil test is ¼ to 1-pound triple super phosphate (0-46-0) or ammonium phosphate (18-46-0) per 100 square feet.

Potassium

Potassium levels are naturally adequate to high in most Colorado soils. Deficiencies occasionally occur in new gardens low in organic matter and in sandy soils low in organic matter. Excessive potash fertilizer can increase soil salt content.

Routine applications of compost or manure will supply the potassium needs for most Western soils.

Where potash levels are believed to be low, the standard application rate without a soil test is ¼ to ½ pound potassium chloride (0-0-60) or potassium sulfate (0-0-50) per 100 square feet.

Managing Soil Compaction

On clayey soils, soil compaction is a common problem limiting crop growth potential. Soils are typically compacted in the construction process. Walking on wet soils, cultivating wet soils, and the impact of rain are other common forces compacting soils.

The following are suggested to help minimize soil compaction in the garden:

- Add organic matter to clayey soils.
- Avoid cultivating or working a clayey soil when wet. To evaluate, squeeze a handful of soil. Then try to crumble it. If it will crumble, it can be worked. If it will not crumble but stays in mud balls, it is too wet to be worked.
- Avoid cultivating other than to prepare a seed bed or till in organic matter and fertilizers. For weed control, use a mulch, hand removal, or shallow cultivation only.
- Use a raised bed with established walkways, and avoid walking on the growing bed.
- Mulch the soil, year round, to minimize the compaction forces of rain and sprinkler irrigation. Winter rains on bare soil are a major compaction force. This also helps manage weeds and reduces irrigation need.

Authors: David Whiting (CSU Extension, retired), Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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CMG GardenNotes #712

Sample Vegetable Garden Seed Catalogs

Baker Creek Heirloom Seed
2278 Baker Creek Rd.
Mansfield, MO 65704
417-924-8917
www.rareseeds.com

Burpee Seed
300 Park Ave.
Warminster, PA 18974
800-888-1447
www.burpee.com

Gurney Seed
110 Capital St
Yankton, SD 57079
513-354-1492
www.gurneys.com

Harris Seed
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GMG GardenNotes #713

Block Style Layout in Raised Bed Vegetable Gardens

Block Style Garden Layout

Block style garden layout (also called ***close-row*** or ***wide-row*** plantings) ***increase*** yields five fold compared to the traditional row-style garden layout, and 15-fold for the smaller kitchen garden vegetables. The compact design reduces weeding and is ideal for raised bed gardening.

The basic technique used in close-row, block planting is to eliminate unnecessary walkways by planting vegetables in rectangular-shaped beds or blocks instead of long single rows. For example, plant a block of carrots next to a block of beets, followed with a block of lettuce and so forth down the bed area.

Plant crops with an equal-distance space between neighboring plants in both directions. For example, space a carrot patch on 3-inch by 3-inch centers. It may be easier to visualize this plant layout as running rows spaced 3 inches apart across the bed, and thinning the carrots within the row to 3 inches. A 24-foot long “traditional” row of carrots will fit into a 3 foot by 2-foot bed. [Figure 1]

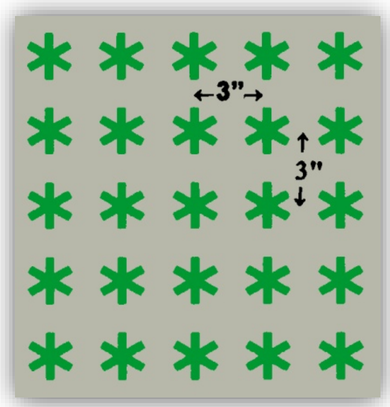

Figure 1. Carrots planted on 3-inch centers

Design the planting beds to be 3 to 4 feet wide and any desired length. This width makes it easy to reach into the growing bed from walkways for planting, weeding and harvesting.

Limiting foot traffic to the established walkways between planting beds reduces soil compaction. Design walkways to 18-24 inches wide. Mulch walkways with dry grass clippings, wood chips, or other organic mulch.

As the vegetable foliage grows together, the shade cast suppresses weed germination.

After harvesting a row of radishes, beets, lettuce, or spinach, replant for continual summer production.

Due to the higher plant density, block plantings require a weed-free, fertile, well-drained soil that is rich in organic matter. Give extra attention to watering and frequent, light fertilization to nourish the dense plant population. Avoid over-crowding vegetables; the reduced air circulation can increase disease problems.

Figure 2. Kitchen garden in block-style layout with (top to bottom) spinach, assorted lettuce varieties) and Swiss chard. Note that rows run across the four-foot wide bed. As a row of lettuce is harvested, it is replanted for continual production or neighboring crops fills in the space.

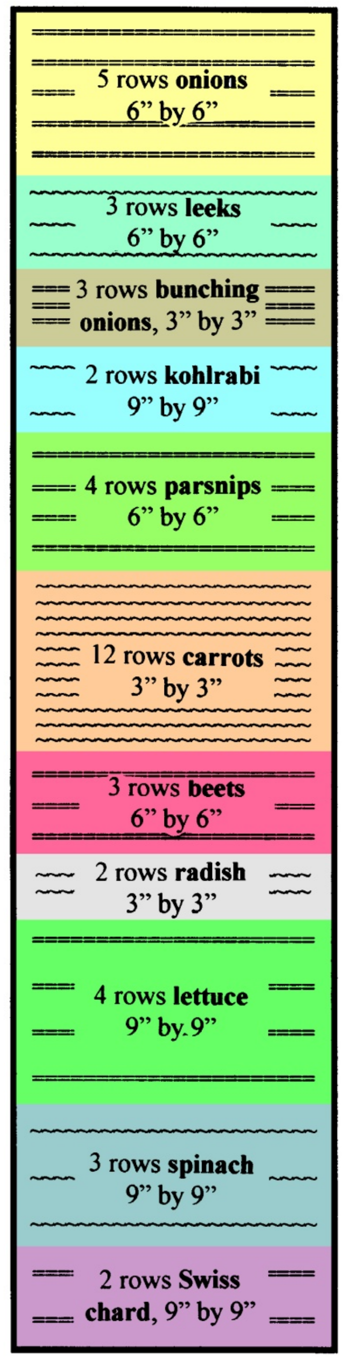

Figure 3. Sample layout of kitchen garden vegetables.

Suggested Spacing

Suggested spacing for kitchen garden vegetables: (Start with the wider spacings, reducing spacing with experience and as soil improves in fertility and tilth.)

- Beets: 4-6” by 4-6"
- Carrots: 2-3" by 2-3"
- Celery: 7-9" by 7-9"
- Garlic: 4-6” by 4-6"
- Kohlrabi: 7-9" by 7-9"
- Leeks: 4-6” by 4-6"
- Lettuce, head: l0-l2” by 10-12"
- Lettuce, leaf: 7-9" by 7-9"
- Onions, bunching” 2-3" by 2-3"
- Onions, dry: 4-6" by 4-6”
- Parsnips: 5-6” by 5-6"
- Radishes: 2-3" by 2-3"
- Spinach: 4-6” by 4-6”
- Swiss chard: 7-9” by 7-9”
- Turnips: 4-6”by 4-6"

Other vegetables suited to block planting

Cole crops (broccoli, cabbage, Brussels sprouts and cauliflower) – Spaced at 18 by 18-inches', or three plants across a 4-foot bed.

Corn – Always plant in a block to facilitate pollination. Five rows wide is recommended for the best “pollen shower" to maximize kernel set; three rows wide is minimum. Space at 12” by 24” or four rows across two, four-foot wide beds.

Eggplant – Space at 18-24 by 18-24 inches (or two or three plants across a four-foot wide bed).

Peppers – Space at 15 by 15 inches (or three plants across a four-foot wide bed).

Potatoes – Space at 12-15 by 12-15 inches (or three plants across a four-foot wide box).

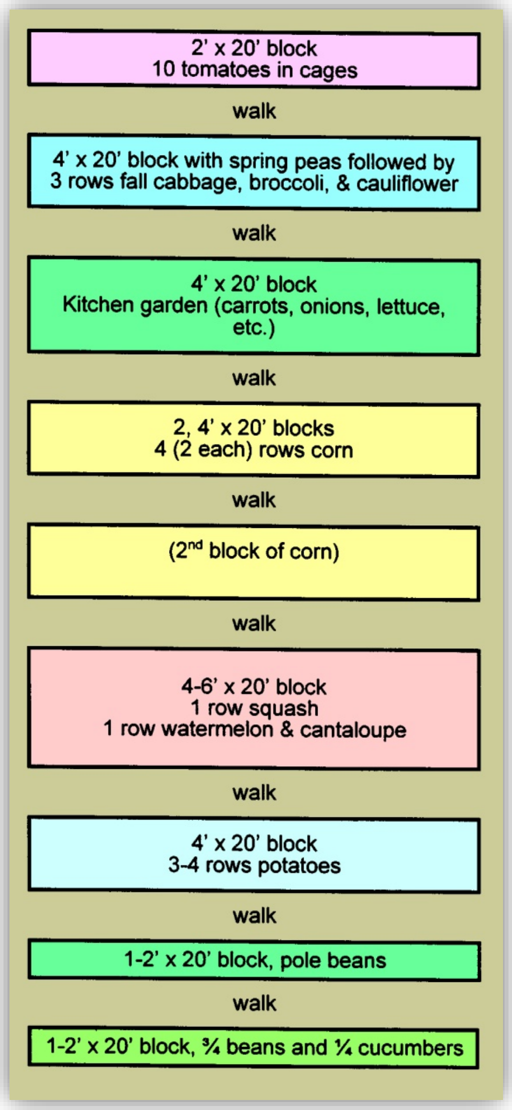

Figure 4. Sample block-style garden

Vine crops (squash, cantaloupes, pumpkins, and watermelons) – Place a single row down the center of a 4-foot wide box. They may also be planted in larger blocks, several rows wide. Place the winter squash and pumpkins in the center of the block and cantaloupes, watermelons, and summer squash around the edge where they can be reached for summer harvest.

Trellis tomatoes and cucumbers to save space and make harvest easier. The increased air circulation around trellised tomatoes helps suppress tomato blight. Space trellised tomatoes a minimum of 24 inches apart down a single row, in a block two to three feet wide. Plant cucumbers along a trellis at 9-12 inch spacings.

Beans and peas may be easier to pick and are less disease-prone if planted in single or double rows, rather than block style planting. Space beans 12 inches between rows and 4 inches between plants. Plant a double row down a block 2 to 3 feet wide.

Figure 5. Raised bed garden with chard, lettuce varieties, spinach, beets, and onions. Because even water distribution is needed for this bed with a heavy plant population, the drip irrigation hose is run up and down the bed four times on a 12 inches spacing. The bed will be mulched with dry grass clippings to conserve water and control weeds in summer. Wood chips make an excellent mulching material for the walkways.

Raised Bed Gardening

Raised bed gardens with block style layout have many advantages, including the following:

Higher yields and less area to weed – The block style layout, eliminating unnecessary walkways increases yields by five-fold over the traditional row-path-row garden layout.

Reduced soil compaction – Established walkways keep foot traffic off the growing bed, reducing soil compaction.

Earlier planting – The raised bed facilitates better runoff and drainage allowing soil to warm faster in the spring. Beds can be covered with plastic during spring rains, allowing for early planting even in rainy years.

Frost protection – The block-style layout is easy to cover for spring and fall frost protection. It can also be shaded in the hot summer.

Soil improvement – The raised bed is a clearly defined area where the gardener can concentrate on soil improvement techniques, (e.g., the addition of soil organic matter). In situations where the soil is poor, and limits plant growth, good planting soil may be added to the box.

Architectural interest – Raised beds become an architectural feature of the landscape design.

Accessible gardening – The raised bed is ideal for enabling persons with limited mobility to garden.

Constructing a Raised Bed Garden

Size – A bed 4 feet wide is ideal for most vegetable crops, allowing the gardener to reach the entire bed from the side without ever stepping on the soil in the growing bed. Length can be whatever works for the space.

Tomatoes are well suited to a bed 24 to 36 inches wide, with one row of plants down the middle. Beans and peas are easier to pick in a single or double row down a bed rather than in the block-style planting. Here a bed 24 inches wide would be ideal.

Depth / Height – The height of the beds is generally of no consequence, assuming that crops can root down into the soil below the bed. For most home garden situations, the role of a raised bed is to define and separate the growing bed from the walkway. Here a four-inch height would be adequate. Variations in heights (4", 6", 8", and 10") among different beds may help create an appealing landscape feature.

In situations where the soil below is not suitable for crop growth, 8 to 12 inches of soil is considered minimal. Deeper beds would make management easier.

To accommodate gardeners with special needs, bed height may be raised to minimize bending or to allow gardening work from a chair or wheelchair. Plan walkway space between beds wide enough to accommodate specialized equipment or mobility.

For ease of irrigation, beds should be reasonably level, both across and lengthwise.

Orientation – For frost protection, an east-west orientation has a slight advantage of collecting heat. For summer crop growth, a north-south orientation has a slight advantage of sunlight on both sides of the plant row each day. Because there is no clear advantage, orient the beds in whatever direction work best for the landscape design. Often beds are best arranged to be an appealing landscape feature of the property.

Construction materials – A simple way to construct a raised bed garden is to use construction lumber (2 by 4s, 2 by 6s, 2 by 8s, and 2 by 10s). Untreated lumber will last for several years, except in high salt areas or wet sites. Treated lumber will last longer. Simply cut two pieces the width of the bed (typically 4 feet) and two others to the desired bed length. Using 3½ to 4 inch decking screws, screw the corners together to make a four-sided box. Place the box-like frame on the soil and fill.

Various landscaping timbers may also be used in like fashion. Cooper treated lumber is safe for garden boxes. However, do not use railroad ties (creosote cancer concerns) or CCA pressure treated lumber (removed from the market several years ago due to arsenic concerns). Brick or other building materials may also be suitable.

Raised beds may also be made without sides. Here, organic matter is mixed as the garden is tilled. Walkways are dug down with the soil thrown up on the bed. Beds are 4 feet wide at the base and three feet wide at the top. The entire bed is covered with organic mulch like dry grass clippings to prevent soil erosion and reduce compaction from rain and sprinkler irrigation. [Figure 6]

Figure 6. Raised bed garden without sides. Beds are 4 feet wide at the base and t3 feet wide at the top. Walks were dug down with soil placed on the beds.

Adding soil – In the typical garden setting where crop roots will spread down into the soil below the bed, it is best to use similar soils. It may be beneficial to double-dig the beds. In ***double-digging***, the top 6 inches of soil is moved from one side of the bed to the other side of the bed. Mix organic matter into the soil below the excavated side. Return the soil to the top, mixing in organic matter. Then repeat the process for the other side of the bed.

When adding soil, avoid creating a situation where one type of soil ends and another begins. This creates a line between soil types that impedes water and air infiltration and slows, or even stops, root penetration. If the soil being added to the bed is different from the soil below, mix some of the two together before adding the remainder to avoid a distinct line of change.

In situations where the entire rooting zone will be in the raised bed, a soil on the sandy side with 4-5% organic matter would be preferred.

When purchasing soil, be aware that there is no legal definition of topsoil or planting soil. Just because it is commercially available in bulk or sold in bags, does not necessarily mean that it is good for gardening. Many bagged and bulk soils and soil amendments are prepared with compost made with manure and may be high in salts.

Figure 7. A recently planted raised bed garden. Corn boxes to left, kitchen garden in center, strawberry patch on right, tomato patch in back with black plastic mulch. Growing beds are mulched with grass clippings; wood chips were used between beds.

Gardening in a Raised Bed

Due to the high plant population, raised beds require better than average soils, and more frequent irrigation and fertilization. Concentrate on improving soils with routine applications of organic matter. For details on soil improvement and fertilization, refer to the various *CMG GardenNotes* #711, **Vegetable Garden: Soil Management and Fertilization**.

Mulching – Mulch beds to control weeds, conserve soil moisture, and regulate soil temperatures. Grass clippings make great mulch when applied in thin layers (up to ¼ inches thick). Allow each layer to dry between applications. Do not use clippings from lawns treated with weed killers or other pesticides for at least four weeks after application. Wood/bark chips are great for mulching between the beds. Three to four inches of chips will minimize the compaction forces of foot traffic. However, do NOT mix wood/bark chips into the growing bed, it will interfere with seedbed preparation. For additional information on mulching, refer the to the *CMG GardenNotes* #715, **Mulches for the Vegetable Garden**.

Watering a raised bed – Drip irrigation is well suited to raised bed gardening. It is rather easy and inexpensive to add a water tap at the end of each box. Alternatively, simply move a garden hose in turn to each box and connect the drip hose. Sprinkler irrigation is also suitable, but less desirable due to potential disease problems. For details on irrigation, refer the *CMG GardenNotes* #714, **Irrigating the Vegetable Garden**.

As a point of clarification, raised bed gardening is a water conservation technique. It does require more frequent irrigation due to the higher plant density. However, it is more efficient resulting in higher yields for the amount of water applied compared to the larger areas watered in traditional row-walkway-row culture. Raised beds become even more efficient when watered with drip irrigation or soaker hoses on timers.

Frost protection – An advantage of raised bed, block style layout is that the bed is easy to cover for protection from springs rains and frost, allowing for early planting.

Figure 8. Frost protection covering adds two to six plus weeks to the growing season.

This picture illustrates a Quonset-type cold frame covering made of concrete reinforcing mesh covered with plastic. This style of frost protection adds two to six plus weeks on both ends of the growing season for cool season vegetables. Any type of covering must be opened during the day to prevent overheating.

Authors: David Whiting (CSU Extension, retired), Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.

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CMG GardenNotes #714

Irrigating the Vegetable Garden

Garden Irrigation

In vegetable production, an adequate supply of water during the growing season is directly related to produce quality and yields. Many vegetables become strong-flavored or stringy with water stress.

Several gardening techniques (including soil preparation, mulching, and efficient irrigation) help conserve water in the vegetable garden.

As a rule of thumb, vegetables use around ¼ inch of water per day during typical summer weather. If the garden is watered every four days, apply one inch of water per irrigation. Hot, windy weather will increase water demand significantly. Beans and corn will be significantly higher in water demand during blooming or tasseling/silking.

Checking Soil Moisture Content

Check soil moisture regularly. Irrigate when the top two to four inches of soil is dry to the touch. This is especially important if using mulch, where surface evaporation is reduced.

Evaluating when the soil needs irrigation is rather subjective. The "stick" method (judging moisture by the relative easy or difficulty of pushing a stick or screwdriver into the soil) is an old farmer's standard. It will be easier when wet than when dry. However, this very subjective method is specific to soil types and can be misleading to the novice. On compacted clayey soils, it may be somewhat difficult when moist and very difficult when dry. On sandy soils, it may be somewhat easy wet or dry.

To check moisture levels, a soil probe is a useful tool to pull up soil samples from the rooting zone at a six to eight inch depth. A small garden spade could be used.

Houseplant watering meters are helpful in evaluating the soil moisture content under mulch. Realize however, that these inexpensive meters are somewhat inaccurate. If the fertility level is high, the meter will read on the wet side. If the fertility is low, the meter will read on the dry side. Learn to interpret the meter reading for a specific soil by trial and error. [Figure 1]

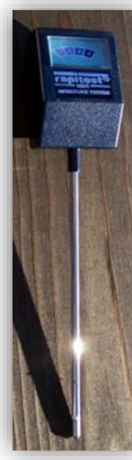

Figure 1. Although somewhat inaccurate, a houseplant water meter is a tool to evaluate water needs in the garden.

Automate the System with Controllers

Sprinkler or drip systems can be easily automated with a multi-zone controller like the lawn. A small garden could be connected to the lawn's controller as a separate zone and run on a different program. However, do not have the lawn and vegetable garden on the same zone, as water needs are not the same.

Single zone controllers connect to the garden hose. Some simple models are manually turned on and automatically turn off after the set number of minutes or gallons. More elaborate battery operated models turn the water on and off at the day and time interval set by the gardener. [Figure 2]

Figure 2. Single zone controllers connect to the hose line. Left: This style is manually turned on and automatically turns off the water flow after the set number of minutes. Right: This battery powered controller turns water on and off at the day and time intervals set by the gardener.

Furrow Irrigation

For gardeners who have irrigation water from a ditch, furrow irrigation in the traditional row-style garden layout may be most practical. As a rule of thumb, adjust water flow for the furrow so that the water reaches the end of the row 1/3 of the time into the irrigation period. For example, if the irrigation period is 15 minutes, the water should reach the end of the row in five minutes. Soil erosion and runoff are major disadvantages of furrow irrigation.

Sprinkler Irrigation

Sprinkler irrigation is considered more efficient in water delivery than furrow irrigation. It is easy to measure the amount of water applied and easy to manage. Because it wets the entire soil surface, weed seed germination may be high.

Sprinkler irrigation is discouraged on vegetables prone to foliar diseases such as Early Blight (tomatoes, peppers, and potatoes). The splashing water spreads disease organisms and water on the leaves creates favorable conditions for disease development. Tall crops, such as corn and pole beans may interfere with water delivery patterns.

As a rule of thumb, vegetables use around ¼ inch of water per day, depending on temperature, wind, and stage of crop development. For example, if the garden is watered every four days, apply one inch of water per irrigation. The gardener can quickly learn how long to run the sprinklers by measuring the amount of water in several straight-sided cans placed around the garden.

Delivery rates depend on the type of sprinkler heads used, pressure, and the spacing of heads in the garden. For example, pop-up spray heads deliver around 1½ inches per hour and would typically run 40 minutes to apply 1-inch of water. Rotor type heads deliver around 1/2 inch per hour and would typically run for 120 minutes to apply 1-inch of water.

Because the water needs of the vegetable garden are different from a lawn, it should be on a different irrigation zone than the lawn. Water use will be low in the spring when crops are small and temperature are cool and will increase as the temperatures rise and crops come into bloom.

Drip Irrigation

Drip irrigation is well suited for the block-style garden layout and raised beds. Several different types of drip systems are available including:

- **In-line drip tubing** – Emitters are found in the tubing every 6, 12, or 24 inches; 12 inches is most common in the home garden trade.
- **Soaker hose** and **soaker tubing** – Emits water along the entire length of the hose.
- **Bubblers** and **drippers** – Emitter or drippers are placed to water individual plants.

A disadvantage of a drip system is that they require relatively clean water. Systems readily plug with dirt, algae, or salts in the water. This is generally not a problem when using drinking quality municipal water supplies. Depending on water quality, drip irrigation may not practical for many non-potable water sources. The filtering system required may be expensive and high maintenance.

Ideally, an in-line drip hose or soaker hose is placed on the soil surface under the mulch. The soaker hose may also be buried a couple of inches into the soil to protect the hose from breakdown by sunlight.

On a raised-bed box, space the drip line/soaker hose at 12-inch spacing. A four-foot wide box would have four runs of the drip line/soaker hose up and down the box (as illustrated in Figure 1). For larger vegetables like corn, squash, and cole crops (three plants across a four-foot wide bed) make three runs up and down a four-foot wide box. On a two-foot wide raised bed box for tomatoes or beans, the drip line/soaker hose runs down and back. [Figure 3]

Figure 3. On this four-foot wide box, the drip line or soaker hose makes four runs up and down the box at 12-inch spacing. Carrot rows are running across the box.

Drip systems are designed to run on low pressure. High pressure may split the hose and pop connections. The desired low pressure is easy to achieve with pressure regulators that have hose-end fitting (found with the drip system supplies). If the garden has changing elevations, a pressure regulator will be needed for every couple of feet change in elevation. [Figure 4]

Figure 4. With irrigation pipe, it is easy to plumb a tap at each raised bed box. Here a pressure regulator with hose-end fittings reduces pressure to 25 psi. It is connected to a ½-inch soaker hose.

Determine the run time by examining the soil moisture content. Run time will vary with the brand of hose, water pressure, and spacing.

Soaker Hose and Soaker Tube

The soaker hose and soaker tube type of drip system allows water to seep out the entire length of the hose. It is easy to use in traditional row style or raised-bed gardens. [Figure 5]

Figure 5. Soaker hose seeps water out along the length of the hose.

It can be connected by manually connecting the garden hose to each line at each irrigation session or by connecting a series of dedicated garden hoses to a series of lines. On raised-bed gardening, it is easy to run a water line with a tap to each box. Several small boxes may run together on the same zone. [Figure 4]

For uniform water delivery, keep runs short, generally 25 feet or less. With long lengths, water delivery will be higher at the top of the hose line and less at the bottom. The ground must be reasonably level. On slopes, run several short lengths.

Several brands and styles are available in the home garden trade.

- **Half-Inch Soaker Hose** – Some brands (like *Swans Soaker Hose*) are a ½-inch hose that connects with standard hose fitting. These are found the garden hose section. It can be cut to any length and connected with garden hose fittings.

  A small plastic disc fits inside the female hose connection as a pressure regulator (actually a flow regulator). With the reduced water flow, it may need to run for around an hour to adequately water the garden. It works better to use the pressure regulators with hose-end fittings found with the drip irrigation supplies (figure 4). With this type of regulator, the drip line runs 10-20 minutes to adequately water the garden. Without a pressure regulator of some type, the soaker hose tends to rupture sending out steams of water at spots rather than dripping along the line.

  This half-inch hose style is more tolerant of small amounts of dirt, algae, or salts in the water than other types of drip systems, and may be successful on some nonpotable water sources. Periodically, open up the end of the hose and flush out soil deposits.

- **Quarter-inch Soaker Tubing –** A ¼ inch soaker tubing is availble in the drip irirgaiton section at garden stores. Cut the soaker tubing to desire length and connect with drip system components. An in-line pressure regulator (figure 4) is required; otherwise, the fitting may pop or leak.

  Because the soaker tubing has a higher delivery rate, it can not be on the same zone as other in-line drip hoses, button emitters, or bubblers.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.

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CMG GardenNotes #715

Mulches for the Vegetable Garden

Benefits

The benefits of mulch depend on the material used and depth to which it is applied. In general, mulching minimizes evaporation of water from the soil surface, reducing irrigation need by around 50%. It helps stabilize soil moisture levels, thereby improving vegetable quality and encouraging the beneficial activity of soil organisms.

Mulching helps reduce soil compaction forces from rain and traffic. Some may later be plowed into the garden as a soil amendment, adding organic matter to the soil. Mulching may cool or warm soil temperatures. It may control weeds.

Grass Clippings

Grass clippings make excellent mulch for the vegetable garden. Apply fresh clippings in thin layers (up to 1/4 inch thick) and allow each layer to dry before adding more. The clippings quickly dry down and additional layers can be added weekly. A few layers will stop weed seed germination. Do not place fresh clippings in thick piles, as they will mat, reducing water and air infiltration, stink, and may become hydrophobic. Do not use clippings from lawns that have been treated with herbicides or other pesticides in the past month. [Figure 1]

Figure 1. Grass clippings being applied to garden directly from lawn mower bag. Apply only in thin layers, allowing the grass layers to dry between applications.

Around lettuce and other leafy vegetable, mulch by carefully hand placing the grass at the base of the plants. Grass sticks to wet lettuce, creating a problem in food preparation.

A couple of sheets of newspaper may be used under the clippings to help control weeds. The newspapers blow away with a light wind. It must be covered immediately with grass to hold it in place. It shuts out the light preventing seed germination. Do not apply newspapers more than a couple of sheets thick or a soil carbon to nitrogen imbalance may occur. Do not use glossy print materials; their inks may not be soy-based like newspapers. The grass and newspaper mulch may be cultivated into the soil in the fall adding small amounts of organic matter. [Figure 2]

Figure 2. Corn bed being mulched with newspapers (only a couple of sheets thick) covered with grass clippings.

Wood or Bark Chips

Do not use wood or bark chips in the growing beds since they will interfere with future seedbed preparation. It takes several years for chips to decompose in the soil.

In a raised-bed garden, wood or bark chips make excellent mulch between the boxes. Apply three to four inches deep to control weeds. At this depth, chips also prevent soil compaction from foot traffic, allowing crop roots to spread out under the walkways. [Figure 3]

When placed on the soil surface as mulch, wood/bark chips do not tie-up soil nitrogen. Does not use fine sawdust for mulch because it could create carbon to nitrogen imbalance.

Figure 3. Wood or bark chips make excellent mulch between raised-bed boxes.

Do NOT put wood or bark chips on the growing bed. The chips take years to breakdown and will interfere with seedbed preparation.

Black Plastic

Black or colored plastic mulch is extensively used in commercial tomato, pepper, and melon production in Colorado. It merits consideration for the tomato family (tomatoes, peppers, eggplant) and the vine crops (cucumbers, summer and winter squash, pumpkins, watermelons, cantaloupes and other melons). Because it warms the soil, it is undesirable for other crops.

Put the plastic on the growing bed early in the season to start the soil warming. **Crops must be planted early so plant growth shades the plastic before summer heat arrives.** Otherwise, the plastic can be too hot for crops and must be removed.

The plastic warms the soil allowing for earlier crop growth. Along the Colorado Front Range, crops average 2-3 weeks earlier production and produce higher yields. In cooler locations, crops could be three to over four weeks earlier in production.

The black plastic mulch also controls weeds and reduces the need for irrigation. Because there is no surface evaporation of water, it is easy to over-irrigate crops.

Applying plastic mulch

1. Prepare the soil and irrigation system. Drip irrigation with a soaker-type hose works well. Slightly mound the soil so the plastic makes direct contact with the ground.
2. Cover the growing bed with the plastic. Bury all edges two to four inches. On a raised-bed box made with lumber, staple the plastic on the sides of the box.
3. Cut holes to plant or transplant into. Do not cut “X’s”— the hot plastic touching tender plants can burn.

Figure 4. Tomatoes planted down a 30-inch wide raised-bed box. Plastic mulch is stapled to side of box. Plants are spaced at 24 inches in the center of 24-inch wide cages.

Figure 5. Trellised tomatoes in raised-bed box with black plastic mulch.

With plastic mulch, crops must be planted early so plant growth shades the plastic before summer heat arrives.

The plastic fluttering in the wind pumps air into the soil. However, covering the plastic with organic mulch like grass clippings or chips could reduce soil oxygen levels.

In the fall, do NOT plow in the plastic, rather remove and put it in the trash. Polyethylene plastic will never decompose in the soil. Because it breaks down with sunlight, it generally can be used only for a single season. Chemists are working on biodegradable plastics for horticultural uses. It will be a few years before they are available.

Some gardening magazines talk of colored plastics. For example, red plastic is reported to increase tomato yields in cloudy climates. It also makes the fruits softer in texture. With Colorado's high light intensity, color is insignificant.

Warming the soil for other crops – Plastic may also be used to warm the soil for other crops, being applied early and **removed prior to planting**. For maximum soil warming, clear plastic is most effective. However, it will also encourage weeds to grow under the warm, greenhouse-like covering.

Straw

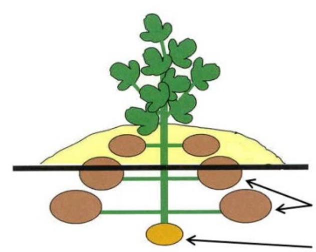
Weed free (seed free) straw makes excellent mulch for potatoes. When purchasing straw, look for certified weed (seed) free products. Otherwise, the potato patch may be thick with oats!

The straw protects tubers growing near the surface from sunlight, so the potato plants do not have to be mounded. (When a potato tuber is exposed to sunlight, it turns green, becoming mildly poisonous.) [Figure 6]

Certified weed (seed) free straw is also a good organic source for clayey soils. After using it as a summer mulch, thoroughly cultivate it into the soil as a soil amendment in the fall.

Figure 6. The new crop of potatoes grows above the seed piece.

To shield growing tubers from sunlight (which turns them green), soil is "hilled" (mounded) around the base of the plant. Straw mulch may be used as an alternative to hilling.



Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County) and Carl Wilson (CSU Extension, retired). Photographs and line drawings by David Whiting; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #716

Water Conservation in the Vegetable Garden

In vegetable production, an adequate supply of water during the growing season is directly related to produce quality and yields. Many vegetables become strong flavored with water stress. Unlike bluegrass and other landscape plants, vegetables cannot go dormant when the water supply is inadequate. However, there are several techniques that will significantly reduce the water requirements of the home vegetable garden.

Always follow efficient irrigation practices. The following practices will allow gardeners to have a productive vegetable garden and still reduce water consumption.

Water Conserving Techniques

Amend Garden Soil with Coarse, Decomposed Organic Matter

In the vegetable garden, the routine addition of organic soil amendments, such as compost, will optimize potential yield- and produce quality. The goal in soil management is to increase the organic content to 4-5%, over a period of years.

On sandy soils, organic matter holds over ten times more water and nutrients than the sand. On clayey soil, organic matter glues the tiny soil particles together into larger aggregates, increasing pore space. This process takes place over time. This increases soil oxygen levels and improves soil drainage, which in turn increases the rooting depth allowing roots to reach a larger supply of water and nutrients.

Organic matter also encourages the beneficial activity of soil organisms and helps remediate soil compaction

Manure and compost made from manure may be high in salts that will interfere with crop growth. The standard application rate for plant-based compost (free of salts) is two to three inches per year, cultivate into the soil six to eight inches deep. After a few years, the application rate should be cut back to avoid excessive soil salts, phosphorus, and potassium.

Manure and manure-based compost may be high in soil salts. The standard application rate is one-inch maximum per year, cultivated into the soil six to eight inches deep. Do not add more unless a soil test on the specific batch indicates low soil salt levels. Soil testing on many commercially available products available in Colorado markets found extremely high salt levels in some products. For high salt products, the one-inch application rate may be too high.

Be sure that the organic matter is thoroughly cultivated into the soil. Leaving chunks of organic matter will interfere with seeding, root spread, and water movement through the soil profile.

In the vegetable garden, do not plow in woody materials such as bark or wood chips, as they may interfere with seedbed preparation and may result in soil nitrogen depletion. Wood chips take several years to decompose in the soil.

Due to a health issue (*E coli* contamination), fresh manure additions should be made at least four months prior to the harvest of any edible crops. In other words, apply fresh manure only in the fall after crops are harvested.

Another method to add organic matter is to replant the fall garden with a green manure crop such as winter rye or Austrian peas. For details, refer to *CMG GardenNotes* #244, **Green Manure and Cover Crops.**

For additional details, refer to *CMG GardenNotes* #711, **Vegetable Garden: Soil Management and Fertilization**.

Reducing Water Need with Drip Irrigation and Mulching

Use of a drip system on a mulched garden reduces water need by around 50%.

Other Water Saving Techniques

Plant in blocks, rather than rows. This creates shade for roots and reduces evaporation. For details, refer to the *CMG GardenNotes* #713, **Block Style Layout in a Raised Bed Garden**.

Control weeds that compete with vegetables for water.

Group plants with similar water needs in the same section of the garden for easy irrigation. Cucumber, zucchinis, and squash, for example, require similar water applications.

Protect plants and soil from wind with windbreaks to reduce evaporation.

Critical Water Periods for Vegetables

You can target the timing and amount of water to add. As a rule of thumb, water is most critical during seed germination, the first few weeks of development, immediately after transplanting, and during flowering and fruit production. The critical watering periods for selected vegetables follow:

Asparagus needs water most critically during spear production and fern (foliage) development. Less water is needed after ferns reach full size.

Cole crops (broccoli, cabbage, cauliflower, collards, Brussels sprouts, kale, and kohlrabi) need consistent moisture during their entire life span. The quality of cole crops is significantly reduced if the plants get dry anytime during the growing season. Water use is highest and most critical during head development.

Beans have the highest water use of any common garden vegetable. During blossoming and fruit development, beans use 0.25-inch to over 0.50-inch of water per day (depending on temperature and wind). Blossoms drop with inadequate moisture levels and pods fail to fill. On hot, windy days, blossom drop is common. When moisture levels are adequate, the bean plant is a bright, dark, grass-green. As plants experience water stress, leaf color takes on a slight grayish cast. Water is needed at this point to prevent blossom drop.

Carrot and other root crops require consistent moisture. Cracking, knobby, and hot flavored root crops are symptoms of water stress.

Corn water demand peaks during tasseling, silking, and ear development. Water stress delays the silking period, but not tasseling. Under mild water stress, the crop may tassel and shed pollen before silks on ears are ready for pollination. The lack of pollination may result in missing rows of kernels, reduced yields, or even eliminate ear production. Yield is directly related to quantities of water, nitrogen, and spacing.

Lettuce and other leaf vegetables need water most critically during head (leaf) development. For quality produce, these crops require a constant supply of moisture.

Onion family crops require consistent moisture and frequent irrigation due to their small, inefficient root system.

Peas need water most critically during pod filling.

Potato tubers will be knobby if they become overly dry during tuber development.

Tomato family (tomatoes, peppers, and eggplant) needs water most critically during flowering and fruiting. Blossom end rot (a black sunken area on the bottom of the fruit) is often a symptom of too much or too little water. The tomato family has a lower water requirement than many vegetables and plants are often over-watered in the typical home garden.

Vine crops: cucumbers, summer and winter squash, and assorted melons need water most critically during flowering and fruiting. Vine crops use less water than many vegetables and are often over-watered in the typical home garden.

Vegetable Gardening When Irrigation Interval Is Restricted

- Restrictions that allow for thorough watering only twice a week should not have a major effect on the vegetable garden. With adequate soil organic content, a standard in vegetable production, the garden should be able to go two to seven days between irrigations. Follow recommendations listed above.
- Avoid heavy water use crops such as beans and sweet corn.
- Grow only what you need. Consider that one tomato plant can yield over 20 pounds of fruit.

Vegetable Gardening When No Watering Is Allowed

- When water restrictions prohibit outdoor watering, do not plant a vegetable garden. Vegetables do not go dormant like Kentucky bluegrass lawn. If water restrictions allows, consider planting containers with vegetables and consider planting non-irrigated or minimally-irrigated cover crops in the vegetable garden area.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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CMG GardenNotes #717

Growing Tomatoes

Variety Selection

There are over 2,000 cultivars of tomatoes grown worldwide. Ask neighbors, local gardeners, and garden center staff about local favorites.

Hybrid tomatoes are popular in the United States to reduce problems with *Verticillium* and *Fusarium* wilt, common soil-borne pathogens. Early hybrids were developed for their yields and disease resistance. Flavor became a driving factor in the breeding of newer hybrids. Some gardeners prefer to trade off the disease protection of hybrids for the rich "tomato-ey" flavors of heirloom varieties.

For early production, *Early Girl* is a popular variety with mid-size fruits. *Celebrity*, *Big Boy*, and *Better Boy* are examples of popular main season varieties. Many gardeners prefer the rich tomato flavor of heirloom *Brandywine* or the large beefsteak types. Pear tomatoes and yellow types are gaining popularity.

Cherry and the new grape-type tomatoes are popular for salads and snacking. Many, but not all, have small size vines suitable for container gardening. [Figure 1]

Figure 1. ***Sweet 100*** is the most popular home garden cherry-type tomato. On a large vine, it produces hundreds of sweet, cherry sized fruits with very tender skins.

Requiring less time to cook down, paste types such as *Roma* and its descendents are preferred for making salsa, chili sauce, and other tomato products. Be aware that paste types and standard varieties are not directly interchangeable in recipes.

Where the growing season is short, select *Early Girl* and other cultivars that will mature in 50 days or less. In many mountain communities, tomatoes may only be successfully grown in a structure or adjacent to the south side of a building to provide frost protection and warmer growing temperatures.

Whatever type you prefer, VFN resistant hybrid varieties are recommended. The abbreviation VFN indicates resistance to *Verticillium* wilt, *Fusarium* wilt, and nematodes. Verticillium and Fusarium wilts are common soil-borne fungal diseases. Nematodes are not an issue in Colorado due to cold soil temperatures. Researchers have found multiple strains of *Verticillium* and *Fusarium*, so if you are having problems with these diseases, try <u>other</u> VFN varieties.

<u>Vine types</u> – There are two types of vines: *indeterminant* and *determinant*. Most popular home garden varieties are indeterminant. The vine keeps growing through the growing season, extending fruit production until frost kills the vine. Plant size is typically large. Determinant types are common in commercial production as vine growth stops when flowering begins; plants will typically be moderate in size. Determinant types put on a large single crop. They may be suitable for container planting where trellises are not possible.

Planting

<u>Planting Time</u>

For optimal growing, tomatoes need warm temperatures: above 52ºF at night and above 60ºF during the day at transplant. They are readily killed by a light frost. A week of cool daytime temperatures (below 55ºF) will stunt plants, reducing yields.

With these warm temperature requirements, planting time along the Colorado Front Range is typically late May. Do not plant tomatoes out into a cold spell and make sure soil temperatures are warm.

To get a head start on the season, gardeners use a variety of frost protection techniques. The Wall-of-Water® provides protection into the mid teens, or lower. Cool soil temperatures also inhibit early growth. When using a Wall-of-Water, also use black plastic mulch to help warm the soil. Be cautious in filling the Wall-of-Water not to splash water around, as a wet soil will be slow to dry and warm in the spring. [Figure 2]

Figure 2. Wall-of-Water protects individual plants down to the mid-teens.

Notice that black plastic mulch was also used to warm the soil. Cool soil temperatures are also a growth-limiting factor with early plantings.

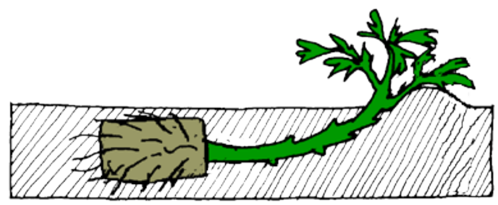
Selecting the Ideal Plants

The ideal tomato transplant is dark grass green and six to eight inches tall. The stem is about pencil size in diameter and the plant has not been pruned or cut back. Transplants are hardened-off (growth rate slows so the plant is more tolerant of the move the greenhouse environment to the bright, windy outdoors) by withholding water and/or nutrients or by exposure to cooler temperature.

Plant leggy transplants horizontally – When gardeners are shopping for transplants in the warm greenhouse conditions of May, tomato plants quickly grow from ideal size to tall and leggy. The white bumps along the leggy tomato stem are roots beginning to form.

Plant these taller leggy transplants horizontally. Dig a trench a two to three inches deep. Place the plant horizontal with only the top two to three sets of leaves showing above the soil. Pinch off other lower leaves below the soil line before planting. These leggy plants readily root out along the stem in the warm soil near the surface, supporting rapid growth. [Figure 3]

Figure 3. Plant tall leggy tomatoes horizontal in a shallow furrow.



Space and Trellis Plants

To minimize Early Blight, space and trellis plants to allow for good air circulation and promote rapid drying. Trellised tomatoes are easier to pick and less preferred by tomato psyllid insects. Trellising eliminates problems with fruit rotting where they touch the ground.

The minimal spacing for trellised tomatoes is two feet apart in a hedgerow. Research has demonstrated that crowding plants will not increase yields, but will increase disease problems.

Cages – The American Society for Horticultural Science suggests a trellis two feet in diameter by four to five feet tall. It is easy to make from a 6½-foot length of concrete reinforcing mesh. Cut off the bottom ring of wire so the cages can be pushed into the ground. When a branch sticks out of the cage, simple tuck it back in. [Figure 4]

For the smaller-vined, determinant types, two cages may be made from a 6½-foot length, cutting the height in half. Cages will be two feet diameter but only 3-feet tall.

Commercially available cages are too small for most popular tomato varieties grown on good soils.

Figure 4. Tomatoes planted in a raised bed with black plastic mulch and cages made from concrete reinforcing mesh.

Cages are six feet around, two feet across, and five feet tall. On improved soils, tomato vines will loosely fill the cage, allowing for good air circulation and easy picking.

Tender transplants are rather sensitive to cool winds. Wrapping the cages with a plastic sheet or newspapers to provide wind protection for the first week helps plants acclimate.

Figure 5. Wrapping the tomato cage with plastic or newspapers protects tender plants from cold winds.

Single pole trellis – Some gardeners prefer to trellis tomatoes on a single pole or stake. To do this, prune plants to a single trunk by removing all side shoots. This requires constant removal of side shoots.

Figure 6. Tomatoes trellised to a single pole.

Fan trellis – Another method, which produces larger fruit, is to trellis to a three-trunk, fan shape, removing all other side shoots. This requires a sturdy frame to support the weight of the vine and fruit.

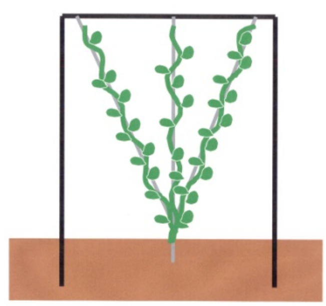


Figure 7. Tomatoes trellised into a fan shape.

Mulching

As with any crop, surface mulch is recommended to conserve soil moisture and manage weeds. Mulching helps reduce the splashing of Early Blight fungal spores from the soil onto the leaves. It also helps stabilize soil moisture levels, reducing the incidence of blossom end rot.

Black plastic mulch is popular for tomatoes, warming the soil and pushing production two to three weeks earlier. When using black plastic mulch, crops must be planted early so plant growth covers and shades the plastic before summer heat sets in. .

Irrigation

Avoid overhead sprinkling on tomatoes. Fungal spores are easily water-splashed from one leaf to another, and water on the leaves creates a favorable environment for disease development. Watering in the morning, allowing plants to dry before nighttime, may also be helpful.

Fertilization

Tomatoes have a low nitrogen requirement. Under high nitrogen conditions, vines grow excessively large at the expense of fruit production. More correctly stated, tomatoes are a fussy nitrogen feeder. On soils low in organic matter, tomatoes typically run out of nitrogen in mid-summer, reducing yields and predisposing the plants to Early Blight.

At transplanting, apply one to three applications (depending on soil organic content) of a water-soluble, "plant starter" fertilizer. This includes any of the water-soluble products like MiracleGro, Peters, RapidGro, Schults, etc. Transplants would have been "hardened off" (growth slowed) in the greenhouse. Water-soluble fertilizers stimulate renewed growth.

If the weather turns cold late spring after tomatoes are out (that is a week with daytime temperatures below 55ºF), use water-soluble fertilizers to stimulate growth when warm temperatures return. A week with daytime temperatures below 55 ºF stunts tomato growth, reducing yields.

Mid-summer – On low organic matter soils, tomatoes typically run out of nitrogen in mid to late summer. Yellowing of the foliage, starting with lower leaves, is the typical symptom of nitrogen stress. Low nitrogen in the plant allows Early Blight disease to spread like wildfire. Keeping nitrogen levels up in mid to late summer is a primary means of Early Blight control and significantly improves yields.

Fertilize tomatoes lightly as the first fruits reach two-inches in diameter. Water-soluble fertilizers (such as MiracleGro, RapidGro, and Peters) used according to label directions make a good summer fertilizer supplement. Make applications every two to four weeks, depending on soil organic content.

If using a dry granular fertilizer, apply 21-0-0 (ammonium sulfate) at the rate of one level tablespoon per plant. Sprinkle the granular fertilizer in a wide circle 12 to 20 inches out from the plant, and water in. Dry granular fertilizers can easily kill tomatoes if over-applied.

Pollination and Summer Temperatures

Tomato pollination is temperature dependant. If nighttime temperatures drop below 55ºF, pollen fails to develop and flowers that open the following morning will not set fruit. Cool nights often interfere with fruit set for early tomatoes and in higher elevations. Blossom set sprays help set fruit even with cool nights.

If the daytime temperature reaches 90ºF by 10 a.m., blossoms that opened that morning abort. Blossom set sprays are not effective under high temperatures.

In July and August along the Colorado Front Range, night temperatures have a 50/50 probability of staying above 55ºF any given night. In unusually warm seasons, tomato fruit set may be unusually high. When poor soil conditions and/or watering problems limit plant growth potential, fruit may ripen while small. With good soil tilth and water conditions, fruit size may be unusually large.

Garden Sanitation

Control weeds. Common weeds harbor many garden insect and disease problems. Volunteer potatoes and tomatoes could be a source of Early Blight infection. [Figure 8]

For Early Blight management, some references suggest removing lower leaves showing symptoms. Symptoms start as tiny black spots on lower leaves. Spots enlarge to light and dark target-like rings. Leaves yellow and the disease progresses from lower leaves up the plant.

If removing lower leaves, focus on leaves with the tiny black spots. Removing just the lower yellow leaves will not be adequate. Wash hands with soap and water immediately after touching diseased leaves to prevent spreading spores to other plants. Avoid working with the plants when they are wet.

Another disease, tobacco mosaic virus (TMV) can readily spread from tobacco smoke residues on the hands and clothing to tomatoes. Prevent TMV infections by washing hands after smoking or handling tobacco products.

Figure 8. Early blight leaf spots [Photo: USDA]

Rotation

Since the common tomato diseases (Early Blight, Verticillium and Fusarium wilt) are soil borne, crop rotation is an effective management tool. However, this may not be practical in most home garden situations, particularly since rotation allows no tomatoes, peppers, potatoes, eggplants, vine crops (cucumbers, squash, pumpkins, and melons), strawberries, or raspberries in the same growing area for at least four years. In a garden bed, moving the tomatoes a few rows to the left or right is not an effective rotation.

Fall Clean Up

Remove all tomatoes and potato debris in the fall. Dispose of debris in municipal trash or by burial. Do not compost unless the compost heats to at least 145ºF and the pile is turned occasionally. Most home compost piles do not heat adequately to kill pathogens.

Common Disorders

- CSU Extension fact sheet #2.949, **Recognizing Tomato Problems**

Figure 9. Blossom end rot on tomato is caused by water imbalance between the fruit and soil. The soil could be too wet, too dry, or root could be cut by cultivation. It could be aggravated by soil compaction and poor soil preparation.

Ripening Fruit at the End of the Season

To speed fruit ripening in the fall, hold back slightly on watering.

Ripening Fruit Indoors

With the forecast of a light frost, tomatoes may be protected by covering. If heavy frost is forecast and covering is not practical, harvest fruit before the frost event and carry indoors.

Pick ripening fruit and green tomatoes with a glossy green appearance that have reached about three-fourths of their full size. Remove stems. Wash fruit under a stream of water and allow to air dry on a clean towel. Save only blemish-free fruits for ripening indoors.

As for humidity, fruit shrivel if it is too low. If the humidity is too high, fruit mold. A gardener will have to learn by trial and error what works for their home. Some gardeners simply hang the whole plant upside down in a dark cool barn or basement to let the fruits ripen gradually. In Colorado's dry climate, fruit tend to shrivel from the low humidity.

Other options include placing tomatoes, one or two layers deep, in a covered box for ripening. Some people find better success by individually wrapping fruit in newspaper or wax paper and placing them in a covered box. Placing a few fruit together in a vegetable storage bag has been effective for others. For higher humidity, place tomatoes up to two layers deep in a blanching pan or strainer inside of a covered pan with some water in the bottom. Make sure the fruit does not touch the water.

Ethylene gas produced by ripening tomatoes is a ripening hormone. To speed the ripening process, place a ripe tomato in the container with the fruit. To slow the ripening of green tomatoes, routinely remove ripening fruit from the container.

Green fruit will ripen in about two weeks at 65ºF to 70ºF, and in about three to four weeks at 55ºF. Storage below 50ºF will give fruit a bland, off-flavor. Ripe tomatoes may be stored in the refrigerator for a few days.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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CMG GardenNotes #718

Tomato Early Blight

Early Blight, caused by the fungus *Alternaria solani*, is common on garden tomatoes and potatoes, and occasionally infects eggplants and peppers.

Symptoms

Symptoms appear soon after fruit set- on the lower leaves- as tiny dark brown spots. The spots enlarge to over 1/2 inch in diameter and develop a grayish-white center with a darker border. As the spots enlarge, they develop concentric, target-like rings. Spots may also develop on fruit and stems.

As the disease progresses, leaves turn yellow, brown and drop off. Black *pycnidia* (fungal fruiting bodies that appear as pinhole sized black dots) form in the center of the spots as they mature.

Figure 1. Yellowing and halo target marking from Early Blight.

When the pycnidia become wet, fungal spores ooze out. The spores are spread by splashing water, insects, wind, and human contact. During rainy weather or overhead irrigation, spores quickly spread the disease through the planting.

The disease is favored by warm wet weather, overhead irrigation, and where heavy foliage delays the drying of leaves. A moist 48-hour period is required for infections to occur. It is not necessary that this be a continuous period, but may be cumulative over several days.

In the garden, the fungus can over-winter on diseased plant debris and in perennial weeds such as horse nettle and nightshade. These serve as sources for inoculum and for primary infections in the spring.

Management

Control measures center around reducing the amount of inoculum (spores) available, and promoting rapid drying of wet leaves.

Spacing and Trellising Plants

Space and trellis plants to allow for good air circulation that promotes rapid drying. Minimal spacing for trellised tomatoes is two feet apart. Crowding plants will not increase yields and increases disease problems.

Trellising also increases the distance of the upper leaves from the sources of inoculum on the soil and lower leaves.

Mulch

Use a mulch (such as black plastic) to help protect the plant from inoculum splashing from the soil onto lower leaves. Removing leaves in the lower 8 to 12 inches of the plant (as the plant grows) also helps protect lower leaves from infections splashing from the soil.

Irrigation

Avoid overhead irrigation on tomato crops. Fungal spores are easily water-splashed from one leaf to another, and they depend on standing water on the plant surface to cause infections. It may also be helpful to water in the morning in order that plants dry quickly. Plants that remain wet all night from evening watering are prime targets for disease infection.

Fertilization

A mid-summer loss of plant vigor from inadequate moisture or fertilizer will leave the plant more susceptible to the fungi. In home gardens, Early Blight frequently erupts due to low nitrogen levels in mid to late summer.

Fertilize tomatoes at planting, flowering and fruiting (as the first fruits reaches two inches in diameter). An additional application can also be made to ensure the plants are not nutrient deprived. Avoid heavy applications of nitrogen that can over- stimulate vine growth at the expense of fruiting.

Water-soluble fertilizers (such as MiracleGro, RapidGro, and Peters) applied according to label directions can be used as summer fertilizer supplements.

If using a dry granular fertilizer (such as 21-0-0, ammonium sulfate), apply one level tablespoon per plant. Sprinkle the granular fertilizer in a wide circle 12 to 20 inches out from the plant, and water in. Dry granular fertilizers can easily kill the tomatoes if over-applied

Weed Control

Keep the garden weed-free. Common weeds harbor many garden diseases. Volunteer potatoes and tomatoes can also be a source of inoculum for Early Blight.

Remove Infected Leaves

Remove infected leaves as soon as noticed. Wash hands with soap and water immediately after touching diseased leaves to prevent spreading spores to other plants. Avoid working with the plants when they are wet.

Rotation

Since fungal spores can be found on plant debris in the soil, crop rotation is a management tool. However, this may not be practical in most small, home garden situations because a rotation plan allows no tomatoes, potatoes, eggplants, vine crops, strawberries, or raspberries in the same growing area for <u>at least four years</u>. In a garden bed, moving the tomatoes a few rows to the left or right is not an effective rotation.

Fall Clean Up

Remove all tomatoes and potato debris in the fall. Dispose of debris in municipal trash or by burial. Do not compost unless the compost heats to at least 145^o and the pile is turned occasionally. Most home compost piles do not adequately heat to kill pathogens.

Fungicides

During years with frequent rains, supplementing the above cultural practices with fungicide applications may be necessary to protect the plants. Start spraying at the first sign of spotting on lower leaves, typically in July. <u>Once the disease begins to cause yellow leaves, fungicides lose effectiveness</u>.

Complete coverage, including the lower leaves, is essential for control. Repeat applications at 10 to 14 day intervals as needed. Under moist conditions, reapplication may be needed at seven-day intervals.

Effective fungicides include Chlorothalonil (Daconil 2787, Ortho Multi-Purpose Fungicide) and EBDC fungicides (such as Mancozeb and Maneb).

The use of these fungicides calls for protective clothing, including <u>rubber gloves, long sleeved shirt, and long pants.</u>

These fungicides are toxic to fish and aquatic life. Do not apply directly to water (lakes, streams, ponds, or wetlands). Do not use on lands adjacent to water or wetlands, where drift or runoff could become hazardous to aquatic life.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Revised by Mary Small, CSU Extension

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MASTER GARDENER
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CMG GardenNotes #719

Vegetable Garden Hints

Harvesting quality and quantity from a vegetable garden starts with the gardener's ability to provide nearly ideal growing conditions for individual crops. Central to all highly productive gardens is a rich soil, high in organic matter, created with annual additions of compost and/or other organic materials. The following home gardening hints summarize a variety of research projects focusing on quality in vegetable production. Crops are grouped by families that have similar cultural practices.

Asparagus

Soils – Asparagus tolerates a wide range of soils as long as they are well drained. It prefers soil high in organic matter, and full sun (eight hours/day minimum).

Fertilizing – Asparagus is a heavy feeder. Fertilize in spring as growth starts and again in mid-summer after the harvest period.

Mulching – Asparagus competes poorly with weeds and other crops for water, nutrients, and space. Organic mulch is recommended. Mulch also provides winter cold protection for the roots.

Harvesting – The asparagus bed can be weakened or destroyed by over harvesting. The harvest period for an established bed is only four to six weeks (May into mid-June). Harvest only larger spears. Stop harvesting if spears decrease to pencil size or smaller. Leave the ferns (foliage) to grow until fall or let stand through the winter, finally cutting before new growth begins in spring.

Planting – Extra efforts in plantings new beds pay off with increased production.

1. Thoroughly work in four inches of well-composted and aged organic matter through the soil to a 12 inch depth.
2. Before planting, soak roots in warm water for a couple of hours.
3. Dig a trench four to five inches deep and wide enough to accommodate the spread-out roots. Space roots, typically 18 inches apart, covering with only two inches of soil.
4. Add additional soil during the growing season, as plants grow. Asparagus roots are easily smothered if initially covered too deep. (Many texts talk of planting six to eight inches deep for better protection from cold winter soil temperatures. However, this deep planting will decrease yields.)

When planting from seed, start seeds indoors 12 weeks prior to transplanting outdoors. Harden off seedlings before transplanting outdoors.

Beans

Soils – Beans are tolerant of a wide range of soils, as long as they are well drained. Beans are rather sensitive to soil salt. A soil rich in organic matter (to hold water and nutrients for growth) is preferred.

Planting – Research clearly demonstrates that early growth sets potential yield.

- Avoid planting too early in the spring. Soil temperature should be above 50ºF, measured at 8 a.m., six inches deep. For example, along the Colorado Front Range, this is typically early May for well-drained sandy soils to late May for clayey soils.
- Rich soil fertility should push early growth of plants. However, heavy nitrogen fertilization will lead to excessive plant growth at the expense of fruiting and increased disease problems.

Spacing affects yields – The potential for disease explodes once the plant canopy grows to cover over the patch; avoid over-crowding! Crop research suggests the following optimum spacings:

- 24 inches between rows with two inches between plants
- 18 inches between rows with three inches between plants
- 12 inches between rows with four inches between plants – (gives 20% higher yield than 24 inches × 2 inches spacing, but may increase disease pressure.)
- Six inches between rows with six inches between plants (this block style spacing will predispose the patch to foliage diseases.)

High water demand – During flowering and fruit production, beans have the highest water use of any vegetable crop. If the water supply is optimum, most varieties will produce until frost. If the water supply is low, beans will respond by:

1. Dropping blossoms
2. Producing pinched, pollywog-shaped fruit

Depending on temperature and wind, water use during fruiting will be ¼-inch to over ½-inch of water per day. Frequent watering in the right amount is essential for bean production.

Figure 1. Beans have a high water use. With inadequate water, blossoms drop, reducing yields. When beans need water, plant color changes slightly from a dark grass green to a grayish green. Windy weather significantly increases the water demand.

Cole Crops: Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, and Kohlrabi

Quality is dependent on the weather and the grower's ability to provide conditions for rapid growth.

Soils – Being shallow rooted, cole crops require a fertile, moist, well-drained soil that is rich in organic matter and nitrogen.

Fertilizer – Cole crops are heavy feeders of nitrogen, phosphorus, and potassium. Apply a plant starter fertilizer (solution of water-soluble fertilizer like MiracleGro, Peters, and Rapid Grow) at planting, three weeks and five weeks. Starter fertilizers increase yields by 20%

Mulch – Because cole crops are poor competitors, mulch to stabilize moisture and control weeds. For early spring plantings, black plastic mulch helps warm cold soils. However, plastic becomes too hot when warm weather arrives. During warm weather, a grass clipping mulch cools the soil and microenvironment.

Irrigation – Cole crops are intolerant of drying. Dry soils quickly lead to strong flavors.

Temperature – Cole crops prefer growing temperatures between 65ºF and 80ºF. Hot weather reduces sweetness. Because seeds do not like cold soils, use transplants for spring planting. For a superior quality fall crop, direct seed the main planting in early-July (Front Range area).
Both broccoli and cauliflower tolerate some frost (down to lower 20's) on maturing plants.

Using Bt – For cabbageworm and looper control, treat with *Bacillus thuringiensis, Bt,* (a biological control product). Because *Bt* is rapidly broken down by sunlight, treat in the evening. *Bt*, a living organism, has only a two-year shelf life and cannot survive storage under extreme heat or cold.

Transplants –

- Preferred growing temperature for transplants is 60ºF to 70ºF. High temperatures result in too rapid growth, and tall, weak plants that are easily broken off in transplanting.

- The ideal transplant is about four inches tall and about four weeks old. Avoid transplants older than six weeks. Quick maturing varieties should be transplanted within four weeks of seeding.

Heading – Yield is based on plant size as the head (curd) starts to develop.

- **Bolting** (rapid head formation)

  - Broccoli and cauliflower are prone to bolting when exposed to cool weather before three to four pair of true leaves develop.
  - Long days and hot weather in the summer cause broccoli to bolt and go to seed, and cause cauliflower curds to develop a red-purple discoloration.
  - Cabbage bolts if exposed to two to three weeks below 50ºF Avoid planting too early in the spring.

- **Buttoning** (development of small heads or curds [buttons] on immature plants) – Factors that restrict early plant growth (including nitrogen deficiency, cold temperatures, shock to young transplants, and drought stress) lead to buttoning. Follow practices that will result in rapid vegetative growth.

- **Blindness** (plants having lost their terminal growing points produce no head) – Damage to the terminal growing point due to low temperatures, cutworms, damage or rough handling of transplants, will result in blind plants. Handle transplants carefully, control cutworms, and avoid planting in low temperatures.

Figure 2. For quality, broccoli, cabbage, and cauliflower need cool temperatures. In warm summer climates (like the Colorado Front Range) plant mid-July for harvest in the cooler temperatures of fall. They will tolerate fall frost down to the mid-20s.

Corn

Variety types –

- Normal sugary, (su) – standard varieties
- Sugar Enhanced, (se) – Sugar Enhanced (se) genes increase the original level of sugar in the kernel and slow the conversion of sugar

into starch. Isolation is helpful, but not required

- Super Sweet, (sh) – Super Sweet (sh) genes increase sugar content two to three fold. Delay planting until soil temperatures reach 70ºF, in June. Isolation from non-super sweet types by 300 to 500 feet or 14 plus day differences in maturity is required.

Yield = water + nitrogen + space

- Water stress will reduce overall plant growth reducing yields. In particular, water stress will delay silking beyond the time when tassels shed pollen, thereby preventing kernel formation.
  -
- Side dress with nitrogen fertilizer frequently (every three to four weeks) through the summer to maintain a dark grass-green color. Sprinkle one cup 21-0-0 (or equivalent) per 50 feet of row, and water in.
  -
- Spacing affects yields. Crowding decreases sunlight to the leaves, reducing the number and size of ears. Optimum spacing is 36 inches between rows with nine inches between plants or 30 inches between rows with 12 inches between plants. Allow side shoots to develop, but do not plant in clumps.

Plant in Blocks – Corn is wind pollinated, so plant in blocks at least three rows wide, preferably four to five rows wide. Single blocks may include only a portion of the row length, with the remainder of the row being part to a block of another variety that matures at different times.

Pollination – Corn is wind pollinated, but bees collecting pollen also frequently visit it. When applying insecticides, use caution to protect pollinating insects. Do NOT spray tassels with insecticides.

Figure 3. Corn needs to be planted in blocks for wind pollination. For pollination, two side-by-side four-foot wide beds are used. Each bed has two rows going down the bed. This makes the block four rows wide. To extend the harvest season, the top of the bed could have an early planting with a later planting at the bottom.

Leafy Vegetables and Salad Crops: Lettuce, Spinach, Swiss Chard, etc.

Quality lettuce, spinach, chard, and other salad crops is the mark of a great gardener. Quality is based on the gardener's ability to match ideal conditions for rapid growth, including water, fertilizer, space, and temperature.

Soils – A rich soil, high in organic matter, is necessary for quality.

Mulch – Organic mulch (like dry grass clippings) reduces summer soil temperatures producing sweeter produce, conserves moisture, and controls weeds. Weeding by cultivation will damage surface roots.

Irrigation – Keep soil moist with 1 to 1½ inches of water per week (including rain). If the crop gets dry, it will become tough and stringy.

Spacing – Thin the crop to reduce competition for nutrients, moisture, light, and space.

Planting for fall harvest – Plant lettuce and spinach in mid to late summer to produce exceptional harvest quality during cool fall weather. It can also be planted mid-fall for extra-early spring crops. Cover the small seedlings with organic mulch for winter protection.

Figure 4. For quality, leafy vegetables need a constant supply of water, rich soils. For best quality, thin plants when crop is tiny. Here a variety of leaf vegetables are in a raised bed, going across the box. As one row is harvested, immediately replant for a continual harvest of young tasty produce.

Onion Family: Garlic, Leeks, Onions, Shallots, etc.

Soils – The onion family has a poor, inefficient root system, making the crop intolerant of poor soils and competition from weeds. The plants are heavy feeders. Quality produce arises from a well-drained, fertile soil, rich in organic matter.

Mulch – The onion family thrives with organic mulch (like dry grass clippings), which cools the soil, conserves moisture, and controls weeds.

Photoperiod sensitivity – The onion family is sensitive to the length of night, which triggers bulb development. In Colorado, plant only long day varieties that start bulbing with day lengths of 14 to 16 hours and temperatures above 65ºF. Plant size at the time conditions trigger bulb development determines the size of the bulb. Plant onions as soon as soil conditions allow in the spring.

Seed head – Keep seed heads picked. They pull plant resources away from bulb development.

Seed, Sets, or Transplants – Onions can be planted from seed, sets, or transplants. If planted from sets, sort sets larger than a dime from smaller ones. Plant small and large sets separately. Harvest from larger sets first because they do not store as well as onions grown from small sets.

Figure 5. Onions have a shallow inefficient root system. For quality they need an even moisture supply and rich soils.

Peas

Soils – Peas grow best in a rich soil, high in organic matter. They require a well-drained soil.

Types of peas –

- English Pea – standard, shelled pea
- Edible Pod Pea, Sugar Pea or Snow Pea – edible pod, pick before seeds swell
- Snap Pea – edible pod and plump sweet pea fruit

Plant as early as possible –

- Peas are sensitive to the photoperiod (length of night), influencing yields. At Colorado's latitude, an April 1st planting will have a 50% higher yield than a May 1st planting.
- Plant when soil temperatures reach 40ºF. Avoid planting in wet soils.

Planting for fall harvest – Peas may be planted in mid-summer for harvest during cooler fall weather. Sweeter peas develop in cooler temperatures. However, yields of the fall crop are reduced due to photoperiodism and the vines are prone to powdery mildew in the fall.

Figure 6. *Snap peas* are edible pod types eaten with plump peas filling the pod. *Edible pod peas*, *sugar peas* or *snow peas* are edible pod types eaten before the pod fills with peas.

Potatoes

Soils – Potatoes thrive in a soil rich in organic matter that provides water and nutrient holding capacity, and improved drainage. However, avoid heavy applications of fresh manure or compost, as it will make the tuber surface rough and increase the occurrence of scab.

Certified Seed – The use of certified seed helps reduce disease problems.

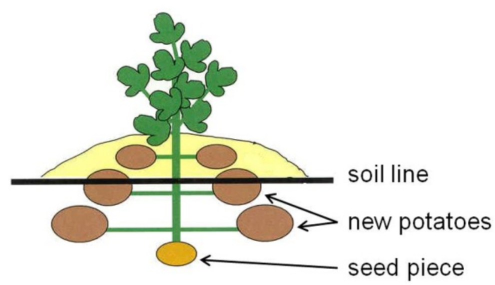
Give the plants a vigorous start –

- Plant when soil temperatures rise above 50°F, four inches deep at 8 a.m.
- Avoid using too small of a seed piece. Cutting seed pieces to 1½ to 2 inches in size provides for early plant vigor. Many gardeners prefer to use seed pieces that require no cutting to reduce decay potential.

Spacing – Plant spacing determines tuber size. Learn by experience the optimum spacing for the variety in a particular garden soil. A starting point is an equal-distant spacing of 12-15 inches between plants and between rows (or three plants across a four-foot wide raised bed). Spacing that allows the plants to close in and shade the soil yields sweeter spuds. However, thick foliage and reduced airflow can also increase the occurrence of disease.

Mulch – Transplants are hardened-off (growth rate slows so the plant is more tolerant of the move the greenhouse environment to the bright, windy outdoors) by withholding water and/or nutrients or by exposure to cooler temperature.

Figure 7. The new crop of potatoes grows above the seed piece. To shield the growing tubers from sunlight (which turns them green) soil is "hilled" (mounded) around the base of the plant. Straw mulch may be used as an alternative to hilling.



Fertilizer – Potatoes are heavy feeders of nitrogen, phosphorus, and potassium. Running out of nitrogen by August is the most common potato problem. Symptoms are a general yellowing of leaves that starts with lower interior leaves. Nitrogen stress pre-disposes the crop to Early Blight.

Moisture – If the soil is too wet or has poor drainage, tubers will rot. If the soil becomes overly dry, tubers will develop knobs.

Rhubarb

Soils -- Rhubarb thrives on any soil that is high in organic matter and well drained.

Yields – Yield is based on the plant's ability to store food reserves in the roots for the next year's crop.

- Keep seed stalk picked off.

- Stop harvest when temperatures rise above 85°F.
- Remove oldest stalks at the base when plants grow crowded, giving room for new stalks to grow. Never remove more than 1/4 of the stalks at one time.

Mulch – Rhubarb is a poor competitor for water and nutrients. Keep mulched with organic mulch.

Sun – It prefers full sun but grows poorly with reflected heat.

Coloration – Poor coloration of stalks develops from too much shade, too much heat, overly wet soils, or an inferior variety.

Re-planting – Reset when stalks become slender and the center of plant dies out, about every eight years. Rhubarb is best transplanted in the fall.

Root Crops: Beets, Carrots, Parsnips, Radish, Rutabagas, Turnips, etc.

Soils – Root crops need a rich, well-drained soil, high in aged organic matter.

Mulch – Use an organic mulch (like dry grass clippings) to cool the soil in summer, stabilize soil moisture, and control weeds.

Irrigation – Consistent soil moisture is a must!

Carrot disorders –

- Strong flavor – Many varieties have a high oil content (and the oil can turn rancid); change varieties.
- Hairy or rough root surface develop from too much <u>fresh</u> organic matter in the soil. Use old, well-aged compost or manure in the root crop section.
- Stubby, knobby, or cracked roots arise from uneven moisture supply, hot soil temperatures, or poor, rocky, or compacted soil conditions.
- Green shoulders result from root crowns exposed to sunlight and reduce sweetness. Mulch with dry grass clippings to shade the crown of the root.
- Failure of seedlings to emerge may arise from soil crusting, planting too deep or high soil temperatures.

Radishes –

- Hot and/or pithy radishes arise from hot weather, hot soil, and/or plants that are past maturity.
- Thin plants as soon as they pop through the ground!

Replanting of root crops for fall harvest – For tender young root crops, replant in mid-summer (Front Range area) for fall harvest.

Winter storage of roots – Some varieties of carrots store well in the garden soil or in a root cellar for year-round use. Other carrot varieties become strong-flavored as the oil becomes rancid. Two useful options for winter storage include:

- Leave undisturbed where growing in the garden and mulch the bed with straw or other organic materials. Dig as needed.
- Place harvested carrots in straw in a garbage can storage pit.

Figure 8. Burpee white radish: for quality, root crops need an even moisture supply and rich soil.

Tomato Family: Tomatoes, Peppers, and Eggplants

Mulch – Use black plastic mulch for earlier production and higher yields. The mulch also helps controls weeds, conserves water, and protects the foliage from disease spores splashing from the soil.

Trellis – Trellis or cage tomatoes to allow for easier picking and suppress Early Blight (the most common tomato disease) and psyllids. Trellising allows plants to dry quickly following rains. An ideal trellis is two feet wide and four to five feet tall. It can be easily made from a six and half-foot length of concrete reinforcing wire coiled in a circle.

Spacing – Avoid crowding plants. Crowding will not increase yields, but will promote disease problems. The minimum spacing for trellised tomatoes is two feet.

Watering – Avoid overhead irrigation, which promotes leaf diseases. A soaker hose type of drip irrigation works well under plastic mulch. Tomatoes can also be furrow irrigated with water running in furrows under the plastic mulch.

Transplanting – Except for avid gardeners who use extra protective efforts to realize a few early tomatoes, avoid early plantings. Plant the main tomato crop when the threat of frost has passed and daytime temperatures are consistently above 60°F. A week of daytime temperatures below 50°F degrees stunts growth.

Fertilizer –

- Over-fertilization causes excessive vine growth at the expense of fruiting.

- However, starter fertilizer at planting and a couple of weeks later will encourage early growth. (MiracleGro, Peters, and Rapid Grow are examples of water-soluble fertilizers that make great starter fertilizers.)
- An additional light fertilization as the first fruits color also will increase yields and resistance to Early Blight.

Blossom drop – Hot, dry summer winds can cause blossoms to drop. Inconsistent watering contributes to this condition. Mulch plants.

With night temperatures below 55°F, blossoms that open the following morning will not have pollen, and blossoms will drop. For example, there is a 50/50 probability along the Colorado Front Range that any given summer night will too cool for pollen development. For early production and in cool locations the "blossom set sprays" effectively improve yields. If daytime temperatures rise above 90°F by 10 a.m., blossom opening that morning will abort.

Blossom end rot – Irregular watering and over-watering causes development of a dark, leathery area on the blossom end of fruits. Water consistently in a deep, improved garden soil and mulch will help prevent this condition.

Figure 9. Sweet 100 Tomato - Over 2,000 cultivars allow the gardener lots of options in flavor, fruit size, and disease management.

Vine Crops: Cucumbers, Melons, Pumpkins, and Squash

Soils – Vine crops thrive in well-drained soils high in organic matter. Yearly applications of compost will likely supply needed nutrients.

Mulch – Use black plastic mulch for earlier production and higher yields. It also controls weeds and conserves water.

Planting time – Do not plant too early. Daytime temperatures should consistently be above 55°F. Protect young, tender plants from cool winds.

Seeds or Transplants – Direct seeding is reported to give higher yields. If using transplants, they should be small, never more than two to four weeks old.

Blossom Drop –

- Vine crops have male flowers and female flowers (small fruit behind the flower). Male flowers develop first, and generally predominate.

Young fruits that are not pollinated will abort.

- When bee activity is limited, increase yields by hand pollination. Pick a male flower, remove petals, and touch the center of the female flowers with the male flower.
- Any form of stress (like too much or too little water, poor soil conditions, extreme heat, and wind) can reduce flowering and lead to abortion of fruits.

Figure 10. Vine crops have female flowers (left blossom) and male flowers (right blossoms). The female blossom has a tiny fruit at the base of the petals. For production, bees or the gardener must move the pollen from the male flower to the female flower.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs and line drawings by David Whiting; used by permission.

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CMG GardenNotes #720

Vegetable Planting Guide

Cool Season Vegetables

These vegetables prefer cool growing temperatures (60°F to 80°F) and lose quality in hot weather. They are often replanted mid-summer for fall harvest.

Hardy Vegetable

Crops: broccoli, cabbage, kohlrabi, onions, lettuce, peas, radish, spinach, turnips

Temperatures: Hardy vegetables grow with daytime temperatures as low as 40°F and may survive a frosty nip.

When to plant:

- Based on soil temperatures, refer to Table 1.
- Plant as soon as soil adequately dries in the spring.
- These crops may be planted as early as 2-4 weeks before the date of the average last spring frost.

Semi-Hardy Vegetables

Crops: beets, carrots, cauliflower, parsley, parsnips, potatoes, and Swiss chard

Temperatures: Semi-hardy vegetables grow with minimum daytime temperatures of 40°F to 50°F, but are less tolerant of a frosty night.
When to plant:

- Based on soil temperature, refer to Table 1.
- Plant as soon as soil adequately dries in the spring.
- These crops may be planted as early as 0-2 weeks before the date of the average last spring frost.

Warm Season Vegetables

Warm season vegetables prefer summer-like weather with temperatures between 70°F and 95°F. They are intolerant of frost and may be sensitive to cool spring winds.

Tender Vegetables

Crops: beans, celery, corn, cucumbers, New Zealand spinach, summer squash

Temperatures: Tender vegetables grow with a daytime temperature above 55°F, and are intolerant of frost.

When to plant:

- Based on soil temperature, refer to Table 1.
- Soil is adequately dry to work.
- These crops may be planted (from seed) around the date of the average last spring frost. Transplants of cucumbers and summer squash without frost protection should be delayed until frost potential is over.

Very Tender Vegetables

Crop: lima beans, cantaloupe, eggplant, pepper, pumpkin, winter squash and pumpkins, tomato, and watermelon

Temperatures: Very tender vegetables are not only intolerant of frost, but also cool spring winds. They need daytime temperatures above 60°F, and prefer temperatures of 70°F to 95°F. A week of daytime temperatures below 55°F, may stunt the crop.

When to plant:

- Based on soil temperature.
- Soil is adequately dry to work.
- These crops are typically planted two plus weeks after the average last spring frost date.
- Weather is becoming summer-like, (i.e., consistently above 55°F (daytime) and breezes should have lost any cool nip).

Table 1 – Vegetable Planting Guide

Vegetable	Germination Temperature[1] Min.	Optimum	Max.	Plant Spacing[2]	Planting Depth	Days to Germination	Typical Days to Harvest	Age of Transplant (weeks)
Cool Season Crops[3]								
Beets	40°	80°	90°	4-6”	¾-1”	7-10	60	
Broccoli[4]	40°	80°	90°	18”	½”	3-10	65T[4]	5-7
Cabbage[4]	40°	80°	90°	18”	½”	3-10	85T[4]	5-7
Carrots	40°	80°	90°	2-3”	¼”	10-17	70	
Cauliflower[4]	40°	80°	90°	18”	½”	3-10	65T[4]	5-7
Kohlrabi	40°	80°	90°	7-9”	½”	3-10	50	
Leeks	40°	80°	90°	4-6”	¼”	7-12	120	
Lettuce (leaf types)	35°	70°	70°	7-9”	¼”	4-10	60	
Onion, green	35°	80°	90°	2-3”	¼”	7-12	60	
Onions, dry (seed)	35°	80°	90°	4-6”	¼”	7-12	110	
(sets)				4-6”	1-2”			
Parsnips	35°	70°	90°	5-6”	½”	15-25	70	
Peas	40°	70°	80°	4-6” or 3”×8”	1”	6-15	65	
Potatoes	45°			12-15”	4-6”		125	
Radish	40°	80°	90°	2-3”	½”	3-10	30	
Spinach	40°	70°	70°	4-6”	½”	6-14	40	
Swiss Chard	40°	85°	95°	7-9”	1”	7-10	60	
Turnips	40°	80°	100°	4-6”	½”	3-10	50	
Warm Season Crops								
Beans, snap	55°	80°	90°	6” or 4” x 12”	1-1½”	6-14	60	
Cantaloupe[5]	60°	90°	100°	36-48”	1-1½”	3-12	85	2-3[5]
Corn	50°	80°	100°	12” x 30” 9” x 36”	1-1½”	5-10	60-90	
Cucumbers	60°	90°	100°	6” trellised 24-36” untrellised	1”	6-10	55	2-3[5]
Eggplant	60°	80°	90°	18-24”	¼”	7-14	60T[6]	6-9
Pepper	60°	80°	90°	15-18”	¼”	10-20	70T[6]	6-8
Tomato	50°	80°	100°	trellised: 24” between plants	¼”	6-14	65T[6]	5-7
Squash, Summer	60°	90°	100°	36-48”	1-1½”	3-12	50	2-3[5]
Squash, Winter	60°	90°	100°	36-48”	1-1½”	6-10	100	2-3[5]
Watermelons	60°	90°	110°	36-48”	1-1½”	3-12	85	2-3[5]

1 **Germination temperature –** Soil temperature is one of the best methods to determine spring planting time. Plant when soils reach minimum temperature measured at 8 a.m., 4 inches deep. Beans are an exception, being measured at 6 inches deep. Optimum temperatures listed in the table are useful for starting seeds indoors. Maximum temperatures are listed in regards to high soil temperatures that may interfere with seed germination in the summer.

2 **Plant Spacing –** Spacings given are equal-distance spacing for crops grown in block or close-row style beds. For example, beets, with a spacing of six inches are thinned to six inches between plants in all directions. In other words, beets are thinned to six inches between beets in the row and six inches between rows. The closer spacing listed should be used only on improved soils with 4-5% organic matter.

Close-row or block style planting works well for raised bed gardening, with blocks/beds 4 feet wide (any length desired) and 2-foot wide walkways between blocks/beds.

3. **Cool Season Crops** – Cool season crops prefer a cool soil. Lawn clipping and newspapers make an excellent mulch for these crops by cooling the soil, preventing weed germination, and conserving water. Apply fresh grass clippings only in thin layers (less than ½ inch) and allow it to dry between applications. Thick layers will mat and smell. Do not use clipping from lawns treated with weed killers or other pesticides. Several layers of newspapers covered with grass clippings also work well between rows. Do not use glossy print materials.

4 **Transplanted Cole Crops –** Since cole crops (cabbage, cauliflower, broccoli, and Brussels sprouts) germinate better in warmer soil, they are typically started from transplants in the spring. Days to harvest are from transplants. In the warmer areas of Colorado, these crops produce the best quality when direct seeded mid-summer (early July for the Front Range area) for harvest during cooler fall weather. Before planting out, harden off seedlings.

5 **Transplanting Vine Crops –** Vine crop (cucumbers, squash, melons) roots are extremely intolerant of being disturbed, and perform best when grown by direct seeding rather than by transplants. With the use of black plastic to warm the soil, direct seeded crops germinate rapidly. If using transplants, select small, young plants, not more than 2-3 weeks from seeding.

6 **Tomato family transplants** – The tomato family is traditionally planted from transplants. In warmer areas of Colorado, they can also be direct seeded with minimal delay. Days to harvest are from transplants.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #721

Sample Planting Guide for Raised-Bed Garden

The following table is a guide for planting a family vegetable garden in a block-style layout. It is based on a raised bed system with boxes four feet wide and rows typically running across the bed (four feet long).

Planting times are based on May 10 and October 10 average frost dates, typical of Colorado's Front Range. In other areas, adjust the planting dates using local average frost dates.

Estimated planting for fresh use and *projected yields* are estimates on what a family of four may consume in fresh use during the harvest period. Actual plantings should be adjusted to the family's likes for various vegetables and desire for canning, freezing, and storage.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.
- No endorsement of products mentioned is intended nor is criticism implied of products not mentioned.

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Cool Season Planting Groups	Crops	Block Style Spacing	Estimated Planting for Fresh Use amd Projected Yield	Planting Time	Harvest Period
Cole Crops	Broccoli, cabbage, and cauliflower	3 plants across a 4-foot wide block (row) with 18 inches between rows	1-2, 4-foot rows each per planting 1 head per plant = 3 heads per 4-foot row	Spring planting for summer harvest: 1. Early April – Broccoli and cabbage from transplants 2. Early May – Broccoli, cabbage, and cauliflower from transplants	Spring plantings/summer harvest in June to early July (1-3 weeks per plantings, depending on temperatures) In warm weather crops come on rapidly with reduced quality (sweetness). Check every couple of days for harvestable stage, and store crops in fridge. Crops over-mature rapidly in warm temperatures.
			2-3+ 4-foot rows each. 1 head per plant = 3 heads per 4-foot row	Summer planted for fall harvest: Broccoli, cabbage, and cauliflower by direct seed, mid-July for fall harvest	Summer planting/fall harvest – 4-8+ weeks with excellent quality due to cool fall temperatures. Harvest crops as needed. They tolerate a mild frost into the mid to low 20s and can be stored in fridge or pit for winter use.
Leafy Vegetables & Salad Crops (Kitchen garden)	Lettuce (leaf and soft head types)	Thin to 7-9 inches, with rows 7-9 inches apart	1-3, 4-foot rows, with assorted varieties per planting ~ 6 heads per 4-foot row ~ 3 lbs. per 4-foot row	1. Early April	May-June
				2. Early May	June-July (depending on temperatures)
				3. Late July	Early September+
				4. Mid August	Late September+
	Spinach	Thin to 4-6 inches, with 6 inches between rows	1-3, 4-foot rows per planting ~8 bunch per 4-foot row ~2 lbs. per 4-foot row	1. Early April	May-June
				2. Early May	June-July (depending on temperature)
				3. Late July	Early September+
				4. Mid August	Late September+
	Chard	Thin to 7-9 inches, with 7-9 inches between rows	1-2, 4-foot rows ~ 4 lbs. per 4-foot row	Late April to early May	Harvest by cutting off leaves, plants grow back, for summer long harvest
	Kohlrabi (a cole crop)	Thin to 7-9 inches, with 7-9 inches between rows	1-2, 4-foot rows per planting ~ 6 heads per 4-foot row	1. Early April	June
				2. Early May	Mid June to early July (depending on temperatures)
				3. Mid to late July	September+

Cool Season Planting Groups	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Onion Family (Kitchen garden)	Dry onions	4-6 inches, with 4-6 inches between rows	2-5, 4-foot rows ~ 10 bulbs per 4-foot row ~ 3 lbs. per 4-foot row	Early April to early May Onions are sensitive to photoperiod, the early the planting the larger the bulbs.	Mid summer through fall
	Green onions	2-3inches, with 2-3inches between rows	1-2, 4-foot rows ~ 4 bunches per 4-foot row	Early April to early May	Early summer through fall
	Leeks (soup onion)	4-6 inches, with 4-6 inches between rows	1-2, 4-foot rows ~ 10 bulbs per 4-foot row	Early April to early May	Fall into winter (for winter harvest leave in garden and mulch to protect from extreme cold, dig as needed.)
Peas	Peas	Thin to 3-4 inches, with 8 inches plus between rows Note: Peas are easier to pick in a single or double row rather than in the block-style plantings	20' double row ~ 12 lbs per 20' double row	1. Early April to early May, as soon as soil temperature reaches 40ºF. Peas are sensitive to photoperiod, early plantings give higher yields.	June
			20' double row ~ 6 lbs. per 20' double row	2. Mid July	September Note: fall plantings are prone to powdery mildew and have lower yields, making them questionable.
Potatoes	Potatoes	3-4 plants across a 4-foot wide bed, with 15 inches between rows	A 16-foot by 4-foot bed of potatoes would produce around 72 pounds.	Early May	July+ Mulch with straw

Cool Season Planting Group	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Root Crops	Carrots	Thin to 2-3 inches, with rows 3 inches between rows	6-18+, 4-foot rows ~ 4 lbs. per 4-foot row	Early May	July through fall; can be left in the garden and mulched for winter harvest.
	Beets	Thin to 4-6 inches, with 4-6 inches between rows	1-2, 4-foot rows per planting ~ 4 lbs. per 4-foot row	1. Early May	June-July – Thin for beet greens. Harvest roots while young (small) for best quality
				2. Mid July	September-October – Thin for beet greens. Harvest roots while young (small) for best quality
	Parsnips	Thin to 5-6 inches, with 5-6 inches between rows	2-6, 4-foot rows ~ 4 lbs. per 4-foot row	Early May	For late fall to winter harvest, after soils cool, mulch for harvest through the winter.
	Radish	Thin to 2-3 inches, with 2-3 inches between rows	1-2, 4-foot rows per planting ~ 4 bunches per 4-foot row	1. Early April	Early May
				2. Early May	Early June
				3. Early August	Early September
				4. Late August	Late September
	Turnips	Thin to 4-6 inches with 4-6 inches between rows	1-2, 4-foot- rows per planting ~ 4 lbs. per 4-foot row	1. Early May	June-July -- Thin for greens. Harvest roots while young (small) for best quality
				2. Mid July	September-October – Thin for greens. Harvest roots while young (small) for best quality

Warm Season Planting Group	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Beans	Pole beans	Thin to 4 inches in a single row	10-20’ row ~ 10 lbs. per 10 foot row	Mid May	July till frost, with adequate water
	Bush beans	Thin to 4 inches , in double row. Beans are easier to pick in a single or double row rather than block-style planting.	10-20’ row ~ 10 lbs. per /10 foot double row	Mid May	July till frost, with adequate water
Corn		For pollination, corn must be planted in block with 4+ rows wide. In a block-style garden, plant 4 rows with 2 rows each going the length of the box, in 2 boxes side by side. Space plant 9 inches in the row.	A block of 4, 6-foot rows will give ~60 ears	1. Mid May 2. Mid June	Late July to October – Harvest period on any variety is only 10 to 20 days. For continual harvest of fresh corn plant varieties with 20+ days difference till harvest OR make second planting 20-30 after the first.
Eggplant		3 plants across a4 foot row, with rows 18-24 inches apart	1, 4-foot rows ~ 12 fruit per 4-foot row (4 fruit per plant)	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)
Peppers		3 plants across a 4-foot row, with rows 18 inches apart	1-4, 4-foot rows, depending on family use Yields vary with variety ~ 18 bell peppers/4-foot row (6 fruit per plant)	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)
Tomatoes		Trellis in single row, plants spaced 24 inches apart.	3-6 plants, depending on family use ~ 26 lbs. (½ bushel) per plant	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)

Warm Season Group	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Vine Crops	Cucumbers	Trellis in single row, plants spaced at 6 inches.	2-4 plants, depending on family use ~ 1 lb. per plant	Mid May for direct seeding OR late May for transplants	Mid July till frost For maximum yields, do not let fruit get large on the vine.
	Zucchini and other summer squash	Single row down center of 4-foot box; two plants take 4-foot by 8-foot	2 plants	Mid May for direct seeding or late May for transplants	Mid July till frost (A Wall-Of-Water can be used for earlier production)
	Cantaloupes, Watermelon, Pumpkins, and Winter Squash	1-3 plants per type, as desired by family 2-6 fruit per plant	Single row down center of 4 inches wide box with 2-3' between plants. Makes a great ground cover for garden areas. ~ 3-4 fruit per plant	Late May, temperatures consistently above 60ºF	September-October

CMG GardenNotes #722

Frost Protection and Extending the Growing Season

Types of Frost

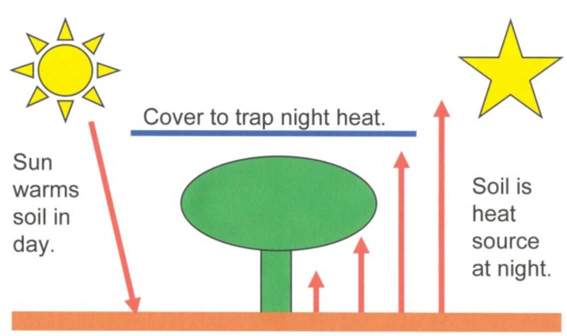
Advective frosts occur when a cold front moves into the area. Temperatures may drop significantly below critical levels thereby making crop protection questionable.

Radiation frosts occur on calm clear nights that lack cloud cover to hold in heat. Radiation frosts at the beginning and end of the growing season are typically only a few degrees below critical levels, making crop protection worthwhile.

Heat Source at Night

Soil, warmed by the sun in the daytime, is the source of heat for frost protection at night. Moist, smooth soil absorbs more heat. To trap heat from the soil around young vegetables at night, place a covering that is low to the ground and spreading. To recharge the heat source for the next night, any covering must allow sunlight to shine through to the soil or must be removed in the daytime. [Figure 1]

Figure 1. The sun warms the soil in the daytime. Heat from the soil keeps crops warm at night. A covering traps heat from the soil around the crops.



Coverings

Blankets and Sheets

Grandma's old method of covering the garden with blankets and sheets works well as long as the fabric remains dry. If the fabric absorbs water, evaporative cooling can lead to colder temperatures adjacent to the blanket. To recharge the heat stored in the soil, the blankets and sheets must be removed in the daytime.

Floating Row Covers

Floating row covers are lightweight fabrics that lay directly over crops. Because they transmit light, they provide crop protection over an extended period of time without being removed. They provide 2°F to 4°F of frost protection, cut wind on tender plants, and screen out some insects. On insect pollinated crops, covers must be removed for pollination to occur. [Figure 2]

Floating row covers are popular in commercial vegetable production where crops planted in large blocks are easily covered with row covers. Many brands and fabric types are commercially available.

Figure 2. Floating row cover on broccoli and cabbage, protecting crops from cabbageworms moths.

Clear Plastic Covering on Frame

When plastic is used as a covering over a growing bed, it must be held up off the plants. Plants will freeze where the plastic touches them.

Tunnel Gardening – Gardening catalogs carry wire hoops for use in "tunnel" or cloche gardening. Hoops are placed at three to five foot intervals depending on the wind exposure of the site. The wire hoops hold up a strip of plastic forming a tunnel-shape covering down the growing bed. Bury the edges of the plastic a few inches into the soil on all sides. On a raised-bed box made with lumber, staple the plastic to the sides of the box. Two-inch holes cut in the sides of the plastic tunnel at two to three foot intervals are essential to reduce overheating.

This type of covering is popular with commercial tomato, pepper, and melon growers for an early start to the growing season. It provides 2°F to 4°F of frost protection, protects tender plants from cold spring wind, and provides warmer growing temperatures inside the tunnel. Tunnels are removed when warm weather arrives and the danger of frost is past.

Plastic Covered Cold Frame Made with Concrete Reinforcing Mesh

An easy cold frame structure for a growing bed is made with 4-mil clear plastic (polyethylene film) draped over concrete reinforcing mesh. The structure is easily opened during warm days and closed for cold nights. It works well with a 4-foot wide, raised-bed garden system. [Figure 3]

Figure 3. Cold frame for a raised bed garden made from concrete reinforcing mesh covered with 4-mil plastic. Notice the belt-like plastic straps, which hold the covering in place. The covering is slid between the straps and mesh to open and close. Pictured open for ventilation on a warm day.

The frame is concrete reinforcing mesh, available at hardware and lumber stores. This stiff wire mesh typically comes five feet wide, in 50 and 100-foot rolls. A six-foot length is required to make a Quonset-type frame over a four-foot wide growing bed. In trials, the low and spreading shape was ideal for trapping heat from the soil during a frosty night.

Cover the frame with clear, 4-mil polyethylene plastic. It typically is sold in 10' by 25' rolls. For a four-foot wide raised bed box, place a 3½-foot wide section on each side, overlapping at the top. On a raised bed box, staple the plastic to the sides of the wood box. In soil bed applications, bury the plastic a few inches along the sides.

Hold the plastic onto the frame with small clips available at local hardware stores. Clothespins do not hold in the wind. Another method is to use a series of 6-inch wide, belt-like plastic straps arching over the frame (above the plastic cover) and stapled onto the box. Open and close the cover by sliding it between the frame and the belt-like straps. Hold the plastic closed at the ends with a rock or brick. [Figure 4]

Figure 4. Clip holds plastic on frame.

During the day, the covering MUST be opened, at least a slit, to prevent overheating. With just an hour of sun, temperatures under a closed cover can quickly rise to over 130°F! [Figure 5]

On cool days, open the top a crack to prevent excessive heat build-up. On a warm day, the plastic can be slid down the side, ventilating and providing crops exposure to the outdoors. On freezing nights, close the cover completely. On warm nights, the covers may be left open a crack. On stormy days with full cloud cover and no direct sun, the cover may remain closed. [Figure 5]

Figure 5. Left: Cover must be opened at least a slit to prevent over-heating. Right: Cold frame pictured closed for a cold night.

Not only will the covers provide frost protection, they also increase growing temperatures for early crop growth and provide protection from cold winds.

In trials in Fort Collins, Colorado, a plastic cover on a frame typically provides 3°F to over 6°F of frost protection. It works well for cool season crops that are somewhat tolerant of frosty nights, and adds two to six weeks or more on both ends of the growing season. For warm season tomatoes and summer squash crops (being intolerant of a frosty nip), adding a small light inside the cold frame provides even better frost protection.

Adding Space Blankets

On extra cold nights, placing an aluminum space blanket over the plastic on the frame significantly adds to the frost protection. With the aluminized side placed down (towards the plants), a space blanket reflects 99% of the heat. They are readily available where camping gear is sold. [Figure 6]

In trials in Fort Collins, topping a plastic-covered, concrete mesh cold frame with a space blanket prevented freezing when outside temperatures dipped to 0°F following a sunny spring day. The space blanket must be removed each day to recharge the soil's stored heat

Figure 6. Aluminum space blanket covering a cold frame for extra protection on cold nights.

Lights for Additional Heat

<u>Christmas tree lights</u> – For additional protection, add Christmas tree lights inside the cold frame. In Fort Collins trials, one 25 light string of C-7 (mid-size) Christmas lights per frame unit (four feet wide by five feet long) gave 6°F to over 18°F frost protection. Lights were hung on the frame under the plastic and turned on at dusk and off at dawn. Christmas lights work better than a single, large light bulb in the center by eliminating cold corners and edges. [Figure 7]

Figure 7. Cold frame with Christmas tree lights for additional warmth.

<u>Space blanket with Christmas tree lights</u> – For the gardener really wanting to extend the growing season, try Christmas lights plus a space blanket. One 25 light string of C-7 (mid-size) Christmas lights per frame unit (four feet wide by five feet long) with a space blanket on top gave 18°F to over 30°F frost protection in Fort Collins trials.

Wall of Water®

The Wall-of-Water® is a cone-shaped ring of connected plastic tubes filled with water that surrounds a single plant, like a tomato, pepper, or summer squash. [Figure 8]

This device works on the chemistry principle of heat release in a phase change; there is a significant amount of heat released as water freezes (changes from the liquid phase to the solid or ice phase). A Wall-of-Water provides frost protection typically down to temperatures in the mid-teens. It also provides wind protection for tender plants and growing temperatures may be slightly warmer inside a Wall-of-Water.

They are helpful to get a few extra weeks head start on vine ripe tomatoes. However, an extra early tomato may out-grow the protection and the tops may be nipped back by frost.

Both cold air temperatures and cold soil temperatures are limiting factors in early crop production. When using a Wall-of-Water to start early crops, warm the soil with black plastic mulch.

In filling the Wall-of-Water, be careful not to splash excessive water onto the soil. A wet soil will be both slow to warm and dry in the spring. Moderately moist soils are best.

Figure 8. Tomato in Wall-of-Water. Notice use of black plastic mulch to warm the soil, another limiting factor of early production. Also, note the plant has grown beyond the device and is now less protected from frost.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs by David Whiting; used by permission.

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MASTER GARDENER
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CMG GardenNotes #723

Growing Vegetables in a Hobby Greenhouse

Extending the Growing Season

Off-season vegetable production in the hobby solar greenhouse is an enjoyable way for year-round gardeners to extend the harvest season of fresh vegetables. However, without the expense of a greenhouse, gardener can extend the growing season weeks to even months with cold frames and plastic tunnel gardening

Winter vegetable production in a greenhouse is only cost effective with an energy efficient greenhouse structure, a well-designed solar collector, and optimum management. Winter vegetables have a slow growth rate due to low light intensity. Crops should be planted to obtain a near harvestable size by mid-October. The use of artificial light for vegetable production (except for starting transplants) is generally not cost effective.

A gardener's success is dependent on the greenhouse design and construction to conserve energy and on the management care given the greenhouse crops.

Before investing in a greenhouse, carefully consider your real interests in extending the gardening season. Are you only interested in adding a few weeks to the harvest season? Are you interested in year-round gardening in a solar greenhouse OR do you need a winter break?

Passive Solar Greenhouse

For the gardener considering a passive solar hobby greenhouse, here are a few key points to consider. Refer to other greenhouse references for additional details.

For solar collectors, any area with direct sun, but not blocking solar illumination of plants, is a potential location. For a hobby greenhouse, solar collectors are typically built into an insulated north wall.

A solid brick wall on the north makes a good solar collector. Brick absorbs 30 to 35% of the solar radiation. With a brick storage wall, the greenhouse quickly heats on a sunny winter day and ventilation will be needed by mid morning. [Figure 1]

Figure 1. Brick storage wall in passive solar hobby greenhouse – Thermal storage mass is a wall made with two layers of brick filled with concrete. In this well-built structure, nighttime temperatures dropped to 35°F with no supplemental heat when outside temperatures dropped to -17°F. Note young crops in raised-bed style garden with drip irrigation.

Water storage using plastic milk jugs makes a great storage system. Water jugs absorb 90% of the solar radiation, holding three times more heat than brick or rock. This increased heat storage holds night temperature higher longer into the night, resulting in slightly improved crop growth compared to brick storage. [Figure 2]

Figure 2. Milk jug water storage wall in a passive solar hobby greenhouse. Disposable milk jugs on left and returnable milk jugs on right are spray painted flat black. In this well-built structure, nighttime temperatures dropped to 39°F with no supplemental heat when outside temperatures dropped to -17°F.

With milk jug storage, spray the milk jugs with flat black paint, and add one tablespoon of liquid bleach per jug (to prevent algae growth in the warm water). Secure the cap back on the jug with a ring of caulk. Place the milk jug on a bookcase type frame not more than two jugs high.

Disposable milk jugs develop leaks over time and require routine replacement. Heavier weight jugs (like returnable plastic milk jugs) last longer. Other types of containers may be used. Keep the size two gallons or smaller or water will stratify with hot water on the top and cooler water on the bottom, reducing efficiency.
A passive solar hobby greenhouse is only effective when built to optimum energy specifications. Because the major heat loss is through the glazing, double-glazing (which reduces heat loss by 25 to 35%) is required. Double glazed patio door glass is great for glazing a hobby greenhouse. Glass suppliers sometimes have recycled

(used) patio door glass available at minimal prices. Night curtains may add an additional 30 to 50% energy conservation. On a passive solar hobby greenhouse, the north, east, and west walls are typically insulated to an R-value of R38. The foundation and floor are insulated from heat loss to the ground. [Figure 3]

Figure 3. Hobby greenhouse being constructed with double glazed patio door glass.

Cold air infiltration is the second major source of heat loss. For passive solar to be effective, minimize cold air infiltration with good design and construction techniques. Insulative vent covers help reduce cold air infiltration at night, but must be removed daily to allow thermostats to maintain proper temperature.

A passive solar hobby greenhouse requires an east to west orientation. In northern Colorado latitudes, an east to west orientation receives 25% more solar energy than a north to south orientation. Sometimes the hobby greenhouse may be oriented slightly to the east for faster morning warming. An orientation 20º off east to west will cut 4 to 5% of the solar potential, while an orientation 45º off east to west will cut 18 to 20% of the solar potential. At northern Colorado latitudes in January, a north to south orientation cuts 25% of the solar potential.

A poorly constructed greenhouse cannot be retrofitted into an efficient passive solar unit.

Cool Season Vegetables

Cool season vegetables do well in the greenhouse or cold frame. High temperatures are not desirable, and an occasional near freezing dip will not harm crops. High light intensity is not as critical for cool season crops as for warm season crops. [Figure 3]

Figure 4. Lettuce in solar greenhouse raised bed.

General temperatures for cool season crops

Daytime: 50ºF to 70ºF   Short-term temperature extremes: 35ºF to 90ºF
Nighttime: 45 ºF to 55 ºF   Germination: 40ºF to 75ºF

Vegetable	Minimum Container Size*	Minimum Equal-Distance Spacing	Remarks
Beets	8” deep	6”	• Grow in fall and hold in cool greenhouse for winter use. • Properly thin.
Broccoli Cabbage Cauliflower	10” deep 5 gallons/plant	18”	• High yield for space used. • Avoid long-term temperature extremes. • Heads split with warm humid conditions.
Carrots	12” deep	3”	• Extremely sweet with adequate water and cool temperatures. • Use short varieties, like Short & Sweet or Scarlet Nantes • Questionable use of greenhouse space.
Chard	8” deep	9-12”	• Does exceptionally well.
Kohlrabi	8” deep	9”	• Does exceptionally well.
Leaf lettuce	4” deep	9”	• Easy to grow in fall, winter and spring in solar greenhouse. • Use softhead or leaf types. • Keep temperatures under 70 ºF.
Green onions	6” deep	3”	• Never let onions get dry. • Sensitive to photoperiod (length of night). With short days (long nights), growth goes into leaf production. With long days (12-16 hours) energy goes into bulb production.
Peas	8” deep	6”	• Use dwarf, edible-pod or snap types for salads and stir-fry. • Avoid temperature extremes. • Questionable use of space. • Do not transplant well, not well suited to container gardening.
Radish	5” deep	2-3”	• Avoid water and heat stress. • Must have 12 hours of light to root. • For fall and spring crops in greenhouse.
Spinach	8” deep	6”	• Needs cool greenhouse (45ºF to 50ºF) for best quality. • Avoid temperature fluctuations.
Turnips	8” deep	6”	• Good for fall and spring crops.

Many oriental vegetables are also suited for greenhouse production.
*A larger container size will make crop easier to care for, providing a larger supply of water and nutrients.

Warm Season Vegetables

Warm season vegetables require high light intensity and moderate night temperatures. They cannot be cost effectively grown during the winter in a hobby greenhouse without solar heat collectors. Greenhouse climates control is critical for these fruiting crops to produce. Warm season crops are not compatible with cool season crops due to differing temperature needs.

General temperatures for warm season crops

Daytime – 60ºF to 85ºF
Nighttime – 55ºF to 65ºF
Short-term temperature extremes – 50ºF to 95ºF
Germination – 60ºF to 85ºF

Vegetable	Minimum Container Size	Minimum Equal-Distance Spacing	Remarks
Beans	8” deep	6”	• Not a common greenhouse crop. • Good production with adequate light and spacing in spring and fall. Poor winter production. • May be questionable use of greenhouse space.
Cucumbers	8” deep 3-4 gallons/plant	18”	• Requires high humidity, high light intensity, and good moisture. • Needs 75ºF to 80ºF day temperatures and 50ºF minimum nights. • Avoid temperature fluctuations greater than 20ºF. • Poor mid-winter production. • Plant gynecious greenhouse types. • Needs good air circulation to minimize powdery mildew.
Eggplant	8” deep 4-5 gallons/plant	24”	• Hand pollination required.
Muskmelon	8” deep 5 gallons/plant	24”	• Uses lots of space for yield, try trellising. • Needs 80ºF day temperatures. • Requires hand pollination. • Needs good air circulation to minimize powdery mildew.
Peppers	8” deep 2-5 gallons/plants	15”	• Minimum night temperatures of 55ºF. • Hand pollination required.
Summer Squash	8” deep 5 gallons/plant	24”	• Hand pollination required. • Needs good air circulation to minimize powdery mildew. • Productive with good sunshine.
Tomatoes	12” deep 2-5 gallons/plant (depending on cultivar/plant size)	24”	• Minimum night temperature of 55 F. • Hand pollination required. • Productive with good sunshine.

*A larger container size will make crop easier to care for, providing a larger supply of water and nutrients.

Figure 5. Beans in solar greenhouse raised bed

Figure 6. Raised bed in solar greenhouse.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs by David Whiting; used by permission.

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CMG GardenNotes #724

Vegetable Gardening in Containers

Container vegetable production is somewhat more demanding than growing flowers and other ornamentals in containers. Quality of most vegetables is based on the soil's ability to provide a constant supply of water and nutrients. Vegetables become strong flavored, stringy, and tough under dry or low fertility conditions. With the limited root spread in a container, the gardener must frequently and regularly supply water and fertilizer. In growing container flowers, minor lapses in daily care may interrupt flower production, but flowering eventually resumes with returned quality care. With container vegetables, minor lapses in daily care may significantly reduce produce quality.

Warm Season Vegetables

Warm season vegetables prefer warmer summer temperatures (70ºF to 95ºF) and are intolerant of frost. They are typically planted after the average spring frost date as summery weather moves into the area. Along the Colorado Front Range, planting time would be mid-May to early June. Warm season crops need full sun.

Cool Season Vegetables

Cool season vegetables prefer the cool growing temperatures (60ºF to 80ºF) of spring and fall. Most are intolerant of summer heat. They do tolerate light frosts. Leafy and root vegetables prefer full sun, but are tolerant of partial shade. They are intolerant of reflected heat during the summer season.

Spring crops are typically planted two to four weeks before the average spring frost date. Along the Colorado Front Range, spring planting times are mid-April to early-May. Most are replanted in mid-July to mid-August for a fall harvest.

The quality of these vegetables is directly related to their ability to grow rapidly in a good soil mix under frequent light fertilization and a constant supply of water. Crops become strong flavored if they become dry.

Warm Season Vegetables

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Beans	8" deep	full sun	• In a long box 12 inches wide, plant bush beans or trellis pole beans. • Beans have a high water requirement during blossoming. • Beans drop blossoms with dry soil or excessive wind.
Cantaloupes Muskmelons	5+ gallons/plant	full sun	• May be trellised to conserve space. • Compact varieties preferred for container gardening. • With male and female blossoms, may need hand pollination. • Needs good air circulation to minimize powdery mildew.
Cucumbers	8" deep 3+ gallons/plant	full sun	• Grow bush-types in hanging baskets or on a trellis (vines grow 18-24 inches long). • Grow strong vining-types on trellis. • Needs good air circulation to minimize powdery mildew. • Young plants are very sensitive to wind burn.
Eggplant	8" deep 4-5 gallons/plant	full sun	• One plant per container. • Needs night temperatures above 55ºF for pollen development.
Peppers	8" deep 2-5 gallons/plants	full sun	• One plant per container or space to 14 to 18 inches in row. • Needs night temperatures above 55ºF for pollen development. • Decorative, attractive plant with fruit.
Summer Squash (Zucchini)	36" by 36" space 8" deep 5 gallons/plant	full sun	• Compact varieties more suited to container gardening. • Great in a whiskey barrel size container. • One plant will produce six or more fruit per week. • Has male and female blossoms. May need hand pollination. • Needs good air circulation to minimize powdery mildew. • Keep fruit picked for continued production.
Tomatoes	12" deep 2-5 gallons/plant depending on variety (plant size)	full sun	• Varieties vary in mature plant size from determinate (bush) types to large, indeterminate vines over 6 feet tall. • Patio types (small vines) are great for container gardening and may be grown as hanging baskets or trellised. • Standard garden types require a larger container (like a whiskey barrel) and trellising. • Needs night temperatures above 55ºF for pollen development. • Crowding cuts yields and increases disease potential. • Blossom end rot (black sunken area on bottom of fruit) is a symptom of inconsistent watering or a soil that does not have enough water storage.

* Larger container sizes will make crop easier to care for, providing a bigger supply of water and nutrients.

Cool Season Vegetables

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Beets	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • To give space for root development, thin greens to 3”. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Broccoli Cabbage Cauliflower Kale Collards	10” deep 5 gallons/plant	8 hours	• Best in fall production (e.g., plant mid July for fall harvest along the Colorado Front Range). • Minimum spacing per plant is 18 by 18 inches. • A consistent supply of water and nutrients promotes rapid growth and is essential for quality produce. • Heavy feeder, requiring frequent light fertilization. • Crops develop a strong flavor if the soil gets dry.
Carrots	12” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • Use short root varieties. • Roots will crack and be strong flavored if the soil gets dry. • Thin early to two to three inches apart. • Foliage is rather decorative.
Chard	8” deep	6 hours	• Space to six plus inches between plants in a row. • Harvest outer leaves allowing plants to continue to grow. Makes an excellent “cut and grow again” crop. • Colored varieties are very decorative. • Responds to frequent light fertilization. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Kohlrabi	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce. • Never allow soil to become dry. • Kohlrabi is a heavy feeder, requiring frequent, light fertilization.
Lettuce (leaf)	8” deep	6 hours	• Grow as a spring or fall crop; avoid hot summer temperatures. • Use softhead or leaf types. • As the young crop grows, thin to 9” spacing; crowding (competition for space, water and nutrients) reduces quality. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce. • Responds to frequent light fertilization. • Lettuce become strong flavored if the soil become dry, during hot weather, and with crowded plants

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Onions (green)	6” deep	8 hours	• Onions require a consistent supply of water. Never allow soil to become dry. • Thin the crop by harvesting young plants. • Plant in early spring. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Peas	8” deep	Full sun	• Not well suited to container gardening. • Best in cool temperatures, grow a spring and fall crop. • Use dwarf, edible-pod or snap types for salads and stir-fry. • May be grown in hanging baskets or trellised. • Needs good air circulation to avoid powdery mildew.
Radish	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients to promote rapid growth is essential for quality produce.
Spinach	8” deep	6 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Turnips	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • When large enough to make greens, thin to four inches allowing roots to develop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.

* Larger container sizes will make crop easier to care for, providing a bigger supply of water and nutrients.

Authors: David Whiting (CSU Extension, retired), with Carol O’Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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CMG GardenNotes #610-617

The Science of Pruning

Red Handled Pruners
Artwork by Melissa Schreiner © 2023

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CMG GardenNotes #610

The Science of Pruning

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #611, *Tree Growth and Decay.*
- #612, *Pruning Cuts*.
- #613, *Structural Training of Young Shade Trees*.
- #615, *Pruning Mature Shade Trees*.
- #616, *Pruning Flowering Shrubs*.
- #617, *Pruning Evergreens*.

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #7.003, *Training and Pruning Fruit Trees*.

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.
- #1210, *Pruning Mature Fruit Trees*.
- #1713, *Pruning Shrubs*.

Other

- *An Illustrated Guide to Pruning,* Third Edition. Edward F. Gilman. 2012. Available from the International Society of Arboriculture, https://wwv.isa-arbor.com/store/product/24.
- *Best Management Practices – Pruning,* Third Edition. Sharon J. Lilly, and E. Thomas Smiley. 2019. Available from the International Society of Arboriculture, https://wwv.isa-arbor.com/store/product/58/.
- *ANSI A300 Pruning Standards, Part 1*. American National Standards Institute. 2017. Available from TCIA, https://treecareindustryassociation.org/business-support/ansi-a300-standards/.
- *Structural Pruning, A Guide for the Green Industry*. Dr. Edward F. Gilman, Brian Kempf, Nelda Matheny, and Jim Clark. 2013. Available from the International Society of Arboriculture, https://wwv.isa-arbor.com/store/product/500/.
- Find an Arborist (ISA), https://www.treesaregood.org/findanarborist.
- The Urban Tree Foundation, http://www.urbantree.org/.

Learning Objectives

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

- Explain how trees grow, describe their tissues, and understand decay.
- Know the three different types of pruning cuts (removal cuts, reduction cuts, and heading cuts) and be able to explain their uses and how to execute them.
- Structurally prune a young shade tree.
- Describe pruning of maturing shade trees, including objectives and methods.
- Prune flowering shrubs.
- Prune evergreen shrubs.

Review Questions

Tree Growth and Decay

1. What is a branch collar?
2. Explain how a branch collar develops.
3. Explain the size relationship between the side branch and trunk/parent branch necessary for a branch collar to develop.
4. Define the following terms:
    - Phloem.
    - Xylem.
    - Sapwood.
    - Heartwood.
    - Ray cells.
    - Compartmentalization.
5. How do trees respond to decay?
6. Describe the four ‘walls’ of CODIT (Compartmentalization of Decay in Trees).
7. What are some visual indicators of decay?

Pruning Cuts

8. Identify/define the following:
    - Branch collar.
    - Branch bark ridge.
    - Branch defense zone.
    - Reaction zone.
    - Wound wood.
9. Answer the following questions about removal cuts:
    - In what situation would you use a removal cut?
    - What are the advantages of a removal cut?
    - When the branch bark ridge is visible, where is the removal cut made?
    - If the branch collar is not easy to identify, where is the removal cut made?
    - If the branch has no branch collar, where is the removal cut made?
    - What happens when the branch collar is injured or removed?
10. Answer the following questions about reduction cuts:
    - In what situation would you use a reduction cut?
    - What are the uses and limitations of reduction cuts?
    - What is the proper angle for a reduction cut?
    - In a reduction cut, what is the proper size relationship of the branch being removed to the branch pruned back to? Is it important?
11. Answer the following questions about heading cuts:
    - In what situation would you use a heading cut?
    - How does it influence regrowth of the plant?
    - What are the effects of using heading cuts on larger branches?
12. Explain the three-step method for pruning large branches. Why is it needed? When is it needed?
13. Ideally, what time of year should major pruning of shade trees or larger evergreens be undertaken?

Structural Training of Young Shade Trees

14. In structural training of young shade trees, give the rule-of-thumb for dosage (i.e., the maximum amount of live wood/foliage removed per season)? How is the dosage range adjusted for the specific tree?
15. What are the pruning objectives for young trees.
16. Define codominant trunks. Why do arborists have zero tolerance for codominant trunks?
17. What is the standard height for the lowest permanent branch of sidewalk trees? Street tree? Trees in forest areas (fire management)?
18. What is the proper size relationship between the trunk and side branch? Why is it important? What are the options if a side branch is growing too large?
19. Define scaffold branch. What is the rule of thumb for minimum spacing of scaffold branches?
20. How do multiple branches arising at one site influence the branch collar and thus structural integrity?
21. What is the role of temporary branches on young trees?
22. Describe the management of temporary branches.

Pruning Mature Trees

23. List the objectives for pruning a mature tree.
24. List the methods of pruning to achieve purposes.
25. Describe key elements in writing specifications for general pruning of maturing trees.
26. What is the overall objective in structural pruning of medium-aged and mature trees? Why will it generally require work over a period of years? How does larger branch size influence the potential for structural pruning?
27. Describe subordinate pruning. What factors should be considered when deciding where to make a subordinate pruning cut?
28. Describe how to subordinate prune a medium-aged tree with the following situations:
    - Codominant trunks.
    - Rounded off.
    - Choked-out central leader.
    - Too many upright-growing branches.
29. Describe key elements in writing specifications for structural pruning of medium-aged trees.
30. Define cleaning. In cleaning, how much of the live wood should be removed? Why?
31. When is it important to remove dead branches? At what size and height does dead branch removal become an important management issue?
32. When removing a dead branch, where is the final cut made?
33. Describe key elements in writing specifications for cleaning.
34. Describe thinning.
    - What are the purposes of thinning the crown?
    - In thinning the crown, what types of cuts are made?
    - What is the general maximum size of branches to be removed?
    - What is the long-term effectiveness in overall crown thinning to reduce storm damage potential? What pruning method would be more effective?
35. Describe the key elements in writing specifications for thinning.
36. What is lion-tailing? How does it differ from thinning the crown? What are the problems associated with lion-tailing?
37. What is the rule of thumb on dealing with excessive sucker growth?
38. In raising, what is the minimum live crown ratio?
39. In raising, what options may be workable other than removal of lower branches? Why may removal of lower branches cause problems?
40. Describe the key elements in writing specifications for crown raising.
41. Describe the reasons for crown reduction. Describe the limitations of crown reduction.
42. List pointers on crown reduction, as given in chapter.
43. What is the long-term effectiveness in overall crown reduction to reduce storm damage potential? What pruning method would be more effective?

44. How does topping a tree impact its structural integrity and internal decay potential?
45. Describe the key elements in writing specifications for crown reduction.

Flowering Shrubs

46. What is the difference between spring-flowering shrubs and summer-flowering shrubs? How does this affect pruning?
47. Many gardeners prune flowering shrubs by topping or shearing them. Describe the impact on growth and flowering.
48. Explain the pros of, and limitations for, shrub pruning by:
    - Shearing to shape.
    - Thinning old wood.
    - Pruning to the ground.
    - Replacement.
49. What types of shrubs are successfully renewed by pruning to the ground? List situations where this approach may not work.

Evergreens

50. Why should you avoid pruning the evergreen tree back further than where it has foliage?
51. A large evergreen tree is overgrowing the space. Explain options to prune back the bottom branches for spruce, fir, and Douglas-fir and pines.
52. Explain what happens when a gardener shears a pine shrub. What is another technique to keep a young pine shorter and bushier?
53. On junipers and arborvitae, explain the pros and cons of:
    - Shearing.
    - Thinning.
54. Explain the problems associated with trying to prune back a severely overgrown juniper or arborvitae.

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #611

Tree Growth and Decay

Outline:

As forest scientists observed how trees respond to wounds, pruning techniques changed and pruning objectives were clarified.

This CMG GardenNotes provides background information on how trees grow and decay and therefore the implications of pruning cuts and structural training. For additional information, see CMG GardenNotes #610-617 on *The Science of Pruning*.

Note: In this publication, the term "trunk" refers to a trunk or parent branch, and "side branch" refers to a side branch arising from the trunk (parent branch). The same relationship would exist between a side branch and a secondary side branch.

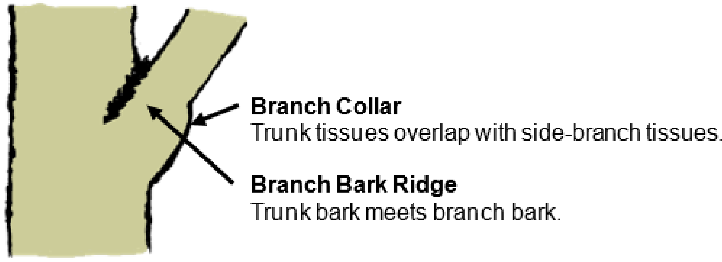
Developing a Strong Branch Union

In Colorado (and other snowy climates) the most common type of significant storm damage in landscape trees results from failures at the ***branch union*** (crotch), primarily with ***codominant trunks*** (adjacent trunks of similar size). Primary objectives in training young trees are to develop strong branch unions and eliminate structurally weak codominant trunks. [**Figure 1**]

The structural strength of a branch union is based on the development of a ***branch collar***. The branch collar is where the annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. In lumber, the branch collar is called the knot. [**Figures 2** and **3**]

Figure 1. Codominant trunks account for the majority of storm damage in Colorado landscapes.

Figure 2. Structural strength of the branch union (crotch) is based on development of a branch collar.



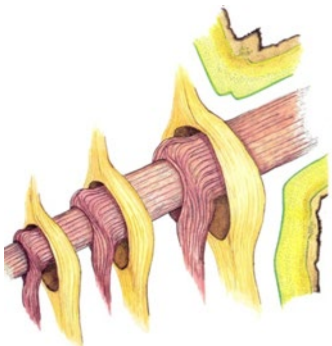


Figure 3. The branch collar is where annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. This creates a very solid section of wood, known as the "knot" in lumber. Line drawing: U.S.D.A.

As the branch collar develops, side branch tissues connect into the trunk in a wedge shape, making a structurally strong unit. **For the branch collar to develop, the side branch must be less than half the diameter of the adjacent trunk. Less than one-third is preferred.**

If the side branch is too large in diameter, prune back the side branch by one-third to two-thirds to slow growth or remove the branch entirely. Over a period of years, a branch collar will develop. [**Figure 4**]

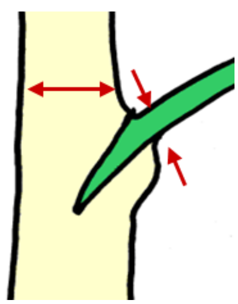


Figure 4. As the branch collar develops, side branch tissues connect into the trunk in a wedge shape making a structurally strong unit. For the branch collar to develop, the diameter of the side branch must be less than half the diameter of the adjacent trunk. Less than one-third is preferred.

The size relationship between the trunk and side branch is called ***aspect ratio***. A branch union with high aspect ratio, like one-to-one (two trunks of the same diameter), is highly prone to failure in wind and snow loading. A branch union with a low aspect ratio, like one-to-three (side branch is one-third the diameter of the adjacent trunk), would not likely fail due to the development of the branch collar.

A branch collar will not develop on codominant trunks (adjoining trunks of similar size), making this branch union structurally weak. [**Figure 5**]

Multiple branches arising at the same location also compromise the branch collar's structural strength. Some tree species, such as elm, maple, and crabapple, naturally develop multiple branches at one location. This predisposes the tree to storm damage if the situation is not corrected by structural training when the tree is young. [**Figure 5**] Choosing structurally correct trees or fixing when young is ideal. Refer to CMG GardenNotes #632, *Tree Selection: Right Plant, Right Place*.

Figure 5.
Left: A branch collar does not develop on co-dominant trunks, making the branch union structurally weak. Tight angled V-shaped branch unions are more prone to decay and storm damage.
Right: Multiple branches arising at the same location are also structurally weak as the branch collars cannot knit together into a strong union.

Spread of Decay. Due to the constriction of xylem cells where the side branch annual growth rings are overlapped by the trunk annual growth rings, the development of a branch collar significantly reduces the potential spread of decay. In addition, branch unions with a right angle of attachment are more effective in preventing the spread of decay.

To reduce the potential for decay, prune to develop branch collars. The side branch must be less than half the diameter of the adjacent trunk. Also select branch unions with a wide angle of attachment. In pruning, remove codominant trunks and narrow branch unions while young (smaller than two inches). If the branch is larger, a heading cut can be made one year, and removal can happen the following year to reduce the percentage of removal as needed. [**Figure 6**]

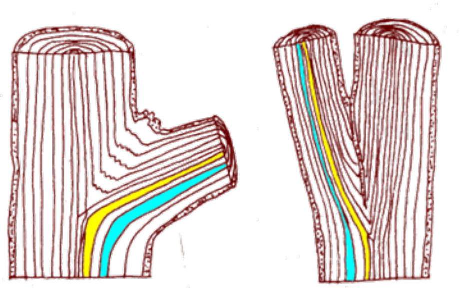


Figure 6. Branch unions that form a right angle are more resistant to decay. A branch union with codominant trunks and a narrow angle of attachment is highly prone to the spread of decay.

How Trees Grow

Xylem Tissues. Each year a tree puts a new outer ring of wood (xylem tissue) under the bark resulting in the increased diameter of a trunk or branch. The number of rings indicates the limb's age, and the width of individual rings indicates that year's growing conditions. [**Figures 7** and **8**]

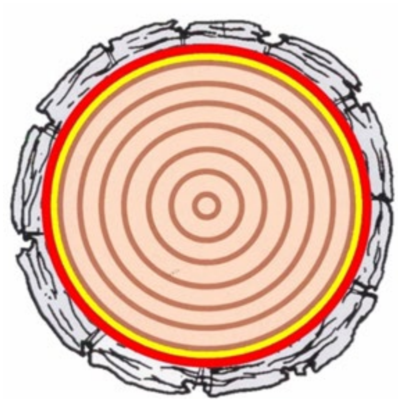


Figure 7. Cross section of a tree.
Bark is the outer protective covering.
Phloem (red in drawing) is the inner bark tissue. Photosynthates (sugars and carbohydrates produced in the leaves by photosynthesis) move throughout the tree in the phloem tissues, including down to feed the roots.
Cambial Zone (yellow in drawing) is the layer of active cell division between bark and xylem.
Xylem (brown layers in drawing) shows each year that the cambium adds a new ring of xylem tissue just under the cambium layer, resulting in a growth in limb diameter. Xylem tissues are the technical name for the "wood."

Figure 8. The “wood” of a tree is the xylem tissue. Xylem tissues that grew in the spring and early summer enlarge and are the tubes in which water with minerals flows from the roots to the leaves. In a cross-section of the log, these are light colored rings. Xylem tissues that grew mid-summer, at the end of the growth cycle, are higher in fiber content, creating a wall to the outside. In a cross-section of a log, these are the darker colored rings.

Younger ***annual growth rings*** (annual rings of xylem tissue) with their living cells active in water transport and storage of photosynthates are called ***sapwood***. Depending on the species and vigor, sapwood comprises approximately the five youngest (outer) annual growth rings. ***Heartwood***, the older annual xylem rings no longer active in water transport, is very susceptible to decay organisms. Due to chemical changes in these non-living cells, heartwood is often darker in color. [**Figure 9**]

Ray cells grow through the annual growth rings, functioning like staples or nails to hold the growth rings together. Ray cells also function as the path to move photosynthates in and out of storage in the xylem tissues. On some species, ray cells are not readily visible. On other species, ray cells create interesting patterns in the wood. [**Figure 10**]

Figure 9. On this Douglas-fir log, the sapwood is the light colored annual growth rings active in water transport and storage of photosynthates. The darker colored heartwood in the center has no resistance to decay.

Figure 10. The cracks on this willow stump show ray cells.

The wood is a series of boxes or “compartments” framed by the ***annual growth rings*** and ***ray cells***. Each compartment is filled with xylem tubes in which water with minerals moves from the roots to the leaves. [**Figures 11** and **12**]

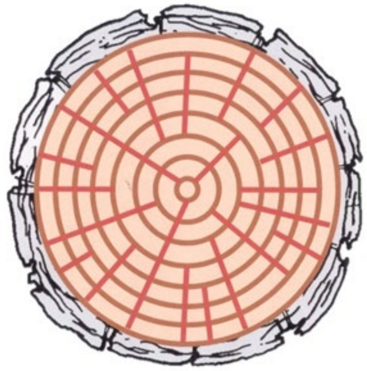


Figure 11. The xylem tissue (wood) is a series of compartments or boxes created by the annual growth rings and ray cells.

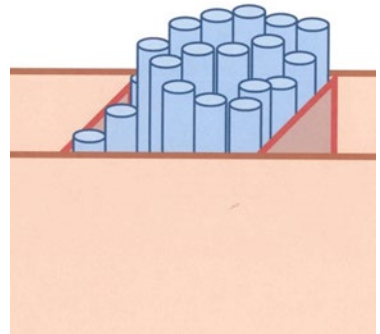


Figure 12. Each compartment or box framed by the annual growth rings and ray cells is filled with xylem tubes. Water moves in the xylem tubes up from the roots.

CODIT: Compartmentalization of Decay in Trees (How Trees Decay)

Unlike animals and people, trees do not replace damaged tissues. Rather, cells in the damaged area undergo a chemical change in a method to seal off or “compartmentalize” the damaged area from the spread of decay. This area of chemical change is called the ***reaction zone***. In most species, a reaction zone appears as darker colored wood.

The spread of decay is related to this compartmentalization of the xylem tubes in a box-like structure created by the annual growth rings and ray cells. In this box-like structure, the four walls differ in their resistance to the spread of decay. [**Figure 11**]

Wall 1 – Resistance to the spread of decay is very weak up and down inside the xylem tubes. Otherwise, the tubes would plug, stopping the flow of water, and kill the plant. From the point of injury, decay moves upwards to a small degree, but readily moves downward. The downward movement may be twenty or more feet and can include the root system.

Wall 2 – The walls into the older xylem tissues (toward the center of the tree) are also rather weak, allowing decay to readily move into <u>older</u> annual growth rings.

Wall 3 – The walls created by the ray cells (being high in photosynthates) are somewhat resistant to decay organisms. This may help suppress the spread of decay <u>around</u> the tree.

Wall 4 – New annual growth rings that grow in years <u>after</u> the injury are highly resistant to the spread of decay.

Resistance to the spread of decay by the new annual growth ring and ray cells creates a pipe-like structure, with a decayed center. This concept of how decay spreads in a tree (as controlled by the annual growth rings and ray cells) is called CODIT, for Compartmentalization of Decay in Trees. [**Figures 13** and **14**]

The spread of decay in trees is suppressed by the four walls created by compartmentalization of the annual growth rings and ray cells.

Figure 13. The heartwood has completely decayed away.

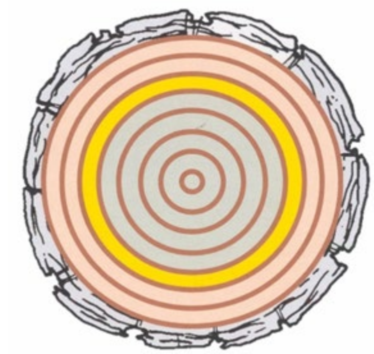


Figure 14. Decay in a tree creates a pipe-like structure with a hollow center. The light colored wood represents new annual growth rings that grew after the year of injury. The darker colored ring is a reaction zone created in the sapwood. The heartwood has completely decayed away.

In the drawing, an injury occurred three years ago when the yellow-colored annual growth ring was the youngest. That year and everything older (grayed annual growth rings) are subject to a reaction zone and decay. The two new annual growth rings (brown color) that grew in years after the injury are highly resistant to decay.

Evaluating Decay

Evaluation of decay and if a tree is hazardous must be done by a **TRAQ (Tree Risk Assessment Qualification) certified arborist**. A commercial arborist or arborists with the Colorado State Forest Service with this TRAQ certification should be the only ones discussing risk! When evaluating risk of the tree, arborists look at tree history, tree vigor, species, crown density, potential targets, consequences of failure, and if there are mitigation steps that can be taken. The following is for knowledge only.

Percent Decay or Hollowness

A trunk or branch with some internal decay is not necessarily at risk for failure. Structural strength is based on the minimum thickness of the healthy wood (xylem tissues) and the structural strength of wood (tree species).

In evaluating potential hazards, arborists (tree care professionals) calculate by dividing the thickness of the healthy wood at the thinnest point (not including bark, reaction wood, or decaying tissue) by the radius of the trunk/branch (not including bark). This healthy wood is sometimes called holding wood and mainly consists of sapwood. A tree with a 33% healthy wood is labelled high risk potential. A tree with a 20% healthy wood is labeled as critical risk potential.

The cottonwood branch above [**Figure 13**] has 25% healthy wood, putting it at “high risk” for potential failure. This *calculation* is valid only when the decay column is centered in the trunk/branch. Other factors are used to evaluate the tree’s health and risk.

On older mature trees, percent holding wood or sapwood (healthy wood) formula standards may overstate the thickness of healthy wood needed to be structurally acceptable. Additional research is needed to better clarify this standard for older/mature trees.

Measuring Decay

So, how thick is the healthy wood in a trunk or branch? Researchers are working to address this big question. Arborists that have specific training in Tree Risk Assessment Qualification (TRAQ) use a Basic Tree Risk Assessment form and certain tools to assess trees. These trained arborists are the ones that should address any question of risk. The following are procedures with limited potential to evaluate the internal structure of trees.

Visual Indicators for Decay

Large pruning wounds suggest the potential for internal decay. Often decay may be observed within the pruning wound. [**Figure 15**]

Figure 15. The black material in the pruning cut is decay fungus. Notice the cracking; it also raises flags of structural integrity.

Cankers suggest the potential for internal decay. If the canker extends down into the soil, decay organisms will always be active.

Valleys, ridges, cracks, and splits along the trunk/branch suggest the potential for decay. Wildlife living inside the tree is a sign of decay.

Abnormal swellings or shapes could be a sign that the tree is growing around a decayed area.

Coring Devices

Note: All coring devices may spread decay since the core is taken through healthy and decayed layers of the wood, so it is only used when evaluating risk potential. Coring devices only indicate the decay potential at the point of drilling and do not represent the entire trunk or branch.

The tools used to measure risk based on decay and health of trees can include an increment borer tool, a drill with a small bit, a Resistograph, digital microprobe, sonic tomograph, electrical impedance tomograph, sonic hammer, tree motion sensors, or chlorophyll fluorimeter.

Listening and Radar Devices
Various methods are used today to predict the risk potential of trees. These methods may include using instruments to measure sound to determine internal decay, visualizing sound waves, measuring the electric field of the wood, or using radar. Some of these methods are financially prohibitive tools for arborists.

Breaks in the Pipe-Like Structure

When a wound or pruning cut breaks the pipe-like structure of a trunk/branch, the tree is especially weak at this location creating a higher potential for tree failure. [**Figure 16**]

Figure 16. Structural strength is significantly compromised when the pipe-like structure of a trunk has a break in the cylinder wall.

Lack of Trunk/Branch Taper

Branch failure (often breaking a few feet to one-third of the branch length out from the branch union) is a common type of storm damage. Branch failures often cause minimal damage to the tree. However, failure of a major branch may create holes in the tree canopy, introduce decay and cracking, and make the tree look unacceptable. ***Trunk failure*** refers to breaking of the lower trunk, above ground level (not at a branch union).

Branch and trunk failures are associated with lack of trunk/branch taper. That is, the trunk/branch does not thicken adequately moving down the trunk/branch. This can be caused by pruning up the trunk too fast and by removing small branches and twigs on the lower trunk or lower interior canopy of the tree.

Very upright branches without a lot of side branches also typically fail to develop adequate taper. For structural integrity, shorten these branches with appropriate reduction or heading cuts.

Authors: David Whiting, CSU Extension, retired, and Carol O'Meara, CSU Extension, retired. Artwork by David Whiting. Used with permission. Reviewed May 2018. Reviewed May 2023 by Susan Carter, CSU Extension.

Reviewed May 2023

CMG GardenNotes #612

Pruning Cuts

A pruning cut is a controlled wounding of a tree. Pruning a tree has potential negative consequences for its health, including reduced production of photosynthates, lower vigor, and creating pathways into the tree for decay organisms. To mitigate the risk pruning poses, a tree should only be pruned when needed (when there is a beneficial objective) and pruning cuts should be executed properly. For details on tree growth and decay, refer to CMG GardenNotes #611, *Tree Growth and Decay*.

There are three types of pruning cuts: **removal cuts**, **reduction cuts**, and **heading cuts**, each of which is executed and used differently.

Note: In this publication, the term “trunk” refers to the trunk or parent branch, and “side branch” refers to the adjacent side branch arising from the trunk (parent branch). The same relationship exists between a side branch and secondary side branches.

Maximum Diameter of Pruning Cuts

Ideally all pruning cuts would be made on branches two inches or less in diameter. Smaller cuts are more quickly covered with wound wood and avoid exposing large amounts of heartwood. ***Sapwood*** is the newer xylem rings. It is active in water transport and storage of photosynthates and is composed of both living and dead cells. Because it contains living cells it can actively resist the spread of decay organisms. On branches two inches and less in diameter, sapwood dominates the branch structure and in many cases is the only type of wood present.

Heartwood, the older xylem rings no longer active in water transport, has no way to actively resist decay. Due to chemical changes in these nonliving cells, heartwood is often darker in color. Depending on species and growth rates, heartwood becomes significant as branches reach two to four inches in diameter. [**Figure 1**]

Figure 1. Cross section of a Douglas fir. The light colored outer ring of wood is the sapwood. The dark wood in the center is the heartwood.

Sometimes larger diameter cuts are needed to achieve critical pruning objectives. Any pruning cut larger than four inches needs to take into account the increased risk of decay organisms colonizing the tree's wood through the cut.

Removal Cuts

Removal cuts (also known as thinning cuts or collar cuts) remove side branches back to the larger parent branch or trunk. If the branch union has a branch collar, removal cuts have the advantage of preserving the branch defense zone, providing a strong defense against internal decay.

Removal cuts reduce the canopy density but have little influence on height. Thinning with removal cuts allows better light penetration into the canopy, which encourages desired diameter growth of interior branches. Removal cuts reduce the weight on large branches, giving the tree resilience to snow loading. The primary use of removal cuts is in structural pruning of small, middle-aged and older trees and on shrubs.
[**Figure 2**]

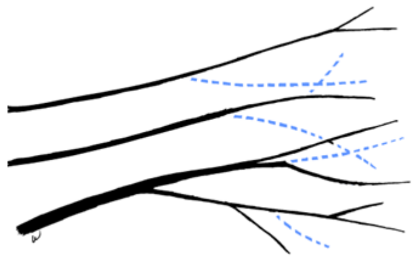


Figure 2. Removal cuts eliminate a side branch back to the trunk or parent branch.

Two features on the branch, the branch collar and the branch bark ridge, help identify the proper cut angle. The branch collar is the area where the annual growth rings of the trunk overlap with the annual growth rings of the side branch, in a manner similar to shuffling a deck of cards. On some species, the branch collar is noticeable, while on other species the branch collar is less obvious.
[**Figure 3**]

The ***branch bark ridge*** is where the bark from the trunk joins the bark from the side branch. Where they meet, the bark rises into a ridge. It mirrors the angle of attachment of the side branch.
[**Figure 3**]

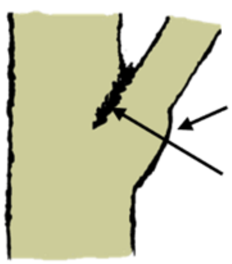


Figure 3. Branch collar and branch bark ridge.

Branch Collar
Trunk tissues overlap with side branch tissues.

Branch Bark Ridge
Trunk bark meets side branch bark.

Within the branch collar is a narrow cone of cells called the branch defense zone. [**Figure 4**] This area plays an important role by inhibiting the spread of decay organisms into the trunk. If the branch collar is injured or removed during pruning, the tree will be predisposed to decay organisms entering through the cut.

A primary objective in a correct removal cut is to preserve the branch collar.

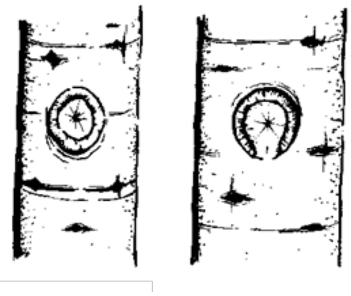


Figure 4. Branch Defense Zone
Within the branch collar is the branch defense zone, a narrow ring of cells that effectively initiates a strong reaction in which chemical changes protect the trunk from decay. If the branch collar is cut or nicked in pruning, the defense zone may fail, predisposing the wound to decay.

With a *removal cut*, the final cut should be just beyond the branch collar. [**Figure 5**]

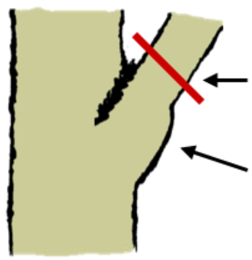


Figure 5. Removal Cut

Final Cut made just outside the branch collar, taking care not to nick the branch collar.

Branch Collar
Trunk tissues overlap with side branch tissues.

In species where the branch collar is not clearly identifiable, look for the branch bark ridge. Make the final cut at the angle that mirrors (lies opposite) the angle of the branch bark ridge. [**Figure 6**]

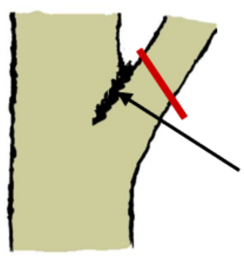


Figure 6. When the branch collar is not clearly identifiable, make the final *thinning cut* at the angle that mirrors the angle of the *branch bark ridge*.

Branch Bark Ridge

When a branch union has no branch collar (the side branch is greater than half the diameter of the adjacent trunk), tilt the angle of the final cut out a little more to minimize the size of the wound. Be aware that in the absence of a branch collar there is no branch defense zone to activate rapid woundwood growth and activate a strong reaction to suppress the potential for decay. [**Figure 7**]

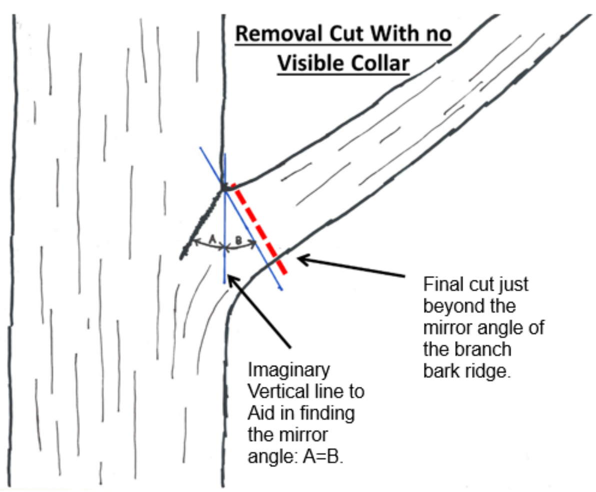


Figure 7. Correct angle for a removal cut with no visible collar.

When removing a dead branch, the final cut should be just outside the branch collar of live bark tissue. If a collar of live wood has begun to grow out along the dead branch, remove only the dead stub, leaving the collar intact. Do not cut into living tissue. [**Figure 8**]

Figure 8. Do not cut into or otherwise damage the branch collar or woundwood growing around the dead branch.

Reduction Cuts

Reduction cuts remove a larger branch or trunk back to a smaller-diameter side branch. Reduction cuts are commonly used in training young trees. They are also the only type of cut that will significantly lower a tree's height.

The branch removed with a reduction cut does not have a branch defense zone. This means that reduction cuts have a high risk of leading to decay, especially when they are larger than two inches in diameter. On trees under stress or in decline, avoid reduction cuts as they can accelerate the decline.

In a reduction cut, make the final cut straight across at the base of the branch being removed. If the branch is vertical add a slight angle to the cut to help with drainage. The exact angle is not critical as long as it is not flat on top (water needs to readily run off). [**Figure 9**]

To prevent undesired suckering at this point, the diameter of the smaller side branch should be at least one-third the diameter of the larger branch being removed. If the diameter of the smaller branch is less than one-third the diameter of the larger branch being removed, the cut is considered a heading cut and is generally unacceptable in pruning standards. [**Figures 9** and **10**]

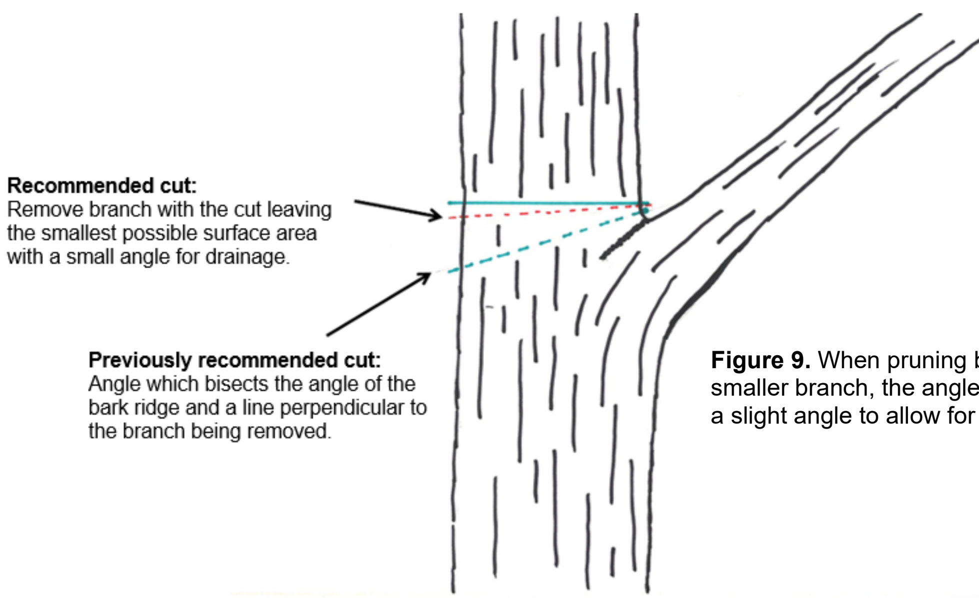


Figure 9. When pruning back a larger branch to a smaller branch, the angle of the final cut should have a slight angle to allow for drainage of rainwater.

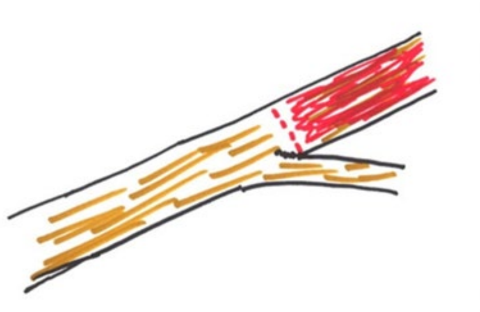


Figure 10. To prevent excessive suckering, the branch which is left should be at least 1/3 the diameter of the larger branch being removed (shown in red).

Heading Cuts

Heading cuts are made at a node (location where there is a bud) instead of at a union of branches. These cuts should be avoided in most landscape situations. These types of cuts remove the terminal bud which releases lateral buds below the cut allowing them to grow. This creates undesirable structure and necessitates that the resulting branches be thinned and/or suppressed. [**Figure 11**]

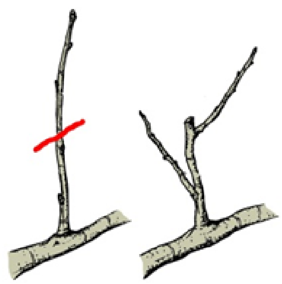


Figure 11. Heading cuts remove the growing tips of branches, releasing side buds to grow.

Another type of heading cut is the removal of a large trunk/branch back to a smaller side branch when the side branch is less than one-third the size of the larger trunk being removed. Structurally unsound water sprouts often emerge along the branch. This type of heading cut is very undesirable for most landscape trees. [**Figure 12**]

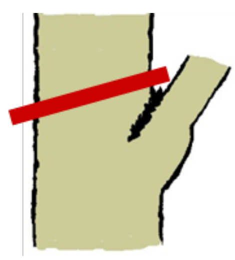


Figure 12. Removing a larger trunk or branch back to a small side branch when the side branch is less than one-third the diameter of the adjacent trunk is also considered a heading cut. This leads to structurally unsound growth of water sprouts and is not considered an acceptable pruning cut.

Three-Cut Method for Larger Branches

When removing any branch larger than one inch in diameter, use a three-cut method to protect the bark from tearing. [**Figure 13**]

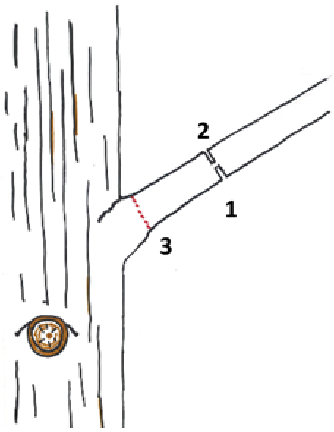


Figure 13. Three-cut method for any branch larger than one inch.

Cut One
Twelve to fifteen inches from the branch union (crotch), make an undercut approximately one-third to halfway through the branch.

Cut Two
Directly above the undercut make a second downward cut. The branch will break as you are making the second cut removing most of its weight. This double-cut method prevents the weight of the branch from tearing the bark below the collar.

Cut Three
Make the third and final cut at the correct pruning point. For example, on a removal cut, just outside the branch collar.

Alternate Three-Cut Method [**Figure 14**]

Cut One
Twelve to fifteen inches from the branch union (crotch), make an undercut approximately one-third to halfway through the branch.

Cut Two
Moving a couple of inches out past the first cut, make the second cut from above, removing the branch. This double-cut method prevents the weight of the branch from tearing the bark below the collar.

Cut Three
Make the third and final cut at the correct pruning point. For example, on a removal cut, just outside the branch collar.

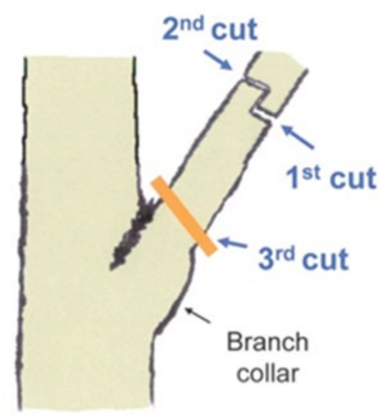


Figure 14. Alternate three-cut method for any branch larger than one inch. Fine for non-chainsaw work.

Wound Dressings

Generally wound dressings do not benefit a tree and in some cases they can be harmful. They can interfere with normal wound closure, may trap moisture in dead wood (compartmentalized wood or heartwood) and some dressings may harm plant tissue (i.e., they kill living plant cells).

Wound dressings can be used as part of a management plan for specific disease and insect issues which are not major factors in Colorado landscapes.

Time of Year to Prune

Dead, diseased, and damaged wood can be removed any time of year. Likewise, minor pruning of live wood (less than 10% of the foliage and/or only small diameter branches are removed) can be done any time of year on healthy trees. From a plant health perspective it is safer to prune a tree from late winter until late summer while the tree is not dormant.

Late winter: Pruning in the late dormant season (before buds swell) is a good time of year to prune most trees from a plant health perspective. Some species are prone to “bleeding” sap if pruned during this time of year. This is a cosmetic issue, but it can be avoided by pruning after the spring flush of growth is done. [**Table 1**]

Table 1. Examples of Trees Prone to Spring Bleeding	
• Birch • Black locust • Elms • Golden chain tree • Hackberry • Japanese pagoda tree	• Kentucky coffeetree • Maple • Mulberry • Poplar • Walnut • Willow

Spring to summer, following growth flush (as leaves reach full size, harden, and turn dark green) is considered a good time to prune.

Fall is generally considered an undesirable time to prune. It may stimulate canopy growth and interfere with winter hardiness.

Late fall to mid-winter is generally considered an undesirable time to prune. Cold temperatures can lead to cracking and damage wood exposed by pruning.

Drought. Do not remove live wood from trees in drought stress. This removes stored photosynthates that the tree is living on during the stress.

Pest management consideration. In some insect management programs, pruning may need to be timed before insect flight periods or avoided during insect flight periods.

Pruning Equipment

Hand pruners are used to cut small limbs up to ¼ to ½ inch in diameter (depending on the wood hardness). The bypass or scissor-type pruner (cutting as the blade crosses past the hooked anvil in a scissor action) is considered the best type. The anvil type (cutting as the blade pushes against the anvil) is more prone to tearing and mashing the tissues. The best advice on pruners is to purchase the best pair you can afford. It will last for years. Inexpensive pruners are short-lived.

In using bypass-type hand pruners, place the blade toward the tree with the anvil toward the outside. This allows for a closer cut. For bypass pruners, sharpen only the beveled edge of the blade pointing toward the anvil, never the anvil side of the blade.

Loppers are used for larger branches, generally up to two inches in diameter but should be used with caution as they can crush branches and damage tissues.

Pole pruners are used to cut small branches which cannot be reached from the ground. Making good pruning cuts with pole pruners can be difficult.

Handsaws are used for branches larger than ½ inch. There are two general types of tree saws. Tree saws with curved blades cut as the saw is pulled and are considered safer to use. Tree saws with straight blades cut as the saw is pushed. To remove the moist sawdust, tree saws have wider teeth spread than lumber saws. In a cut larger than one inch, a three-cut method should be used.

Chain saws are extremely dangerous. In the United States, 40,000 to 90,000 people have serious injuries, and 40 to 60 are fatally injured each year from chain saw accidents. Most accidents occur to the left leg, the shoulders, and the face. Chain saws should only be used by someone specifically trained in chain saw safety. A common accident occurs when the limb kicks back as the cut is being completed. Personal protective clothing is also needed. Safety glasses and boots are required by law. Helmet, hearing protection, gloves, and leg protection are also recommended.

Authors: David Whiting, CSU Extension, retired; Alison O'Connor, PhD, CSU Extension; and Eric Hammond, CSU Extension. Artwork by Scott Johnson, David Whiting, and Eric Hammond. Used with permission. Revised May 2018. Revised September 2023 by Eric Hammond, CSU Extension and Micaela Truslove, CSU Extension.

Revised September 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #613

Structural Pruning of Young Shade Trees

Structural Pruning Basics

Structural pruning of trees is undertaken with the broad objective of developing and maintaining a branch structure which is less prone to failure. It can be conducted on trees of any age; however, it is most effective, and mostly undertaken, on young-to-middle-aged trees as their branch structure can be more easily changed. A mature tree's structure can be changed to some extent using the principles of structural pruning. Doing so may take many years, especially in cool, dry climates such as Colorado's where trees grow relatively slowly.

Landscapes are fundamentally different than the forests where most trees evolved. In a forest setting, trees compete with their neighbors for light. This incentivizes them to have a single tall trunk, be relatively narrow, and have fewer and smaller lateral branches in their lower canopy. In a landscape setting, there is less competition for light. Trees in landscapes tend to be wider, have multiple competing leaders, and have larger and longer lateral branches. Trees evolved to support their forest form and are at a higher risk of failure in landscapes without structural pruning.

Determining Good Structure

Trees are less likely to fail if:

1) They have a single dominant leader.
2) Lateral branches have a strong attachment to their parent branch which means:
    a. Lateral branches are less than half the size of their parent branch, so they form a branch collar. [**Figure 1**]
    b. They have wider branch unions and more horizontal branching.
    c. Branch unions are free of ***bark inclusions*** (bark pressed against bark rather than connected by sound wood).
3) Scaffold branches are spaced with 3% or more of the expected mature height of the tree between them.
4) They have a live crown ratio (the proportion of tree which is canopy versus bare trunk below the canopy) of 60% or greater.

For additional information on a tree's life cycle, refer to CMG GardenNotes #101, *IPM and Plant Health Care*. For additional information on branch collar development, refer to GardenNotes #611, *Tree Growth and Decay*. For additional information on pruning cuts, refer to GardenNotes #612, *Pruning Cuts*.

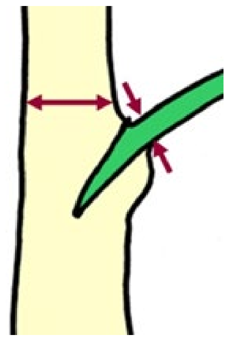


Figure 1. For a branch collar to develop, the side branch must be less than one-half the diameter of the adjacent trunk. See GardenNotes #611.

Time of Year to Prune

Structural pruning is typically done in late winter before trees break dormancy. This is a good time to prune from a tree health perspective as wounds will close quicker and the tree generally has a high amount of stored energy from the previous growing season. It is also easier to evaluate the tree's branch structure and make decisions about where to prune before the tree leafs out. Pruning is generally avoided during the spring growth flush as tissues in branches can easily separate at this time. Mid-summer is also a good time for pruning. Major pruning should not be done from early fall to mid-winter due to the risk of frost cracks and the fact that trees are dormant during this time and cannot actively respond to recovery from pruning. Minor pruning (branches two inches or less in diameter and less than 10% of the trees foliage removed) can be done anytime.

Acceptable Size of Pruning Cuts

If possible, all pruning cuts should be two inches in diameter and smaller. Pruning cuts larger than four inches in diameter should be made only in cases where there are no other options to achieve a critical pruning objective. Large pruning cuts increase the potential for decay.

Pruning Dose (Percent of Live Foliage Removed)

The amount of foliage which can be removed in a given pruning is referred to as the "pruning dose." Until a newly planted tree becomes established, pruning should be limited to dead and broken branches and correcting major structural defects. Once a tree has established following transplant, the amount of live foliage or number of live buds that can be removed depends on the tree's age and health and the pruning cycle (frequency) for the tree.

The American National Standards Institute (ANSI) standards state that 25% of a healthy tree's foliage is the maximum that can be removed each year. This is a good starting point and is useful in forming specifications for pruning. Mature trees are less tolerant of pruning. However, from a plant health perspective, no more than 10% of a mature tree's foliage should be removed annually. Young trees can tolerate more pruning. Up to 50% of a young tree's foliage can be removed annually if needed. These percentage guidelines are maximums. In situations where trees are pruned annually, the appropriate pruning dose would be lighter. However, if a tree goes several years between pruning cycles, the appropriate dose might be higher. Remove as little foliage as possible while still completing your pruning objectives. Trees that are in poor health or under stress should be pruned more lightly. Trees that are under persistent drought stress should not be pruned.

Terms Used to Describe Branches

Permanent Branch – A branch selected to be part of the permanent structure of the tree. This means it will never intentionally be removed. Also referred to as scaffold branches.

Temporary Branch – A branch that will be removed at some point as the tree grows, usually before it reaches two inches in diameter. Normally these are low branches below the permanent crown, or branches located between permanent scaffold branches.

Dominant Trunk/Central Leader – The main trunk of a tree from which primary scaffold branches originate.

Codominant Trunks/Leaders – When trees have two or more upright competing leaders of near equal size. This condition is a major structural defect as the unions between codominant leaders do not develop a branch collar and are prone to having included bark. Trees with codominant trunks are more likely to suffer damage or fail from snow and wind loading. [**Figure 2**]

Figure 2. Codominant Trunks
A branch union with two trunks of similar size is structurally weak and prone to storm damage. "Included bark" (hidden bark) between the trunks prevents the wood from growing together. Without a branch collar, wood of the two trunks does not knit together. In structural pruning, there is zero tolerance for codominant trunks.

Parent Branch – A larger branch that smaller lateral branches originate from.

Structural Pruning Objectives for Young Shade Trees

1) Remove dead, damaged, crossing, or rubbing branches.
2) Maintain a single dominant leader to near the top of a tree's canopy.
3) Keep temporary branches less than half the size of their parent branch and remove them before they grow larger than two inches.
4) Choose well-spaced permanent branches and maintain them at less than half the size of their parent branch.
5) Maintain a live crown ratio of 60% or greater.

To achieve these objectives, structural pruning manages the growth rate of a tree's branches through pruning. If part of a branch is removed, it will have fewer leaves to perform photosynthesis and will grow slower than if it had not been pruned. This also means that over time it may become relatively smaller compared to its parent branch.

Strategies for Structural Pruning of Young Shade Trees

Here are general strategies to achieve structural pruning objectives (adapted from *An Illustrated Guide to Pruning,* 3rd Edition, Dr. Edward Gilman).

Before Beginning Structural Pruning: Remove Dead and Damaged Branches

Start by removing dead, damaged, crossing, or rubbing branches from the tree. Any dead material removed does not count toward your pruning dose. However, live branches removed at this point should be considered part of your pruning dose. [**Figure 3**]

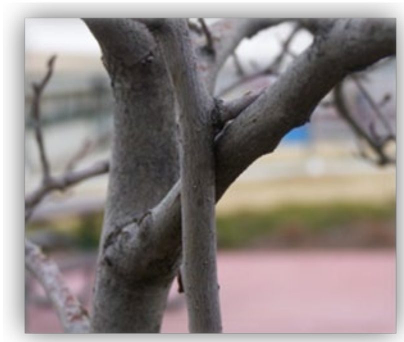


Figure 3. Rubbing branches.

Strategy 1 – Select and maintain a single dominant central leader.

Select a trunk to be the tree's dominant leader and remove or shorten all competing leaders. Generally select an upright growing branch that has the best combination of larger size and more vertical growth near the center of the tree's canopy.

> **Structural Pruning in Practice, Strategy 1:**
>
> A tree has two competing leaders. One of the two, normally the most vertical or tallest, is selected to be the dominant leader. The other is shortened with a reduction cut. It will grow more slowly as it will have less leaves going forward. Additionally, shortening the competing leader may allow the main leader to get more sunlight and thus grow more rapidly. Shortening the competing leader subordinates it to the unpruned leader which is now the central or dominant leader. Another possibility is that the competing leader could be removed completely to achieve our objective of having one dominant leader.
>
> The correct choice to shorten or remove the competing leader in this example is based on several factors including: the relative and absolute sizes of the branches involved, how much of the pruning dose for the tree we can afford to use, and the branching structure of the tree. If the competing leader is approaching two inches in diameter it might be best to remove it before it gets larger and develops heartwood. On the other hand, if it is larger than four inches in diameter, it is probably best to shorten it rather than risk exposing heartwood by removing it. If the branches are less than two inches in diameter and equal in size so a branch collar has not developed, it might be better to shorten the branch so that it can develop a collar over time. However, if the branches are equal in size but are approaching a size that makes them too large to remove without an increased risk of decay, it might be best to remove the branch regardless of whether there is a collar. There are a lot of factors that go into making this sort of pruning decision, and it takes knowledge and experience to be comfortable making them.

Strategy 2 – Select the lowest permanent branch.

It is often desirable to raise the canopy (remove lower branches) to provide clearance for human and vehicle traffic. For shade trees in lawns, patios, and along sidewalks, the lowest permanent branch is normally seven to ten feet above ground level. On smaller ornamental trees, lower branching may be preferred. Over streets, the lowest branches should be 14 feet or higher. In wooded settings, the canopy is raised to 10 feet as a fire prevention technique. Many newly planted trees are short enough that they have no permanent lateral branches at the time of planting, meaning most or all the branches present at planting will be strategically removed over time.

Strategy 3 – Keep branches below the permanent crown from growing too large and remove them over time.

Once the lowest permanent branch has been selected, it is easier to identify how to manage other branches. All branches below this branch are temporary and should be kept relatively small through pruning. They should be kept less than half the size of their parent branch (which is normally the tree's trunk). They should be removed over time before they reach two inches in diameter. The growth rate of branches can be managed by using removal and reduction cuts to remove foliage from them, which in turn will reduce their growth rate.

At least 60% of a tree's height should be canopy as opposed to bare trunk (the live crown ratio should be 60% or greater). Do not raise a tree too high or too rapidly. Lower limbs provide energy to support the development of proper trunk taper (i.e., proper diameter growth of the main trunk) and help distribute wind load placed on the tree. This means lower branches should be kept short by pruning and be removed gradually over time. Temporary branches are often reduced by pruning and retained for many years before being removed. [**Figure 4**]

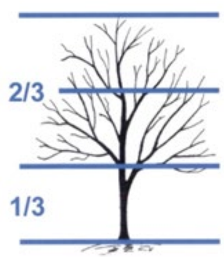


Figure 4. Temporary branches below the lowest permanent branches will be removed over time.

If lower branches grow larger than four inches in diameter, shortening them with proper pruning cuts may be a safer option than removing them.

Strategy 4 – Develop branch structure in the tree's permanent canopy by selecting well-placed permanent branches.

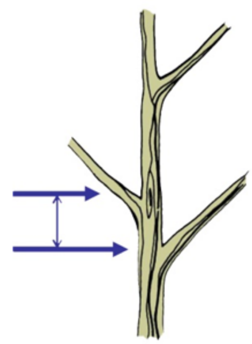
Above the lowest permanent branch there is a mix of temporary and permanent branches. The permanent branches are often referred to as scaffold branches. When selecting scaffold branches, look for branches that are well spaced with branch unions that have desirable traits (e.g., wide branch angles, a well-developed branch collar, and no included bark).

Spacing of Scaffold Branches – When selecting scaffold branches, space branches so the space between permanent branches equals approximately 3%-5% of the tree's expected mature height. **Table 1** shows spacing based on 5% of a tree's expected mature height.

Table 1. Scaffold Branch Spacing Based on 5% of Mature Tree Height	
Mature Tree Height	**Minimum Scaffold Branch Spacing**
20 feet.	1 foot.
30 feet.	1.5 feet.
40 feet.	2 feet.
50 feet.	2.5 feet.
60 feet.	3 feet.
70 feet.	3.5 feet.
80 feet.	4 feet.

Select scaffold branches with an even radial distribution around the tree's trunk. Try not to select branches on the same side of the tree which are directly above or below other nearby scaffold branches. [**Figure 5**]

Figure 5. Minimum scaffold branch spacing is based on the mature height of the tree at 6 inches per 10 feet of mature height. A tree that will grow to 30 feet should have scaffold branches spaced at least 18 inches apart.



Poorly spaced or clustered branches can negatively impact the way a tree responds to wind and snow loading by concentrating the load placed on the tree at one point on the trunk, increasing the risk of failure. Additionally, clustered branches are less likely to form proper branch collars. [**Figure 6**]

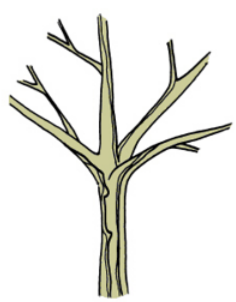


Figure 6. Multiple branches originating from the same location are structurally weak. An objective in structural training is to space scaffold branches.

Selecting Branches with Strong Unions

When selecting scaffold branches, try to select outward growing branches with a wide angle of attachment rather than upward growing branches. Narrow unions are prone to having included bark (bark pressed against bark rather than connected by sound wood). The presence of included bark is a critical defect. Branches growing closer to horizontal continually bear a greater gravitational load and thus develop more reaction wood (additional wood which is anatomically stronger) on the tops or bottoms of branches, making them stronger and more resistant to wind and snow loading.

Strategy 5 – Remove temporary branches in the tree's permanent crown before they get too large.

Temporary branches in a tree's permanent crown are branches growing between permanent scaffold branches. They should be managed in the same way as temporary branches below the permanent crown. They should be kept relatively small through pruning (less than half the size of their parent branch) and be removed before they grow larger than two inches in diameter.

Strategy 6 – Maintain all scaffold branches at half the diameter of the trunk or less in size.

Branches that are half the diameter of their parent branch have a stronger connection due to the development of a branch collar. Scaffold branches that are growing too large relative to the trunk can have their growth slowed with proper removal and reduction cuts.

Another way to think about this strategy is to keep all branches less than one-half the diameter of their parent branch so they develop a branch collar. Temporary branches also benefit from having a collar as it can help prevent decay from entering the tree. In this document, management of temporary branches is covered in Strategies 3 and 4.

Strategy 7 – Remove or shorten branches whose unions have bark inclusions.

Bark being included within the union between branches makes the union much weaker and prone to failure. Branches with inclusions should be shortened with reduction cuts or removed.

Bark inclusions can be identified by looking for bark which rolls smoothly into the union rather than creating a rough ridge where the branches meet (the branch bark ridge). Old inclusions develop an "elephant ear" appearance as the tree tries to grow over them. Included bark is also more common on upright growing branches. Some species of trees are more prone to forming bark inclusions than others (e.g., trees in the genus *Tilia*).

Authors: David Whiting, CSU Extension, retired; Alison O'Connor, PhD, CSU Extension; and Eric Hammond, CSU Extension. Artwork by David Whiting. Used with permission. Revised May 2018. Revised September 2023 by Eric Hammond, CSU Extension; Micaela Truslove, CSU Extension; and Alison O'Connor, PhD, CSU Extension

Revised September 2023

CMG GardenNotes #615

Pruning Mature Shade Trees

Outline:

Mature Trees and Pruning

Mature trees contribute a tremendous amount of aesthetic and financial value to a property. Trees take decades to reach maturity and cannot be easily replaced, so, caring for them correctly is critical. One important aspect of tree care is pruning. Proper pruning can prevent structural issues, mitigate hazards, improve a tree's appearance, and generally ensure a tree remains healthy and structurally sound.

Mature trees are less tolerant of pruning than young trees and incorrectly pruning them can also have major consequences for their health and stability. This means mature trees should not be pruned unless there is a reason to do so. Common acceptable reasons to prune mature trees include removal of dead or diseased wood, removing or managing water sprouts, improving light penetration into, and air movement through the canopy, reducing the size of the crown in order to prevent interference with other landscape features, and mitigating their risk of failing.

Pruning larger trees is extremely dangerous work. Hundreds of arborists are severely injured or killed every year. It is important to know your limitations; mature tree pruning is best left to professional arborists. Never remove large limbs while on a ladder.

Finding a Good Arborist

A professional arborist is licensed and insured. Your local city forester may maintain a list of arborists that are licensed to work in your municipality.

Industry groups, such as the International Society of Arboriculture, administer arborist certification programs that train arborists and require them to adhere to a code of ethics. Accreditation is based on experience and demonstrated knowledge, and arborists must maintain accreditation by completing continuing education units. This continuing education requirement ensures they always have the most up-to-date training on proper tree care. Industry groups maintain searchable databases of certified arborists to aid the public in hiring a trained and certified professional. Not all tree care workers are certified arborists. It is a good idea to make sure any tree care company you hire has a certified arborist on staff and ideally, that one will be on site when your tree is pruned.

Pruning Specifications

A pruning specification is a document that describes how a tree or group of trees will be pruned. Having a good pruning specification or similar document agreed upon by the property owner and arborist limits the opportunities for misunderstanding and poor pruning. A good specification should state at a minimum which trees on the site will be pruned, the type of pruning the trees will receive, the objective of the pruning, the maximum percentage of a tree's canopy that will be removed and the maximum diameter of live branches that will be removed. It may also specify that the tree will not be topped or "lion tailed." An arborist may have a general set of specifications they use, or it may be provided by the property owner in some cases.

General Pruning Guidelines

Limitations on Diameter of Cut

Ideally all pruning cuts are made on branches two inches or less in diameter. Smaller cuts are more quickly covered with wound wood and avoid exposing large amounts of heartwood. ***Sapwood*** is the newer xylem rings. It is active in water transport and storage of photosynthates and is composed of both living and dead cells. Because it contains living cells it can actively resist the spread of decay organisms. On branches two inches and less in diameter, sapwood dominates the branch structure and in many cases is the only type of wood present.

Figure 1. Cross section of Douglas fir. Light colored outer rings are sapwood. The dark wood in center is the heartwood.

Heartwood, the older xylem rings no longer active in water transport, has no way to actively resist decay. Due to chemical changes in these nonliving cells, heartwood is often darker in color. Depending on species and growth rates, heartwood becomes significant as branches reach two to four inches in diameter. [**Figure 1**]

If decay organisms successfully colonize a tree's heartwood, over time they can spread to all the heartwood in the tree, creating large columns of decay. When a pruning cut or other injury opens a branch to decay, the decay organisms will potentially affect the current season of xylem rings and everything older over time. Decay creates a pipe-like structure in the branch. The healthy, undecayed wood will be the xylem rings that grow in future years. [**Figure 2**]

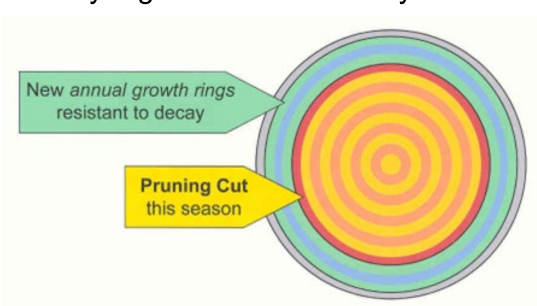


Figure 2. Cutaway showing new annual growth rings resistant to decay with a pruning cut made this season.

Proper Pruning Cuts

For information on making proper pruning cuts, refer to CMG GardenNotes #612, *Pruning Cuts*.

Pruning Dosage: Maximum Amount of Live Wood/Foliage to Remove

Mature trees are less tolerant of pruning than younger trees. When pruning them you should remove the least amount of foliage required to meet your pruning objectives. From a plant health perspective, a maximum of 10% of a mature tree's foliage should be removed during each pruning cycle. However, to meet your pruning objectives a larger pruning dose—or amount of live tissue removed during a single pruning cycle—may be necessary and is acceptable if the tree is in good health.

In situations where trees are pruned annually, the appropriate pruning dose will normally be smaller. However, trees are often pruned only once every several years. Here the appropriate pruning dose may be larger. In situations where heavy pruning is needed, complete the work over a period of years.

Excessive pruning can lead to ***water sprouts*** (sucker-like shoots on the trunk or branches). Water sprouts are structurally unsound because they are superficially attached to the tree. In contrast, structurally sound branches contain overlapping branch and trunk wood. This means branch wood is enveloped with trunk wood, and each year a new layer of branch and trunk wood form at the branch collar in a ball-and-socket fashion ensuring a strong branch attachment.

Excessive pruning also creates a hormone imbalance between auxins (produced in the terminal buds of the canopy) which stimulates root growth and gibberellins (produced in the root tips) which stimulates canopy growth. This puts the root system into a multi-year decline cycle, resulting in a multi-year decline in canopy growth.

Removal of dead wood does not count toward your dosage.

Pruning Objectives

Pruning is stressful and should only be undertaken with objectives (why to prune). Do not indiscriminately remove branches. Pruning objectives determine methods to be used (how to prune), which in turn determine the type of pruning cuts to be made. **Table 1** lists common objectives, methods, and types of pruning cuts.

Table 1. Objectives and Methods for Pruning Maturing Trees

Objectives (Why)	Methods (How)	Pruning Cuts
Reduce Risk of Failure (Wind and Snow)	Structural	Removal Cut
Improve Structure	Cleaning	Reduction Cut
Maintain Health	Thinning	Heading Cut
Improve Aesthetics	Raising	-
Provide Clearance	Reducing	-
Improve View	Restoring	-
Reduce Shade	-	-
Influence Flowering and Fruiting	-	-

Pruning Methods

Structural Pruning

Structural pruning centers around developing a dominant trunk with subordinate and properly spaced side branches and secondary limbs. To be most effective, it requires annual pruning over a period of years. It is a proactive practice that seeks to establish a resilient structure and prevent major structural defects in a tree. It is mostly carried out on younger trees as mature trees have already developed their structure.

Some of the principles of structural pruning can be applied to mature trees to reduce the risk of branches failing due to wind or snow loading. For more information, see the section on reduction pruning later in this document. [**Figure 3**]

Figure 3. Codominant trunks (adjacent trunks of similar size) account for the majority of storm damage in Colorado landscapes.

Cleaning

Cleaning is the most common type of pruning mature trees need and the most common type of pruning performed on them.

The objective of cleaning is to improve the tree's health and reduce the risk posed to people and property by removing dead, broken, cracked or diseased wood, rubbing branches, and weakly attached branches. Examples of weakly attached branches include branch unions with included bark, unions where the branches are equal in size (codominant branches), and water sprouts.

If a mature tree has many water sprouts, leaving some is considered good practice. They are a stress response and attempt by the tree to produce more energy. If water sprouts are abundant or associated with a wound, prune out approximately one third of them such that remaining sprouts are spaced evenly along branches. If there are only a few water sprouts and they are not associated with a wound, they should be removed. Water sprouts below the canopy and suckers from a tree's root system should be removed. [**Figure 4**]

Figure 4. This old cottonwood needs cleaning to remove dead branches and reduce the risks associated with branch failure.

Removing Dead Branches

To minimize risk if the branch were to fail, it is advisable to remove any dead branch larger than two inches in diameter and higher than thirty feet. Dead branches may also become a source of insect and disease pressure in the tree.

Remove the dead branches using the three-step pruning technique. For details refer to CMG GardenNotes #612, *Pruning Cuts.* Do not cut into the branch collar, which would result in a high potential for decay to spread into the trunk. If live wood has begun to grow out along the dead limb, cut just beyond the live wood, being cautious not to nick the live tissue. Never "flush cut" the dead branch even with the trunk. Always cut outside of the branch bark ridge and branch collar. [**Figure 5**]

Figure 5. When removing dead branches, do not cut into the living tissues.

Written specifications for cleaning should specify the minimum size of dead branches to be removed. For example, *"Remove dead branches one inch in diameter and larger"* or *"Remove dead branches two inches in diameter and larger that are 30 feet and higher above the ground."* The location of the branch to be removed should be specific if the entire crown is not going to be cleaned.

Thinning

In properly executed thinning, some small branches are removed from a tree's canopy, primarily from its outer edge, with the objective of increasing light penetration into, and airflow through, the canopy. [**Figure 6**] The potential benefits of this include a reduced risk of failure due to a reduction of branch weight and decrease in load placed on branches from wind or snow, better taper (increased diameter growth) of interior branches due to increased sunlight in the inner canopy and a reduction of foliar diseases.

The benefits of thinning are short lived as the tree continues to grow and replaces removed branches in future years. Thinning is frequently executed incorrectly with too many branches being removed from the interior of a tree's canopy. Results of improper thinning can be similar to "lion tailing." Thinning is most appropriate for trees that have a confined or reduced rooting area, are in windy sites to reduce wind loading, or for mitigating a specific hazard.

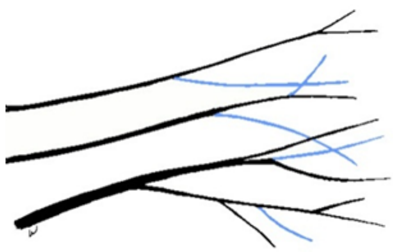


Figure 6. Thinning is the selective removal of small branches, growing parallel to each other, in the leafy upper/outer tree canopy.

Potential Benefits of Thinning

- Thinning can reduce limb weight in order to compensate for structural defects.
- Thinning increases light penetration into the tree's interior. This can invigorate the tree and help retain the tree's natural shape. Thinning may adequately reduce shade for shade tolerant understory plants below the tree. However, thinning middle-aged and mature trees will not adequately promote growth of sun loving plants like Kentucky bluegrass growing in the tree's shade.
- Thinning is a technique to partially open a view without removing or structurally influencing a tree. This is often referred to as *vista pruning*.

Limitations of Thinning

- On a tall tree, thinning may not be an effective technique to reduce wind sail and potential for breakage in strong winds. Reducing is the most effective way to deal with wind loading issues.
- In most situations the benefits of thinning will be short-lived as the tree puts on new growth. This makes it most relevant to higher value trees which have a known hazard.

Improper Thinning

- *Thinning* should be carried out on relatively small branches in the outer canopy. Thinning should not remove large branches or many interior branches. Doing so can have results similar to lion tailing which reduces the tree's vigor and increases the risk of damage from wind. [**Figures 7** and **8**]

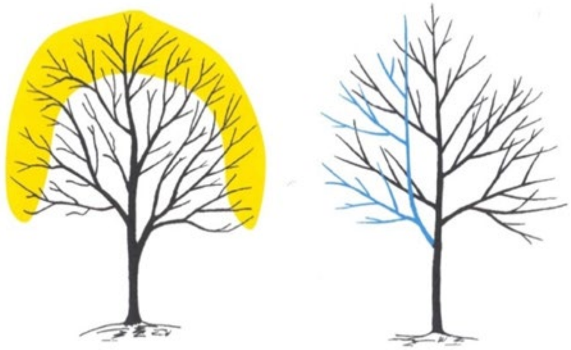


Figure 7.
Left: Thinning focuses on small branches in the upper/outer tree canopy.
Right: Thinning does NOT remove large branches, creating a gap in the tree canopy.

Figure 8. Do not "lion-tail" trees as in the photo. Removal of the smaller twiggy wood in the inner tree canopy decreases vigor, reduces the development of taper, and increases potential for wind damage by reducing the tree's ability to dampen what wind is distributed.

Written specifications for a thinning job should specify the following:

- Clarify the dosage (percent of the tree's canopy that may be removed). For example*, "Pruning should not exceed 15% of the total live canopy."*
- Clarify where in the tree the pruning will occur. For example, *"Pruning should occur in the outer third of the crown."*
- Clarify size of branches to be removed. For example, *"Pruning should remove branches up to two inches in diameter."*

Raising

Raising is the removal of lower branches to provide clearance for people, traffic, buildings, or a view. When removing lower branches, maintain at least one-half of the foliage in the lower two-thirds of the tree. The lowest branch should originate in the bottom one-third of the tree (live crown ratio). [**Figure 9**]

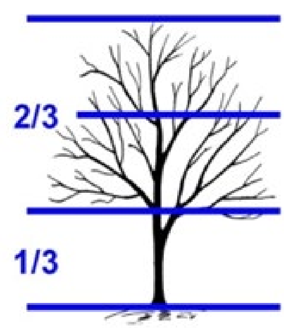


Figure 9. When removing lower branches, maintain at least one-half of the foliage in the bottom two-thirds of the tree. The lowest branch should originate in the lower one-third of the tree.

Raising should be part of the tree's structural training while young. Ideally raising would be done before branches to be removed exceed two inches in diameter. The potential for decay is high when the branch removed is larger than four inches or when a two inch and larger branch is greater than half the diameter of the adjacent trunk. Removing branches greater than half the diameter of the adjacent trunk leaves no branch collar to suppress decay.

On many trees, lower branches make up a significant portion of the tree's entire canopy and cannot be removed without significantly influencing tree health and appearance. When the branch to be removed is larger than two inches, consider other alternatives. Can the clearance required be achieved with removal and reduction cuts out along the branch rather than removing the entire branch? Leaving some small diameter branches on the lower trunk for a year helps close pruning wounds and lessens the potential for trunk cracking. [**Figure 10**]

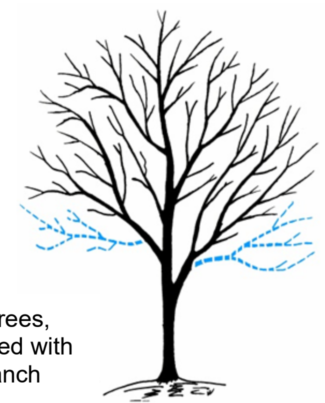


Figure 10. In raising branches on maturing trees, consider if required clearance can be achieved with removal and reduction cuts out along the branch rather than removing large branches entirely.

Excessive removal of lower branches increases the potential for tree failure by decreasing trunk taper, causing trunk cracks and decay, and transferring weight to the upper crown, increasing wind loading.

Written specifications for raising should include the following:

- Clarify the clearance required. For example, *"The tree's crown will be raised to seven feet."*
- Clarify what branch(es) will be pruned and the type of pruning cuts (removal or reduction cut) to be used. For example, *"The lowest branch on the south side shall be removed back to the trunk with a removal cut. The lowest branch on the north side will be reduced with a reduction cut at the branch five feet out from the trunk and a removal cut to the lowest side-branch."*
- Clarify what size of branches will be pruned. For examples, *"All cuts shall be two inches in diameter and smaller."*

Reduction

The objective of reduction pruning is to reduce the size of the tree's canopy. Normally it is undertaken to provide clearance for a structure, power lines, or other element in a landscape. It can also be used to reduce the risk of tree failure.

Reduction pruning is best done before a tree outgrows its space and begins to interfere with structures or power lines. This allows for the use of smaller pruning cuts and for the natural shape of the tree to be preserved. Improper reduction pruning can quickly become topping. [**Figure 11**]

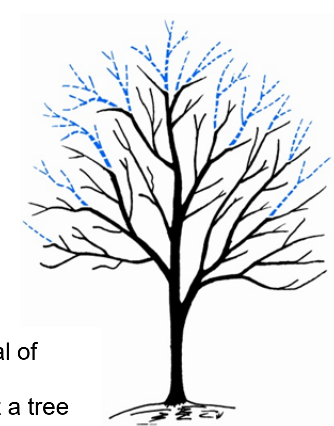


Figure 11. Reducing is the selective removal of branches to decrease a tree's height and/or spread. Just being tall does not indicate that a tree is structurally weak and prone to storm damage.

Not all trees can be reduced without predisposing the tree to decline and death. Crown reducing requires the extensive use of reduction cuts, which can predispose the remaining branch or trunk to internal decay. On older trees showing stress or decline, heading cuts can accelerate decline and death. The need for reduction pruning can be reduced by selecting a tree with an appropriate mature size for a site and by performing proper structural pruning as the tree grows. [**Figure 12**]

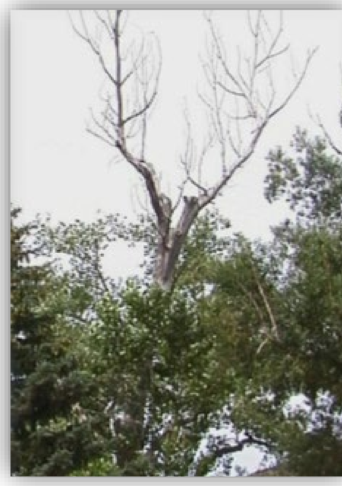


Figure 12. Not every tree should be reduced. Notice the dieback associated with previous reduction pruning on this old cottonwood. On old trees and trees showing stress or decline, heading cuts may accelerate the decline cycle.

In a proper *reduction cut*, the side branch remaining after the cut will be at least one-third the diameter of the trunk/parent branch removed. Under American National Standards Institute (ANSI) pruning standards, if the side branch is less than one-third, it is considered a *heading cut*, which is generally unacceptable. For additional details on proper reduction cuts, refer to CMG GardenNotes #613, *Structural Pruning of Young Shade Trees*.

It is very time intensive to use crown reducing to permanently maintain a tree at a small size without causing tree decline. Ideally, trees should be selected with adequate space to accommodate their mature size. Where size control is necessary, it is best to begin reduction pruning as the tree reaches an acceptable size, rather than when the tree becomes overgrown.

In crown reducing, first visualize the new outer edge of the smaller canopy. Then prune the tree back to appropriate branch unions for a proper reduction cut or removal cut. Some branches will be left taller than the visualized outer edge while others will be cut back below the visualized canopy edge. [**Figure 13**]

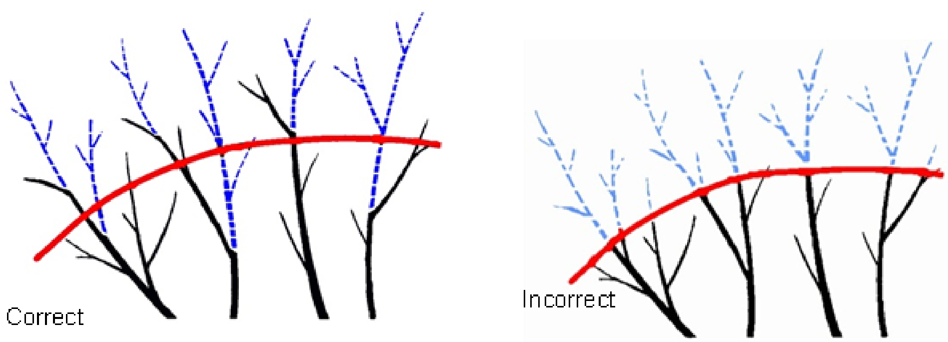


Figure 13.
Left: In reduction, visualize the new outer edge of the smaller canopy. Prune back to branch unions that make proper reduction and thinning cuts. Some branches will be taller than the new outer edge, some shorter.
Right: This tree is incorrectly rounded off with heading cuts.

In shortening primary upward growing trunks/primary branches to a lateral branch, a side branch that is somewhat upward growing with a narrow branch union angle may be stronger than a branch union with a wide angle. [**Figure 14**]

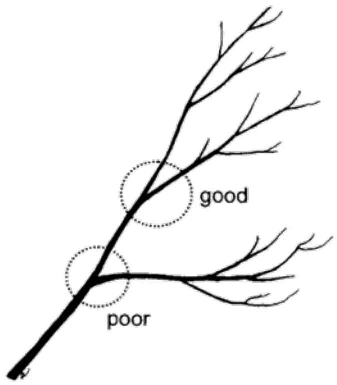


Figure 14. In shortening a main upward growing branch, pruning back to a narrow branch union may be stronger than a wide branch union.

Just because a tree is tall does not indicate that it is structurally unsound. Potential risk of failure should be evaluated by an experienced arborist based on branching structure, branch union integrity, signs of internal decay, and previous damage.

Written specifications for reduction pruning should include the following:

- Clarify the desired reduction in height/spread.
- Specify criteria for reduction cuts. For example, *"All cuts should be made on branches less than two inches in diameter. Diameter of the remaining lateral branch should be at least one-third the diameter of the branch removed."*
- Clarify the dosage (percentage of live wood/foliage to be removed). For example, *"Pruning should not exceed 10% of the total canopy."*

Restoration

Restoration pruning is an advanced type of pruning which has the objective of helping a tree recover from storm damage or prior improper pruning. It seeks to manage the remaining branches and any water sprouts which result from the damage to restore a sound branch structure.

Before a storm damaged tree undergoes restoration pruning it is important to first decide if the tree can be saved. The loss of leaves or broken branches are both conditions a tree can recover from. Cracks or other significant damage to the main trunk often are not.

Actual pruning procedures vary with the situation. When dealing with situations of excessive water sprouts, a rule of thumb is to remove one-third of the sprouts and reduce one-third of the sprouts in height with each annual pruning. Removing all of the water sprouts at one time often stimulates the growth of more water sprouts.

Types of Pruning to Avoid

There are several types of pruning that should be avoided for mature landscape trees. These include, topping, rounding-over and lion tailing. Always have a reason to prune, do not just prune for the sake of pruning.

a) Topping or Rounding Over:
   I. Topping is the arbitrary shortening of a tree's branches or trunks during pruning without regard for tree anatomy or biology. It may produce an abundance of water sprouts which are vigorous and structurally unsound. In some cases, topped trees will decline and die. Topping often occurs when trees are planted in spaces that are too small for their mature size, such as under powerlines, or to give a tree a rounded shape. When planting a tree make sure that its mature size will fit the space and that

it is a cultivar that has the shape you desire. Properly executed reduction cuts can be used to reduce the height of the tree while minimizing negative impacts on the health of the tree.

b) Lion Tailing:

II. Lion tailing is the practice of limbing up a tree taken to an extreme. In the worse cases of lion tailing, all the lower branches of the tree are removed leaving only a few leaves at the ends of long bare branches (like the puff of fur at the end of a lion's tail). In less extreme cases only interior branches are removed creating a shell of foliage around a hollow center. To avoid lion tailing be sure that at least two thirds of a tree's height is left as canopy with no more than the lower one third being bare trunk. Raise the canopy of trees slowly and only as far as needed based on the planting site. Interior branches are important to proper diameter growth of major limbs and trunks and should not be over thinned.

Frequently Asked Questions About Pruning Mature Shade Trees

What About Utility Right-of-Way Pruning?

Pruning for utility line clearance does not always follow desirable pruning techniques regarding appearance and health of the tree. In this situation, the needs of the utility right-of-way take priority over the tree.

When a tree under a power line requires frequent reduction, consider having the tree removed. Utility companies are generally eager to accommodate. In planting trees, selection criteria (i.e., size and placement) should be followed so that a tree's health and appearance will never be compromised by the need for utility pruning.

How Should Storm-Damaged Trees be Pruned?

First, assess if the tree is safe to work on or around. Look for cracked or hanging branches that might fall, downed power lines and other hazards. Once you are sure the area is safe, focus on cleaning (removing broken and damaged limbs), keeping in mind the structural integrity of the tree.

Next, focus on structural pruning to restore the tree's structural integrity and shape to the extent possible. Re-establishing good structure may take place over a period of years.

The maximum amount of tree canopy that can be removed without putting the tree and its root system under stress includes the live wood/foliage removed as a result of storm damage. When too much live wood/foliage is lost to storm damage, limit pruning to cleaning.

On trees where excessive live wood and foliage were removed by storm damage, wait until the roots and crown stabilize (as measured in canopy growth) before performing any pruning other than cleaning. This may take several years.

Figure 15. Keep storm-damaged trees when they can be pruned back to structurally sound wood and have an acceptable appearance.

Keep the tree if it can be pruned back to structurally sound wood and will be esthetically pleasing. Often when more than half the tree is lost to storm damage, the best option is to remove the entire tree. [**Figure 15**]

How Should Trees With Root Damage Be Pruned?

Focus on *cleaning*. Avoid removing live wood and foliage as this could speed the decline. Removing live wood lowers the ***auxin*** content, which is the hormone that promotes root growth. Removing foliage reduces photosynthesis and levels of stored carbohydrates that the tree is living on during the recovery period. Trees in a construction site with damaged roots may require cleaning every three to twelve months for five plus years.

How Should Declining Trees Be Pruned?

Focus on *cleaning*. Avoid removing live wood and foliage as this could speed the decline. Removing live wood lowers the auxin content, which is the hormone that promotes root growth. Removing foliage reduces photosynthesis and levels of stored carbohydrates that the tree is living on.

Authors: David Whiting, CSU Extension, retired; Alison O'Connor, PhD, CSU Extension; and Eric Hammond, CSU Extension. Artwork by David Whiting. Used with permission. Revised May 2018. Revised September 2023 by Eric Hammond, CSU Extension; Micaela Truslove, CSU Extension; and Chris Hilgert, CSU Extension.

Revised September 2023

CMG GardenNotes #616

Pruning Flowering Shrubs

Why Prune?

Pruning has a major influence on a shrub's flowering habit, shape, size, and pest problems.

Prune to Encourage Flowering

Pruning has a major influence on shrub flowering. Over time, an unpruned flowering shrub becomes woody, with little new growth to support flower bud development.

Spring-flowering shrubs bloom on one-year-old wood (new twigs that grew the previous summer). The flower buds develop from midsummer through fall, overwinter, and bloom the following spring. In the early spring, flowering shrubs can be thinned before flowering or growth starts. [**Figure 1**] Thinning or rejuvenation pruning can also be done right after blooming to maximize the next season's flowers. Pruning in the fall and winter will remove wood containing the flower buds, reducing blooms the following spring. [**Figure 2**]

Spring-flowering shrubs include forsythia (*Forsythia* spp.), Nanking cherry (*Prunus tomentosa*), quince (*Chaenomeles* spp.), bridal wreath and Vanhoutte spireas (*Spiraea prunifolia*, *S. pleniflora* 'Plena' and S. x *vanhouttei*), viburnum (*Viburnum* spp.), beautybush (*Kolkwitzia amabilis*), lilac (*Syringa* spp.), honeysuckle (*Lonicera* spp.), peashrub (*Caragana* spp.), deutzia (*Deutzia* spp.), and weigela (*Weigela* spp.).

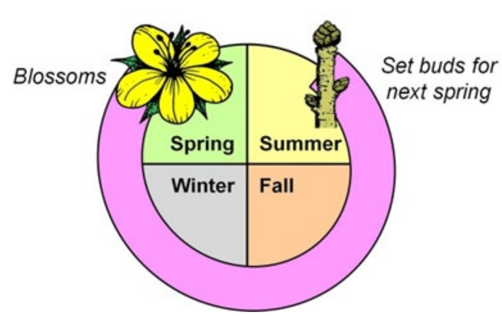


Figure 1. Spring-flowering shrubs bloom from buds that developed on new wood the previous summer.

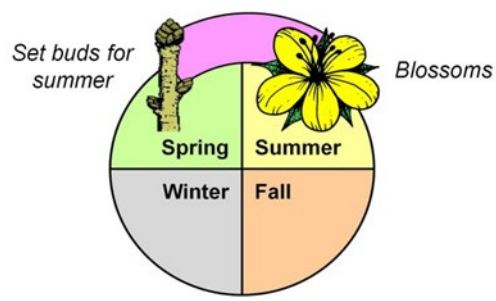
Figure 2. Fall shearing of this spring-flowering lilac removed flower buds on the lower section of the shrubs.

For spring-flowering shrubs, it is recommended to “deadhead” spent blooms (remove flowers after they fade). While time-consuming, deadheading conserves the plant’s energy, which would otherwise be spent on seedpod and seed development. For many flowering shrubs, the spent flowers and seedpods are not attractive and can be removed for aesthetic reasons (lilacs).

Summer-flowering shrubs bloom on new wood that grew earlier in the current growing season. Summer-flowering shrubs can be pruned by thinning or rejuvenation pruning in the early spring before growth starts. [**Figure 3**]

Summer-flowering shrubs include most butterfly bush (*Buddleia* spp. and *Cassia* spp.), blue mist spirea (*Caryopteris* x *clandonensis*), Hancock coralberry (*Symphoricarpos* x *chenaultii* ‘Hancock’), mock orange (*Philadelphus* spp.), potentilla (*Potentilla* spp.), Bumald and Japanese spirea (*Spiraea* x *bumalda* and *S. japonica),* Annabelle and Peegee hydrangea (*Hydrangea arborescens* ‘Annabelle’ and *H. paniculata*), shrub althea or rose of Sharon (*Hibiscus syriacus*), snowberry (*Symphoricarpos albus*) and St. John’s wort (*Hypericum* spp.).

Figure 3. Summer-flowering shrubs bloom from buds which developed on new wood that grew earlier in the current growing season.



Removing older canes of flowering shrubs by thinning also allows for better sunlight penetration into the shrub. This results in better flowering throughout the shrub, instead of flowers just at the top where sunlight is plentiful.

On shrubs noted for their bark color, like red-twig dogwood (*Cornus sericea*), the new shoot growth has a more brilliant color. Routine pruning by thinning at the base encourages new shoots which have the desired red color.

Prune to Direct Shape

Shaping is another reason for pruning shrubs. Shape can be managed to some degree by pruning to side buds or branches growing in the desired direction. While pruning can provide some control over size, it is not an effective method to keep a large shrub in a small space. Where shrubs have overgrown their space, consider replacing the plants with smaller cultivars or other species. [**Figures 4** and **5**]

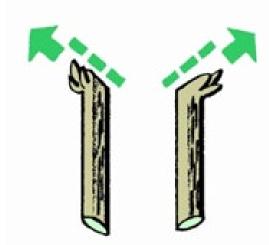
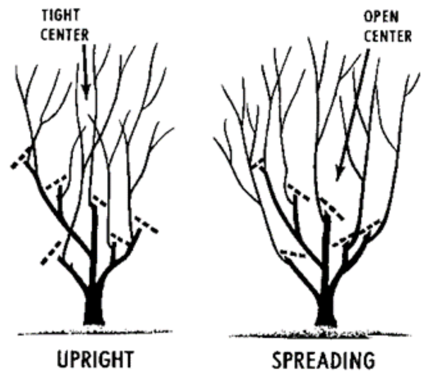


Figure 4. Shape can be managed to some extent by pruning to buds and branches growing in the desired direction of growth.

Figure 5. Pruning to inward growing buds or branches results in narrower shrubs. Pruning to outward-growing buds or branches results in wider shrubs. [Line drawing by USDA]



Prune to Manage Pests

Pruning is a management technique for some insect or disease problems. For example, removing the older wood in lilac can reduce oystershell scale and borer problems. Thinning a shrub to increase air circulation reduces the incidence of powdery mildew and leaf spot diseases.

Pruning Methods for Flowering Shrubs

The primary objective when pruning flowering shrubs is to encourage new (flowering) growth from the base. This is best accomplished by thinning at the base, or rejuvenation.

Branch-by-Branch Shaping

Branch-by-branch shaping involves shortening the length of excessively long branches by cutting them back one-by-one. Cuts are made back in the shrub, leaving branches at varying lengths. Avoid making cuts at a uniform “edge,” creating a rounded ball. Make cuts at appropriate branch unions (crotches) or buds. [**Figure 6**]

Branch-by-branch shaping is a slow process, but this method maintains a more naturally shaped shrub and does not significantly encourage new growth.

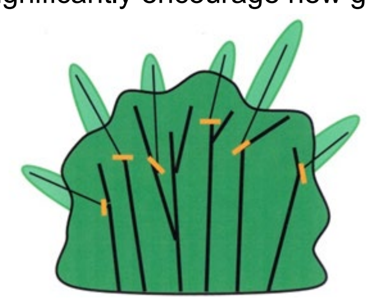


Figure 6. With branch-by-branch shaping, long branches are cut back into the shrub, giving a more natural shape. Avoid making cuts at a uniform “edge,” creating a rounded ball.

Shearing to Shape

Shearing shrubs to round balls or other desired shapes is a common pruning technique because it is quick and easy. However, sheared shrubs lose their natural shape, and the rounded "balls" may detract from a more natural, informal landscape design. Shaping spring-flowering shrubs after midsummer removes the new wood with next year's blossoms. In addition, frequent shearing does not encourage new growth from the base, which is needed to promote flowering.

With frequent shearing, the plant becomes thicker and bushier toward the exterior. The thick outer foliage may shade out the interior and lower foliage, and the plant becomes a thin shell of foliage with a woody interior and base. The thin shell of foliage is prone to browning and burning from wind and cold weather. Over time, shrubs that are sheared become woody, with lots of dead branches and few flowers. When shrubs become overly woody from routine shearing, replacement is the best option to refresh the landscape design.
[**Figures 7** through **11**]

Figure 7. Flowering shrubs pruned by topping or shearing become woody at the base. [Line drawing by USDA]

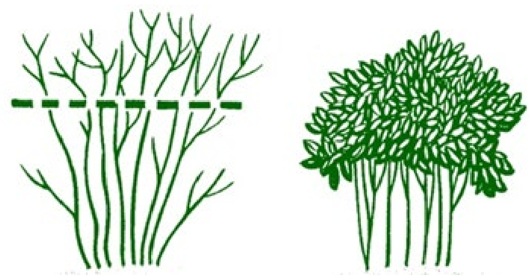


Figure 8. Over time, sheared shrubs become woody and contain dead sections. The only treatment at this point is to replace the shrub.

Figure 9. Sheared forsythia in full bloom. Shearing does not encourage new wood with blossoms.

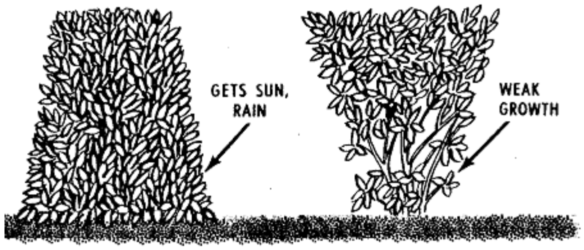


Figure 10. In shearing hedges, maintain the natural shape of the plant. A common mistake is to shape shrubs with a wide top and narrow base. Lack of sunlight shades out lower interior growth, resulting in a woody base. [Line drawing by USDA.]

Figure 11. Properly pruned hedge, wider at the base.

Thinning

One method to encourage shrub flowering is annual thinning. The objective is to **remove one-third of the oldest wood to the ground each year**, which in turn stimulates new, better-flowering growth from the base of the shrub. Thinning is more easily done before growth starts using leafless branches in early spring but can also be done in summer if necessary. This method can be time-consuming and does not work well on twiggy, multi-stem shrubs, like spirea. [**Figure 12**]

Cutting back and thinning an overgrown shrub will not restore its natural, informal form. It will look like an overgrown shrub that has been pruned. <u>Rejuvenation pruning followed by annual thinning is better for overgrown shrubs.</u>

Figure 12. Annual thinning removes one-third of the oldest wood to the base each spring. This encourages new growth from the base, keeping the shrub youthful looking. [Line drawing by USDA.]

Rejuvenation Pruning

Many shrubs can be easily renewed with rejuvenation pruning. The shrub is cut entirely to the ground in <u>the early spring before growth starts</u>. The shrub regrows from roots, giving a compact, youthful plant with maximum bloom. Rejuvenation can have a major effect on size. This method is preferred for many flowering shrubs because it is quick and easy with great results. Initial rejuvenation should be followed by thinning new canes to several strong ones over the next several years. Remove weak cane growth at the base (ground level).

Rejuvenation is typically done no more than every three to five years when a shrub <u>begins</u> to look gangly and woody. It works very well on multi-stemmed, twiggy-type shrubs such as spirea (*Spiraea* spp.), blue mist spirea (*Caryopteris*), *Potentilla*, red-twig dogwood, sumac (*Rhus* spp.), and hydrangea. (Note: *Caryopteris* flowers best if renewed each spring.) Also use this method to rejuvenate lilac, privet (*Ligustrum* spp.), barberry (*Berberis* spp.), forsythia, flowering quince, honeysuckle, mock orange, flowering weigela, beautybush, many viburnums, elderberry (*Sambucus* spp.), and others.

Limitations:
- Spring-flowering shrubs will not bloom the year of rejuvenation.
- On shrubs with a rock and weed fabric mulch, rejuvenation may not be successful due to decreased root vigor and interference of the mulch with growth from the base.
- Extremely overgrown shrubs with large woody bases may not respond well to rejuvenation pruning.
- Shrubs with many dead branches will not respond well to rejuvenation pruning. As a general rule, if more than one-third of the branches are woody and, without healthy foliage, the shrub will probably not respond. Some shrubs are structurally similar to small trees, with only one or a few primary trunks, including several Viburnum and Euonymus species, and shrubby forms of *Rhamnus* (buckthorn). Do not cut these shrubs to the ground. Prune by thinning branches back to side branches.
- Lilac cultivars grafted onto common lilac rootstocks should not be cut to the ground. Regrowth will be of the common lilac rather than the selected cultivar.

Replacement

Shrubs that have been neglected or repeatedly sheared often become woody with many dead twigs. The best option may be to replace them.

Shrubs can also be overwhelmed by weedy invaders, seeded by birds, squirrels, or wind. For example: Common Buckthorn (*Rhamnus cathartica*), Walnut (*Juglans* spp.), Elm (*Ulmus* spp.).If routine clearing of these invading woody species is not done, the original shrubs may be compromised or lost. Replacement may again be needed.

Authors: David Whiting, CSU Extension, retired; with Robert Cox, CSU Extension; Carol O'Meara, CSU Extension, retired; and Carl Wilson, CSU Extension, retired. Artwork by David Whiting and USDA. Used with permission. Revised May 2018. Reviewed May 2023 by Amy Lentz, CSU Extension.

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CMG GardenNotes #617

Pruning Evergreens

Most types of evergreen trees and shrubs need little to no pruning. Pruning may make the new growth bushier but will not effectively control size. Select plants based on mature size to minimize pruning needs. If frequent pruning is necessary to keep plant growth in bounds and prevent interference with a walk, driveway, or view, consider replacing the plant. Evergreen trees and shrubs are pruned according to the species growth characteristics.

Pruning Evergreen Trees

On evergreen trees, avoid pruning the central leader (trunk). This results in the development of multiple leaders that are prone to wind and snow damage. If the central leader is killed back, select one branch to become the new leader and remove potentially competing leaders.

Never allow codominant trunks (trunks of similar size) to develop. If multiple trunks begin to develop, select one and remove the others.

For structural integrity on evergreen trees, all side branches should be less than half the diameter of the adjacent trunk (less than one-third is preferred). If the diameter of a side branch is too large, prune back part of the needled area to slow growth or remove the branch entirely back to the trunk. This is similar to a heading or reduction cut in deciduous trees.

Removing Large Branches on Evergreen Trees

New needles will not grow from branches without needles. When a side branch is removed on an evergreen, cut back to the trunk just outside the ***branch collar*** (the enlarged connecting area on the trunk around the limb).

Do not cut into or otherwise injure the branch collar. Do not make flush cuts; this is removing the collar and cutting flat to the trunk. Remove the branch using a three-cut method. [**Figure 1**]

Cut One. Coming out twelve to fifteen inches from the trunk, make an undercut a third to halfway through the branch.

Cut Two. Moving a couple of inches out past the first cut, make the second cut from the top, removing the branch. This double-cut method prevents the weight of the branch from tearing the branch below the branch collar.

Cut Three. Make the third and final cut just outside the branch bark collar. Take extra caution to not cut into or otherwise injure the branch bark collar. This cut should be perpendicular to the branch that is being removed. A good cut will make a circular shape.

For additional details on pruning cuts, refer to CMG GardenNotes #612, *Pruning Cuts*.

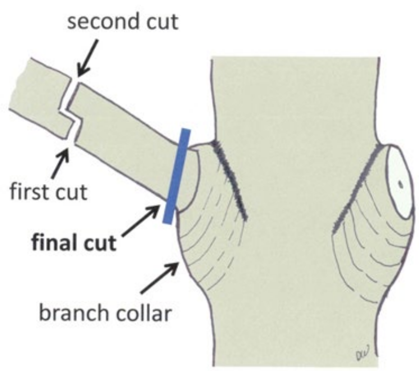

Figure 1. On evergreen trees, remove large branches back to the trunk using a three-cut method. Make the final cut just outside the branch collar. Needles only grow from the growing tips out and will not develop on the interior branch wood without needles.

Pruning Spruce, Fir, and Douglas Fir

Spruce (*Picea* spp.), fir (*Abies* spp.), and Douglas fir (*Pseudotsuga menziesii*) generally need little to no pruning when planted in the right place.

On young trees, pruning is useful in situations where bushier new growth is desired. Because these species produce some side buds, branch tips can be removed encouraging side bud growth. Prune late winter or early spring. [**Figure 2**]

Figure 2. Pruning spruce and fir back to a side bud or side branch will encourage growth of side branches. Line drawing by CSU Extension.

Spruce, fir, and Douglas fir that are over-growing their space are somewhat tolerant of being pruned back if they are not pruned back past the needles. However, with constant pruning the branches may begin to show needle browning and dieback. In situations where the branch must be pruned back past the needles, remove it back to the trunk.

In landscape design, small to midsize evergreen trees, with their pyramidal form, generally look best with their lowest branches allowed to drape to ground level.

On large trees, primary growth occurs at the top with minimal growth at the lower levels. Due to slow growth, pruning of the lower branches may give a “pruned look” for a long time. On large trees, limb up lower branches only if they are in the way.

Very slow-growing species, like the dwarf Alberta spruce (*Picea glauca* var. *albertiana* ‘Conica’), blue nest spruce, aka dwarf black spruce (*Picea mariana* ‘Nana’) and bird’s nest spruce (*Picea abies* ‘Nidiformis’) are rather intolerant of pruning.

Pruning Pine

Pines generally need little to no pruning.

On young plants, if a more compact new growth is desired, “pinching” may be helpful. Using the fingers, snap off one-third of the new growing tips while in the “candle” stage (in the spring, when young needles are in a tight cluster and elongated but needles not expanding). Avoid using pruners or a knife, as it will cut the remaining needles, giving a brown tip appearance. [**Figure 3**]

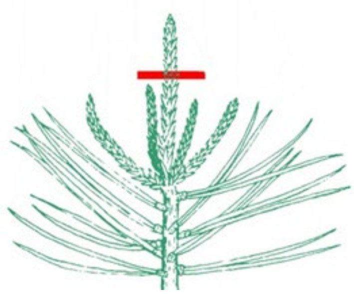

Figure 3. On pines, for bushier new growth “pinch” growing tips by snapping off one-third of the “candle” tips with the fingers. Because pines produce few side buds, they are intolerant of more extensive pruning. Line drawing by CSU Extension.

Because pines produce few side buds, they are intolerant of more extensive pruning. If the terminal bud on a branch is removed, growth on that shoot is stopped, with additional growth occurring only from existing side branches. Do not shear pines. (Cut needles will stay cut and not grow back.)

Like other evergreen trees, small to midsize pine trees look best (from the landscape design perspective) with their lowest branches allowed to drape down near ground level. When a lower branch must be pruned back for space issues, remove it back to the trunk. Mugho pine shrubs are a good candidate for pinching needles to keep them short and bushy.

Pruning Juniper and Arborvitae

Juniper and arborvitae generally need little to no pruning.

They may be pruned at any time except during subzero weather or late summer. Needles form a waxy layer in summer that prevents sunburn of the needles. The best time is early spring, prior to new growth.

The best pruning method is to cut individual branches back to an upward growing side branch. This method of pruning is time-consuming but keeps the plant looking young and natural. [**Figure 4**]

Figure 4. Pruning junipers and arborvitae back to a side shoot hides the pruning cut. Line drawing by CSU Extension.

While shearing is quick and easy, it is not recommended, especially after midsummer. Shearing creates a dense growth of foliage on the plant’s exterior. This in turn shades out the interior growth, and the plant becomes a thin shell of foliage. Frequently sheared plants are more prone to show needle browning and dieback from winter cold and drying winds.

Any pruning that tapers in toward the bottom of the plant will lead to thinning of the lower branches due to shading. To keep the bottom full, the base of the shrub needs to be wider than the top portion.

It is common to see junipers and arborvitae that have overgrown their space. Because new growth comes ONLY from the growing tips, branches cannot be pruned back into wood without needles. If the shrub is pruned back to bare wood, it will have a permanent bare spot.

For shrubs that are getting too large, it is better to prune them back as they begin to overgrow the site. Pruning back severely overgrown shrubs generally gets into wood without needles. Consider replacing severely overgrown plants with smaller cultivars or other species.

Junipers and arborvitae growing in the shade are rather intolerant of pruning due to slow growth rates.

Authors: David Whiting, CSU Extension, retired; and Carol O'Meara, CSU Extension, retired. Artwork by David Whiting and CSU Extension. Used with permission. Revised May 2018. Reviewed May 2023 by Susan Carter, CSU Extension.

Reviewed May 2023

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CMG GardenNotes #770-771

Tree Fruits

Prunus persica, Palisade Peaches
Artwork by Melissa Schreiner © 2023

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Updated 2023

CMG GardenNotes #770

Tree Fruit

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #101, *IPM: Plant Health Care.*
- #771, *Growing Tree Fruit in Colorado Gardens.*

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #2.800, *Backyard Orchard: Apples and Pears* [Pest Management].
- #2.804, *Backyard Orchard: Stone Fruits* [Pest Management].
- #2.907, *Fire Blight in Fruit Trees.*
- #2.914, *Coryneum Blight.*
- #2.954, *Preventative Control for Cytospora Canker on Peach.*
- #5.507, *Spider Mites.*
- #5.560, *Pear Slugs.*
- #5.566, *Peachtree Borer.*
- #5.569, *Insect Control: Horticultural Oils.*
- #5.583, *Tent-Making Caterpillars.*
- #5.613, *Codling Moth: Control in Home Plantings.*
- #7.002, *Pollination of Tree Fruits.*
- #7.003, *Training and Pruning Fruit Trees.*
- #7.612, *Fertilizing Fruit Trees.*

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.
- #1201, *Apples.*
- #1202, *Cherries.*
- #1204, *Peaches.*
- #1205, *Pears.*
- #1206, *Plums.*
- #1209, *Apricots.*
- #1210, *Pruning Mature Fruit Trees.*
- #1211, *Training Young Fruit Trees.*
- #1216, *Fertilizing Fruit Trees.*
- #1217, *Fruit trees for Colorado.*

- #1411, *Fire Blight.*
- #1444, *Coryneum Blight.*
- #1484, *Tent Caterpillars.*
- #1498, *Horticultural Oils*.

Other

- For a deeper dive into fruit trees, see https://intermountainfruit.org/.

Learning Objectives

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

- Discuss considerations in planting fruit trees in the home landscape.
- Describe structural training and annual pruning of dwarf, semi-dwarf, and standard size apples.
- Describe structural training and annual pruning of peaches.

Review Questions

1. Describe considerations in planting fruit trees in the home landscape.
2. What fruits are generally self-fruitful? What fruits require cross pollination by another compatible cultivar?
3. Describe the difference between structural pruning of semi-dwarf apples and annual pruning?
4. Describe the annual pruning of peaches.
5. Explain why thinning of fruit is important.

CMG GardenNotes #771

Growing Tree Fruit in Colorado Gardens

Tree fruits are less suited to the home garden than small fruits. They require more space than can be allocated in a small home yard. Space can be saved by growing hardy semi-dwarf fruit trees and performing tree training and annual pruning maintenance. [**Figure 1**]

Figure 1. Semi-dwarf apple tree, image from Stark Bros.

To be productive fruit trees require specific training and annual pruning. Fruit trees require routine sprays to manage insect and disease problems. In regions with late spring frosts, crops are often lost to frost. Avoid cold sinks to prevent cold damage. Use microclimates to your advantage.

For other information specific to growing fruit trees, view these CSU Extension Fact Sheets:

- #2.800, *Backyard Orchard: Apples and Pears*.
- #2.804, *Backyard Orchard: Stone Fruits*.
- #2.907-1, *Fire Blight in Fruit Trees*.
- #2.954, *Preventative Control for Cytospora Canker on Peach*.
- #5.566, *Peachtree Borer*.
- #5.569, *Insect Control: Horticultural Oils*.

Planting Considerations

Size and Suggested Spacing

Fruit trees can be large, particularly if not carefully trained and pruned. The typical size of fruit trees is given in **Table 1**. Specific rootstocks control the growth and many other growing factors and qualities of fruit trees. In general, dwarf trees tend to be less hardy and take longer to establish than semi-dwarf trees.

Table 1. Typical Average Size of Fruit Trees				
		Typical Spread (Pruned)	Typical Height (Pruned)	Unpruned Spread and Height with No Competition
Apple[1]	Standard Semi-dwarf Dwarf[2]	20 feet 10 feet 6 feet	20+ feet 12-15 feet 5-10	40 feet by 40 feet
Pear	Standard Dwarf[3]	18 feet 12 feet	15 feet 12 feet	40 feet by 25 feet 25 feet by 15 feet
Peach and Nectarine	Standard Dwarf[4]	20 feet 8-10 feet	15 feet 5-10 feet	25 feet by 25 feet 8 feet by 4-6 feet
Apricot	Standard Dwarf[4]	20+ feet 8feet	15 feet 6-8 feet	30 feet by 30 feet 6-8 feet by 6-12 feet
Sweet Cherry	Standard Dwarf[5]	30 feet 4 feet	25 feet 6-8 feet	30 feet by 40 feet 4-8 feet by 6-12 feet
Sour Cherry	Standard Dwarf	18-24 feet 8-10 feet	15 feet 6-8 feet	30 feet by 20 feet 8-10 feet by 20 feet
European Plums and Prunes	Standard	20 feet	15 feet	25 feet by 30 feet
Japanese Plums	Standard	18 feet	15 feet	25 feet by 30 feet

1 Size of apples is controlled by the rootstock and pruning techniques. Depending on rootstock, size may run from standard size down to 40% of standard size trees.
2 Dwarf apples are recommended for home gardeners. However, they require careful training to be highly productive and staking and are not as hardy as semi-dwarfs.
3 Dwarf pears have not proven overly successful and are **not** recommended.
4 Dwarf peach and apricot require careful training to be highly productive. Dwarf apricots are not recommended. Some dwarf peach trees are very small. Semi-dwarf selections are better.
5 Dwarf cherries require careful training to be highly productive.

Pollination

Pollination is a common problem for many gardeners growing tree fruits. Bees do not fly in cool, rainy weather common in many springs.

Apricots, sour cherries, peaches, nectarines, and European plums and prunes are generally ***self-pollinated***. That is, pollen from most cultivars will pollinate itself.

Apples, sweet cherries, pears, and Japanese plums are generally ***cross-pollinated***. That is, two compatible cultivars must be planted within one hundred feet for good pollination.

See CSU Extension Fact Sheet #7.002, *Pollination of Tree Fruits* for more details.

Spring Frost

Frost damage is a common problem in climates with late spring frosts, like Colorado. Commercial orchards are typically located on sides of hills, where cold air drains to the valley floors, giving some frost protection. Gardens located down in a valley floor typically have a shorter growing season than surrounding areas, and the tendency for late spring frosts makes the location unsuitable for tree fruits. **Table 2** gives critical temperatures at various stages of bud development. For more information see: https://intermountainfruit.org/cold-effects/index.

Table 2. Critical Springtime Temperatures – 90% kill / 10% kill				
Fruit	**Swollen Buds**	**Buds Showing Color**	**Full Bloom**	**Green Fruit**
Apples	10/18ºF	24/28ºF	25/28ºF	25/28ºF
Apricots	0/20ºF	14/24ºF	22/27ºF	25/28ºF
Sour Cherries	5/17ºF	24/27ºF	25/28ºF	25/28ºF
Peaches/ Nectarines	1/18ºF	15/25ºF	24/27ºF	25/28ºF
Pears	0/15ºF	19/25ºF	24/28ºF	24/28ºF

Soils

Being prone to root rots, fruit trees are intolerant of soils with poor drainage or heavy irrigation. Fruit trees are not compatible with the frequent irrigation of a typical home lawn and should be located outside of the influence of the lawn area. Commercial orchards are often located on gravelly soils with good drainage.

Fertilization

Fruit trees must have adequate nutrient levels to grow and produce fruit. Which nutrients and the amount needed can be determined through a soil test. The nitrogen requirement can also be based on the amount of growth produced the previous year, and it is applied in the spring just prior to or at bud break. Fertilizer products should be broadcast evenly underneath the tree and watered in. For more information about fertilizing fruit trees, see CSU Extension Fact Sheet, #7.612, *Fertilizing Fruit Trees.*

Training and Pruning

For productivity and quality produce, fruit trees require both specific training and annual pruning. ***Training*** refers to the general structural shape of the tree, achieved by pruning when the tree is young. ***Annual pruning*** refers to the pruning each year to grow quality fruit.

Pruning Basics

Detailed information about fruit tree pruning can be found in CSU Extension Fact Sheet #7.003, *Training and Pruning Fruit Trees*.

Details of specific pruning terms, techniques and styles mentioned here can be found in CMG GardenNotes #612, *Pruning Cuts*, and #613 *Structural Pruning of Young Shade Trees*.

Pruning of fruit trees is similar to the pruning of shade trees in the structural sense. However fruit trees are pruned much heavier and a few of the cuts and tools are different from pruning ornamental and shade trees. The objective in annual pruning of fruit trees is to balance quality and yield of fruit by improving access to sunlight, thinning fruit, and promoting growth of new fruiting wood. The percentage of wood removed is different in shade trees than in fruit trees. In fruit trees, much higher percentages are removed to encourage the growth of new fruiting wood. For example, orchards remove as much as 50% of peaches. To achieve this balance, fruit trees require 1) better general vigor with special attention to watering and fertilization, and 2) heavy pruning to promote fruiting wood. General pruning of fruit trees occurs in late winter, after the high potential for extreme cold (temperatures below zero) has passed but before bud swell and flowering, so there is time to apply dormant oil also known as horticulture oil as a preventative spray.

Apples

Structural Training of Young Apple Trees

Dwarf apples are trained to a central leader Christmas tree shape with branches in whorls. Spread lower branches to near horizontal and upper branches to 45º. With proper training, dwarf apple trees can be kept to an eight to ten foot height. Due to increased sunlight through the tree, dwarf apples produce the best quality fruit on small trees. [**Figure 2**]

Figure 2. Train dwarf apples to a Christmas tree shape.

Semi-dwarf apples are trained to a modified central leader system. When trained, semi-dwarf trees may be kept to a fifteen to eighteen foot height. In selecting scaffold branches, develop openings for ladders. Another option would be to use the open vase method of training.

Modified Central Leader Training. In this pruning style, a dominant central leader is maintained with three to five scaffold branches (vertically spaced at least six inches apart) which become the primary structure of secondary trunks. By definition, the diameter of a “scaffold branch” must be less than one-half the diameter of the adjacent trunk. Being structurally strong, this pruning style is preferred for larger trees. However, fruit production and quality will be low in the center canopy due to shading. [**Figure 3**]

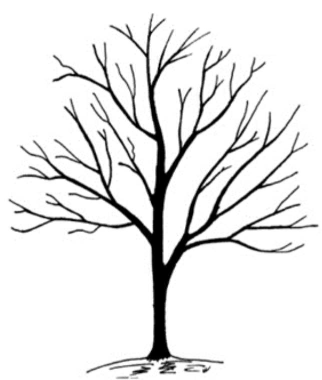

Figure 3. For structural strength, the scaffold branches must be spaced at least six inches apart and the diameter of the scaffold branches

Standard size apples are generally trained to a modified central leader system. The majority of fruit on standard sized apple trees is of inferior quality due to shading of the majority of the tree’s canopy. Standard size apples are rather large for home landscapes.

Annual Pruning of Fruiting Apples

Avoid cleaning out the small twigs and spurs along the branches. Apples fruit on two to five year old twigs. Some cultivars like ‘Gala’ fruit even longer, on spurs that are no thicker than a pencil.

The primary purpose in annual pruning is to increase sunlight penetration and to remove less productive wood. Apples need light annual thinning of the canopy, opening the tree to sunlight. Start at the top working down into the canopy using reduction cuts and thinning cuts. Avoid any heading cuts, as this leads to a thicker canopy that shades out fruit production.

If left un-pruned, the quantity of fruit produced may temporarily be greater, but the quality will be much lower. Apples tend to fruit heavier every other year; pruning, thinning, and proper fertilization will help balance this out.

Remove any ***water sprouts*** (upright vigorous shoots) back to the parent branch/trunk.

Pruning Old Neglected Apple Trees

Over a period of years, thin the canopy, thereby opening the tree to light, not removing more than 20% of live wood. Dead wood does not count. Over time, remove old wood and reduce tree height with reduction cuts.

Fruit Thinning

For quality fruit, thin apples to six to eight inches between fruit, and to one per cluster by mid-June or when fruit is nickel to quarter sized.

Peaches and Nectarines

Structural Training for Young Peach Trees

Peaches and nectarines fruit in the top four to five feet of the tree due to fruiting on one year old growth. With careful pruning, the height of a peach tree can be maintained at seven to ten feet. It is common to find untrained peach trees that fruit in the top four feet of a twelve to sixteen foot tall tree.

Train young peach trees to an open center vase shape. Space four to five scaffold branches at least six inches apart. To keep the tree height low, branching typically starts eighteen to twenty-four inches above the ground. [**Figure 4**]

Figure 4. To open the tree to light, train peaches and nectarines to an open vase system.

Select scaffold branches with wide angle of attachment and evenly spaced around the tree. It is best to develop scaffold branches all at one time and from the same diameter twigs. Otherwise, older/larger ones will dominate the tree.

In early training, allow small twiggy growth along the scaffold branches.

Do not remove all the fruiting shoots in the center of the tree. The most productive trees have fruiting wood throughout the tree canopy. The majority of side branches should be horizontal to the ground, think of a feather as the branch and its side branches. Leave a few small inward and upward stems to prevent sunscald.

Annual Pruning of Fruiting Peaches

The objective in annual pruning of fruiting peach trees is to balance fruit production with growth of new wood. Peaches fruit only on one year old wood. To promote growth of the fruiting wood, removed one-half to two-thirds of the growth each spring with a combination of thinning cuts and reduction cuts.

- Thin fruiting shoots, one year old wood, to a spacing of four to six inches.
- Long branches produce more fruit than short ones. Heading cuts can keep branches lower and outward growing.

- Ideal fruiting shoots are twelve to twenty-four inches long and 3/16 to 1/4 inch diameter at the base. Longer shoots may be headed back by 1/4.
- Remove three to six inch long shoots that are mixed in with the more desirable twelve to eighteen inch shoots.
- Leave small twigs that are not vigorous enough to offer competition in the tree's interior.
- Stimulate growth of one-year-old fruiting wood in the tree center by thinning-out and heading-back inside branches.
- Remove any water sprouts back to the parent branch with thinning cuts.
- Avoid cleaning out the small twigs in the tree's interior. This eliminates the center of the tree from being fruitful.

Fruit Thinning

For quality fruit, thin peaches to six to ten inches between fruit prior to the fruit reaching one inch in diameter. If you wait too long to thin, the fruit will be small and not juicy. Thinning also helps control codling moth in apples, as the female moth likes to lay eggs between touching apples. [**Figure 5**]

Figure 5. Peaches fruit only on one-year-old wood. Trees are heavily pruned to balance the growth between the fruit crop and production of new wood for next year's crop.

Sweet Cherries

Structural Training

Sweet cherries are trained to a modified central leader system. Select scaffold branches that are outward growing rather than upward growing.

Annual Pruning

Cherries are borne on long-lived spurs that produce fruit for ten to twelve years. Little annual pruning is needed on fruiting sweet cherries. Focus pruning on thinning the tree canopy, by removing older wood with thinning and reduction cuts. If making heading cuts to reduce height, make sure to prune to an outward branch to avoid shading other limbs. [**Figure 6**]

Fruit Thinning

Cherry fruit is not generally thinned since the fruit is small and thinning would not improve quality.

Figure 6. Sweet cherry trees are large and occupy a lot of space in the home landscapes. Most cultivars require a second cultivar for cross pollination.

Sour Cherries

Structural Training

Sour or pie cherries are generally much smaller trees or shrubs. Train sour cherries to a modified central leader system or delayed open center system (vase-shaped).

Annual Pruning

Little pruning is needed on fruiting sour cherries. Sour cherries fruit on new wood and spurs and are ***self-fruiting*** (self-pollinating). With routine thinning and removal of older wood, sour cherries may be kept less than twelve feet tall.

Authors: David Whiting, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised June 2018 by Mary Small, CSU Extension, retired. Reviewed May 2023 by Susan Carter, CSU Extension.

Reviewed May 2023

MASTER GARDENER
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CMG GardenNotes #760-764

Small Fruits

Rubus sp., Raspberries
Artwork by Melissa Schreiner © 2023

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Updated 2023

CMG GardenNotes #760

Small Fruits

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #761, *Growing Raspberries in Colorado Gardens.*
- #762, *Growing Blackberries in Colorado Gardens.*
- #763, *Growing Strawberries in Colorado Gardens.*
- #764, *Growing Grapes in Colorado Gardens.*

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #5.507, *Spider Mites*.
- #5.551, *Root Weevils*.
- #5.601, *Japanese Beetles*.
- #7.000, *Strawberries for the Home Garden*.
- #7.005, *Currants, Gooseberries, and Jostaberries*.

Plant*talk* Colorado™

- http://planttalk.org.
- #1203, *Grapes*.
- #1207, *Raspberries*.
- #1208, *Strawberries*.
- #1212, *Elderberries*.
- #1213, *Serviceberries*.
- #1214, *Currants*.
- #1215, *Gooseberries*.
- #1441, *Strawberry Pests and Diseases*.
- #1478, *Raspberry Cane Borer*.

Learning Objectives

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

- Know about the planting of raspberries.
- Pruning of fall-bearing (primocane-fruiting) raspberries and summer-bearing (floricane-fruiting) raspberries.
- Trellising systems for raspberries
- General care of raspberries.
- Trellising and pruning of trailing, erect, and semi-erect type blackberries
- Planting and renewal of June-bearing strawberry cultivars.
- Planting and renewal of fall bearing and day neutral strawberry cultivars.
- General care of strawberries.
- Trellising and pruning of grapes in a single curtain system (include first spring, second spring, third spring, and fourth spring, and beyond.

Review Questions

1. What is the difference between raspberry fruit and blackberry fruit?
2. Describe planting for red raspberries.
3. Describe pruning for summer crop raspberries.
4. Describe pruning for fall-bearing raspberries if you want both the summer and fall crops. Describe pruning for fall-bearing raspberries if you want only the higher quality fall crop.
5. Describe irrigation and fertilization needs of raspberries.
6. Describe planting and care of June-bearing strawberries. How is the patch renewed?
7. Describe planting and care of ever-bearing and day-neutral strawberries. How is the patch renewed?
8. Describe grape pruning at planting, year one, year two, year three, and year four onward. Why are grapes pruned so heavily?

CMG GardenNotes #761

Growing Raspberries in Colorado Gardens

Types and Cultivars

Fall-bearing (primocane-fruiting) red raspberry cultivars are typically hardier than summer crop cultivars. Suggested cultivars include *Autumn Britten*, *Polana*, *Jaclyn*, *Caroline*, *Fall Red, Fall Gold*, and *Heritage*. *Joan-J* and *Himbo-Top* have not performed well in Colorado trials.

Summer-bearing (floricane-fruiting) red raspberry cultivars have some winter hardiness problems in climates like Colorado, with frequent winter to spring and back to winter temperature swings. Suggested cultivars include *Nova*, *Boyne*, *Newburgh Titan*, and *Killarney*.

Figure 1. Raspberries are a good crop for the personal gardener.

Black raspberry or "blackcap" – Suggested cultivars include *MacBlack* and *Jewel*.

Purple raspberries are a hybrid of red and black. Suggested cultivars include *Royalty*.

Yellow raspberries are a mutation of red. Suggested cultivars include *Anne*.

Planting Raspberries

With good growing conditions, a raspberry patch may last ten to fifteen years. [**Figure 1**] Viral diseases and hardiness problems frequently shorten the life of a patch. Raspberries need full sun, but avoid reflected heat in areas with hot summer temperatures. In open windy areas, wind protection is important as dry winds can dehydrate and kill exposed canes.

Raspberries prefer a deep, well-drained, sandy loam soil. They perform poorly on compacted clayey soils and soils with poor drainage. On clayey soils, plant in a raised bed. Because raspberries are a long-term crop, extra efforts to improve the organic content of the soil to 5% gives good dividends. Due to soil borne diseases, do not plant raspberries where raspberries, strawberries, tomatoes, peppers, eggplant, potatoes, or vine crops (cucumbers, squash and melons) have been grown in the past four years. To reduce virus potential, do not plant raspberries next to blackberries. To help manage virus problems, purchase certified virus-free nursery stock.

In the home garden, raspberries are generally planted in a hedgerow. Place plants in a row twelve to eighteen inches between plants with four to eight feet between rows (depending on trellising system and equipment used. If planting bare-root plants, soak plants in water for a few hours before planting. Dig shallow holes large enough to spread out the root mass and set plant with the top root one to two inches below soil level. Water plants to settle the soil. Cut newly planted canes to six inches. Care of the new planting should be similar to vegetable transplants with frequent, light irrigation until the plants become established.

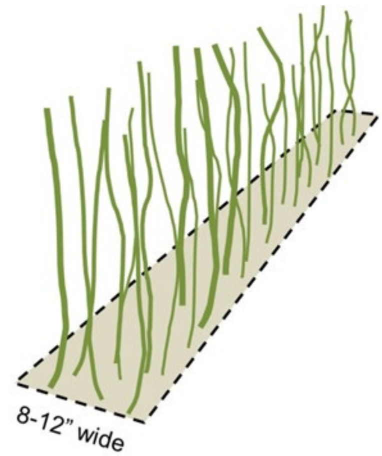

Figure 2. Red raspberries in a hedgerow. For higher yield, keeps width of hedgerow to only 8 to 12 inches wide for fall bearing.

Allow canes to fill in making the hedgerow. By hoeing or cultivation, routinely remove any canes that come up outside of the hedgerow. For higher yields and reduced pest problems, keep the hedgerow width to only eight to twelve inches for fall cultivars and twelve to eighteen inches for summer cultivars. [**Figure 2**]

Pruning

Primocane vs. **Floricane** – The crown and roots system of raspberries are perennial. The canes are biennial. ***Primocane*** refers to the first-year canes; ***floricane*** refers to the second-year canes.

Fall-Bearing (Primocane-Fruiting) Raspberries

In fall-bearing cultivars, the fall crop starts at the top of the primocane (new cane this summer), working its way down the cane with each picking. Next summer, the crop starts at the point where the fall crop ended the previous season, continuing downward.

<u>For best yields and high fruit quality</u>, prune to a fall crop only. In February/March, prune all canes to the ground. This eliminates the summer crop, putting all the growth into the superior fall crop. This also helps eliminate winter injury problems and many common insect pests.

<u>For fall and summer crops</u>, prune the same as summer-bearing cultivars.

Summer-Bearing (Floricane-Fruiting) Raspberries

1. ***Primocanes*** (new canes the first year) are not pruned.
2. In spring (February/March), prune as follows:
    - Remove spindly canes, leaving stocky canes ¼ inch in diameter and larger. Thin stocky canes to about ten canes per foot of hedgerow.
    - <u>For larger fruit size</u>, tip canes at a convenient height where they will be self-supporting, typically around five feet. Canes may be tied in clusters to a trellis.
    - <u>For larger yields</u>, do not tip canes. Canes may be tied in clusters to a trellis.

3. Mid-summer when the fruiting is finished, remove all *floricanes* (flowering/fruiting canes) to the ground. They will not fruit again. This makes room for the new crop of primocanes.

Trellising

Raspberries are easier to manage if trellised. Examples of trellising systems are given in **Figures 3** through **5.**

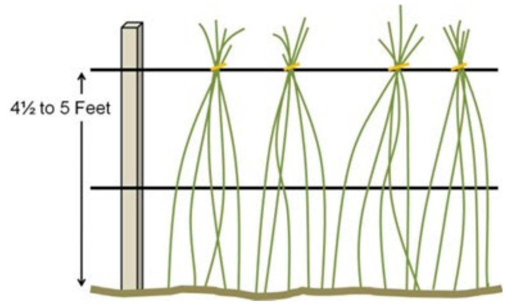

Figure 3. The one-line trellis system has wires running at 30 inches and 4½ to 5 feet. Canes are tied to the lines in bundles.

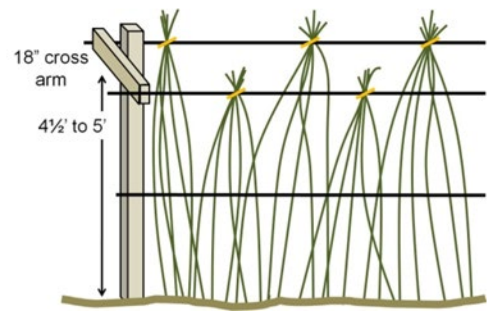

Figure 4. The two-line trellis system added an 18-inch cross arm at 4 ½ to 5 feet. Wires are run at the edge of the cross-arm forming a box. Canes are tied in bundles on the two lines.

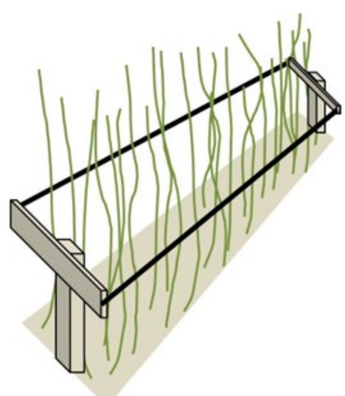

Figure 5. The T-trellis system is popular for fall bearing (primocane-fruiting) cultivars. At knee height, a cross arm and wire form a box. Canes are free floating inside the box.

Irrigating

Raspberries need about one inch of water (rain and irrigation) per week during blooming/fruiting. Depending on soil type, this may require irrigation once to twice a week. When watering, avoid wetting the leaves and fruit as this can cause disease problems. Raspberries work well with drip irrigation under wood chip mulch.

Water use is significantly less during nonfruiting times. Iron chlorosis (yellowing of leaves with veins remaining green) is a common symptom of over-watering. [**Figure 6**]

Figure 6. Iron chlorosis (yellowing of leaves with veins remaining green) is a common symptom of over-watering. Raspberries are commonly over-watered in the spring.

Fertilizing

A good guide for fertilization is to observe plant growth. Leaves should be healthy green and the primocane should grow to five to eight feet. Adjust actual fertilizer rate if plants grow too tall or are too short.

Fertilize all raspberries in the spring as growth starts and repeat in early June. For fall bearing cultivars, make a third application in August. Apply ½ to 1 cup of ammonium sulfate (21-0-0) or similar fertilizer per ten feet of hedgerow. The fertilizer may be broadcast over the hedgerow area and watered in or placed in a band one foot to the side of the row.

If using compost or manure, make application in the late fall or early winter, but avoid early fall applications which can push late fall growth.

Common Raspberry Pests

Abiotic

- **Winter dehydration** is less of a problem in fall bearing cultivars where they are pruned to the ground each spring.
- **Sunburn of fruit** (light color patches on the top side of fruit) is common in hot weather. Raspberries prefer cooler temperatures.
- **Iron chlorosis** (yellow leaves with veins remaining green) is a common symptom of springtime over-watering. See **Figure 6**. Correct watering problems. For additional information on iron chlorosis, refer to CMG GardenNotes #223, *Iron Chlorosis of Woody Plants*.

Insects and mites

- **Spotted wing drosophila flies** can affect ripening raspberries, in particular fall bearing cultivars.
- **Grasshoppers** eat raspberries.
- **Spider mite** populations explode in hot summers and following the use of the insecticide Sevin (carbaryl). Leaves appear bronzed. For additional information, refer to CSU Extension Factsheet #5.507, *Spider Mites*.
- **Cane borer, crown borer**, and **stem borer** are common borers of cane crops. These are less of a problem in fall bearing cultivars where the canes are removed to the ground each spring. For additional information, refer to PlantTalk Colorado #1478, *Raspberry Cane Borers*.
- **Plant bugs** cause misshapen fruit.
- **Raspberry sawflies** are caterpillar-like insects that feed on leaves.
- **Leaf rollers**.

Diseases

- **Virus complex** – Raspberries are prone to a variety of viruses. Simply remove the patch when the fruit becomes small, and the patch is less productive. Start the new patch in another area of the garden using new, virus-free plants.

Authors: David Whiting, CSU Extension, retired, and Merrill Kingsbury, CSU Extension. Artwork by David Whiting. Used with permission. Revised August 2018. Reviewed March 2023 by Merrill Kingsbury, CSU Extension.

Reviewed March 2023

CMG GardenNotes #762

Growing Blackberries in Colorado Gardens

Outline:

In blackberries, the ***receptacle***, which is the white core of the fruit, is part of the fruit when picked. In raspberries the receptacle remains on the plant when picked.

Types and Cultivars

Trailing blackberries produce vigorous ***primocanes*** (first-year vegetative canes) from the crown of the plant rather than roots. Second year ***floricanes*** produce long shaped fruit with relatively small seeds and a highly aromatic, intense flavor. They are not hardy in climates like Colorado, experiencing damage at temperatures of 13ºF and below mid-winter, and in the 20ºF late winter/early spring. [**Figure 1**]

Erect blackberries have stiff arching canes that are somewhat self-supporting. However, they are much easier to manage when trellised and pruned. Plants can become invasive to an area as they can produce new primocanes (suckers) from roots. Summer prune or tip primocanes to encourage branching and increase fruit production on the second year floricanes.

Erect blackberries produce fruit with relatively large seeds. Flavor and aroma are not as intense as in the trailing blackberry cultivars. These are semi-hardy in climates like Colorado with rapid springtime temperature shifts.

Primocane-fruiting cultivars of erect blackberries produce fruit on the new canes. This makes management easier, as the canes can be cut to the ground each winter. Suggested cultivars include *Prime Jan* and *Prime Jim*.

Figure 1. Blackberries

Semi-erect blackberries are thornless and produce vigorous, thick, erect canes from the crown. No primocanes are produced from the roots (suckering). Prune primocanes in the summer to encourage branching and increase fruit production on floricanes. A trellis is required to support the canes.

Semi-erect blackberries generally produce a higher fruit yield than trailing or erect types. Fruit quality is similar to erect blackberries. Suggested cultivars include *Triple Crown* and *Chester Thornless*.

Blackberry/red raspberry hybrids are usually natural crosses between blackberries and raspberries. Because the receptacle (white core) comes off with the fruit, they are generally considered a type of blackberry. Popular cultivars include *Boysen* (Boysenberry), *Logan* (Loganberry), and *Tay* (Tayberry).

Planting and Care of Blackberries

Blackberries produce best in full sun but are tolerant of partial shade. They are more tolerant of clayey soils than raspberries. However, good drainage is essential. Because blackberries may last ten to fifteen years, extra attention to improving the soil organic content to 5% gives big dividends.

For semi-erect cultivars, space plants five to six feet apart. Space erect cultivars two to three feet apart. Space trailing cultivars four to six feet apart. Start with certified disease-free nursery stock. Planting would be similar to raspberries. To reduce virus problems, do not plant blackberries adjacent to raspberries.

Irrigation, fertilization, and pest management are similar to raspberries. Refer to CMG GardenNotes #761, *Growing Raspberries in Colorado Gardens*.

Trellising and Pruning

Trellising is recommended for all blackberries.

Trailing Blackberries. These are easy to grow on a two-wire system. Run a top wire at five to six feet with a second line eighteen inches below the top wire.

After the first year, there will be fruiting floricanes along the wires. Train the new primocanes into a narrow row below the fruiting canes. Directing all canes in one direction may make it simpler.
After the fruit harvest period, the old fruiting (floricanes) should be removed. However, unless there is a significant disease present, it is best to delay removing the old fruiting canes until they have died back considerably. This allows the dying canes to move nutrients back into the crown and roots. After the old fruiting canes are removed, train the primocanes up on the wires. Work with one or two canes at a time in a spiral around the trellis wires. Canes from adjacent plants may overlap a little. No pruning of healthy primocanes should be necessary. [**Figure 2**]

In areas with low winter temperatures, leave the primocanes on the ground for the winter where they can be mulched for winter protection. In the spring, after the chance of extreme cold has passed, train the old primocanes, which are now floricanes, up onto the wires. Avoid working with the canes in cold weather, as they are more prone to breaking.

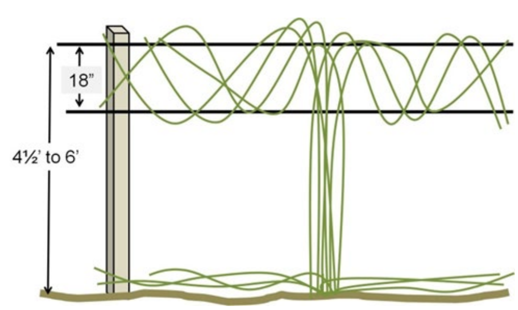

Figure 2. Spread floricanes up on a two-wire system for trailing blackberries.

Erect Blackberries. These produce stiff, shorter canes that come from the crown and root suckering, forming a hedgerow. A T-trellis supports erect blackberries well.

Erect blackberries require summer pruning. Remove the top one to two inches of new primocanes when they are four feet tall. This causes the canes to branch, increasing next year's fruit yields. This will require several pruning sessions to tip each cane as it reaches four-foot height. Primocanes, suckers, which grow outside of the hedgerow should regularly be removed.

In the winter, remove the dead floricanes (old fruiting canes) from the hedgerow. Shorten the lateral branches to 1½ to 2½ feet. [**Figure 3**]

Figure 3. Pruning of erect blackberries after winter pruning.

Primocane-Fruiting Erect Blackberries. For the best quality fruit, cut all canes off just above the ground in the late winter. In the summer, when the primocanes are 3½ feet tall, removed the top six inches. The primocanes will branch, thereby producing larger fruit yields in the fall.

Semi-Erect Blackberries are vigorous and easier to manage on a Double T trellis. Install four-foot cross arms at the top of a six foot post. Install a three-foot cross arm about two feet below the top line. String high-tensile wire (purchase at your local hardware store) down the rows, connecting to the cross arms.

Semi-erect blackberries require summer pruning. When the primocanes are five feet tall, remove the top two inches to encourage branching. This will require several pruning sessions to prune canes as they reach this height.

In the winter, remove the dead floricanes (old fruiting canes). Spread the primocanes (next season's floricanes) out along the trellis. Canes do not need to be shortened; however they can be if they are difficult to train.

Authors: David Whiting, CSU Extension, retired and Merrill Kingsbury, CSU Extension. Artwork by David Whiting. Used with permission. Revised August 2018. Reviewed March 2023 by Merrill Kingsbury, CSU Extension.

Reviewed March 2023

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CMG GardenNotes #763

Growing Strawberries in Colorado Gardens

Types and Cultivars

June-bearing cultivars have one large crop in early summer (late June to early July along the Colorado Front Range) with larger fruit and higher yields. They are less hardy in climates like Colorado because of rapid springtime temperature swings. They are often damaged by late spring frosts. Strawberries are popular for freezing and making jams with flavorful, aromatic berries. Suggested cultivars include Honeoye, Guardian, Kent, Redchief, Delite, Jewel, Mesabi, A.C. Wendy, Cabot, Bloominden Gem, Carskill, and Geneva.

Ever-bearing cultivars have two crops, one in early summer and a second crop in the fall. They tend to be more dependable than June bearing cultivars in cold climates like Colorado. Berries are smaller than the June bearing types. Suggested cultivars include Quinault, Ogallala, and Fort Laramie.

Day-neutral cultivars blossom most of the summer and fall in cycles lasting around six weeks each. Blossoming will slow or stop during hot weather. Fruit is typically small. These provide a light, daily harvest through most of the summer and fall. They need constant, light fertilization, and regular removal of runners. Suggested cultivars include Tribute, Tristar, Fern, and Mara Des Bois.

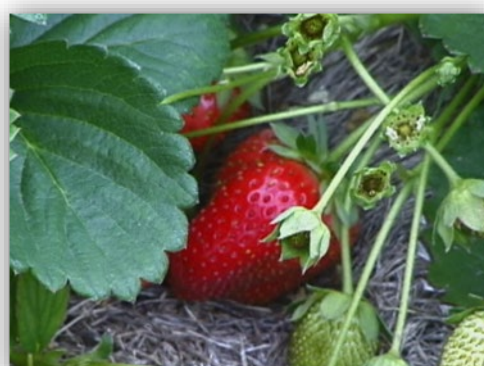

Figure 1. Strawberries

Plantings

The key to a good strawberry patch is well-drained soil high in organic matter. Strawberries need full sun (eight hours minimum), but do not perform well in reflected heat. They need protection from wind. In clayey soils, they grow better in raised beds that provide better drainage. Strawberries are shallow rooted and intolerant of weed competition. [**Figure 1**]

Due to soil borne diseases, avoid soils where strawberries, raspberries, tomatoes, peppers, eggplant, potatoes, and vine crops (squash, melons, pumpkins, and cucumbers) have been growing in the past four years.

Spring is the best time to plant strawberries. Make sure that plants are certified disease and insect free. If ordering bare rooted strawberries, ensure that they are shipped at the right time for your plant hardiness zone. If plants arrive and conditions are not favorable to plant, temporarily cover the roots with soil in a furrow to ensure that roots do not dry out. Do not plant roots that are dark or appear unhealthy. The strawberry patch may need to be covered for spring frost protection.

At the time of planting, strawberry plant crowns (short segment with roots below and leaves above) need to be at the soil line. If the plant is too deep (leaf stems buried), the plant rots. If too shallow (roots exposed), the plant dehydrates. [**Figure 2**]

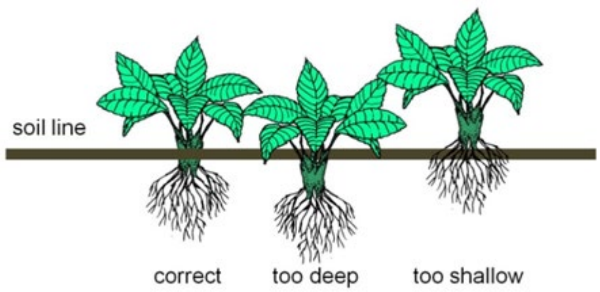

Figure 2. Strawberries are fussy about planting depth. The short crown section needs to be at the soil surface.

June-Bearing Cultivars

Planting – Since June-bearing cultivars set a lot of runners, they are planted in a matted row system. Set plants eighteen to twenty-four inches apart in rows four plus feet apart. Allow runners from the “mother” plant to fill in a matted row, to a plant population of five to six plants per square foot. Remove excessive runners. Prune off runners outside the matted row and all new runners after September 1st. [**Figure 3**]

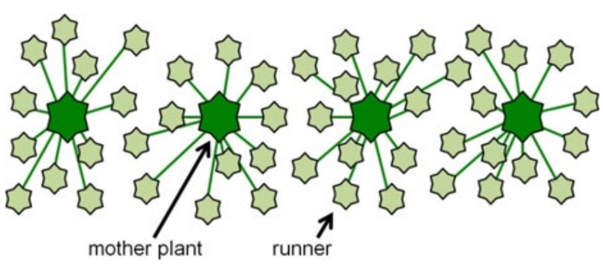

Figure 3. June-bearing cultivars in a matted row system. Runners from the mother plant fill in a block 18-36 inches wide.

First Season Care – Remove all flowers the first year. Flowering the first year decreases the growth and next season’s yields. If growth is weak and leaves are light green, fertilize lightly in June, July, and August. Use water-soluble fertilizers (like Miracle-Gro®, Peters, Rapid Gro, etc.) or one cup of 21-0-0 per one hundred square feet (broadcast over the bed and water it in).

General Care – Fertilize after the summer crop is growing with water solubles or one cup 21-0-0 per one hundred square feet (broadcast over the patch and water in). Strawberries need one inch of water (rain plus irrigation) per week during blossoming/fruiting. Water needs will be significantly less when not in fruit production. Iron chlorosis (yellow leaves with veins remaining green) is a symptom of over watering. Renovate every year or restart bed every two to four years.

Renovation of June-Bearing Growing Bed

1. After the fruiting period, mow or cut foliage to two inches. Remove all plant debris.
2. With shallow cultivation, create alternating strips (eight to ten inches wide) of plants left and plants removed.
3. Allow runners to spread into the cleaned area, up to an optimum plant density of five to six plants per square foot.
4. Remove excessive runners and all runners after September 1.
5. In future years, alternate the strips by taking out the plants from the plant strips left the previous year.

Everbearing and Day-Neutral Cultivars

Planting – Because ever-bearing and day-neutral strawberries have fewer runners, the hill system is typically used. Set plants twelve inches apart in a double or triple wide row bed. Remove all runners as they develop. [**Figure 4**]

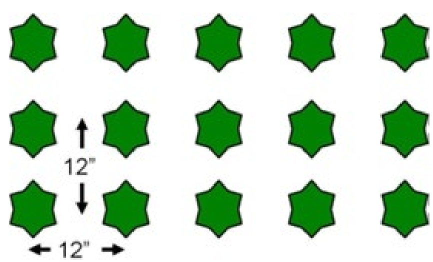

Figure 4. In the hill system, plants are spaced 12 inches apart in double or triple rows at 12 inches apart. All runners are removed.

First Season Care – Remove the first flush of flowers and allow flowers to develop after July 1st.

General Care – Periodically remove all runners. Fertilize lightly throughout the growing season using water-soluble or ¼ cup 21-0-0 per one hundred square feet (broadcast this and water it in). Start a new patch every three to four years.

Harvesting

Pick strawberries every other day during the peak of the season. If berries are eaten or preserved immediately, harvest only red-ripe fruit and leave the caps on the plants. If the fruit will not be used for a few days, harvest the berries, caps and all, while still pink.

Winter Care

Blossom potential for the following year is based on plant health in the fall. Keep soil damp until fall frost. Then, withhold water to help harden off the plants. A final November watering before soils freeze helps prevent winterkill from drying.

In cold winter climates, like Colorado, a winter mulch of clean, seed-free straw (or similar material) is recommended. Apply it when the ground freezes (around December 1st along the Colorado Front Range). Apply two inches, but not more as it could smother the plants. In windy areas, bird netting over the mulch helps hold it in place. Mulching helps protect plants from drying winter winds and from root damage by alternative freezing and thawing of the ground.

In climates with late spring frosts (like Colorado), leave the mulch on as long as possible to restrain plant growth in the early spring. In March, start checking plants under the mulch for growth. As growth begins, remove mulch over time, allowing sunlight into the plants. Some mulch may remain on the soil to keep strawberry fruit off the ground.

Summer Mulch

Because strawberries are shallow rooted, summer mulch helps stabilize soil moisture and also helps suppress weeds. Use grass clippings (that contain no weed killers), seed-free straw, or other mulching materials. On ever-bearing and day-neutral cultivars (where runners are not allowed to set), black plastic mulch may be used. Plants must spread and cover the plastic mulch before summer heat sets in or it will be too hot.

Common Strawberry Pests

Abiotic

- **Iron chlorosis** (yellow leaves with green veins) is a symptom of over-watering. For additional information, refer to CMG GardenNotes #223, Iron Chlorosis of Woody Plants.
- **Winter injury** often kills plants.
- **Drought injury** (Strawberries are shallow rooted, requiring frequent, light irrigations).
- **Hail** readily defoliates strawberries.
- **Wind**.

Insects and Insect Relatives

- **Lygus bugs** feed on fruit. Control weeds, alfalfa, and legumes. Use insecticidal soap, avoid treating during bloom.
- **Aphids**.
- **Slugs and millipedes**. Decrease free moisture with proper watering. Remove fruit and decaying debris. Mulch to raise fruit up off the soil.
- **Spider mites** bronze leaves. Populations explode in hot weather and following the use of the insecticide Sevin (carbaryl).
- **Spotted wing drosophila** flies can affect ripening strawberries.

Diseases

- **Strawberry leaf spots** show as red spots with tan centers on leaves.
- **Powdery mildew** appears as white mold on leaves.
- **Botrytis gray mold** is the fuzzy mold on fruit.
- **Red stele** and **black root rot complex** are common root disorders.
- **Verticillium wilt** is a common soil borne disease.
- **Virus complex**. Strawberries are prone to a variety of viruses.

Wildlife

- **Birds**. Bird netting may be necessary to spread above and over the strawberry patch.
- **Rabbits**.
- **Deer**.

For addition information, refer to the following CSU Extension Publications:

- Fact Sheet #2.931, *Strawberry Diseases*.
- PlantTalk Colorado #1441, *Strawberry Pests and Diseases*.

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Reviewed March 2023

CMG GardenNotes #764

Growing Grapes in Colorado Gardens

Types and Cultivars

Types of Grapes [Figure 1]

- **Table grapes** are used for fresh eating. Most popular cultivars are seedless. Popular cultivars include Himrod, Interlaken, Canadice, St. Theresa, and Reliance.
- **Juice and jelly grapes** whose popular cultivars include Concord, Valiant, Niagra, and St. Croix.
- **Wine grapes.**
- **Raisin grapes.**

Figure 1. Grapes on a trellis.

Types of Cultivars

- **American cultivars**, Vitis labarusca, have a strong “foxy” (musty) flavor and aroma. They are used for juice, fresh eating, and some wines.
- **European cultivars**, Vitis vinifera, with tight clusters, thin skins, and a wine-like flavor, are used for wines. They require more heat units for maturity and have limited potential in Colorado.
- **French-American** hybrids are popular for wine. Characteristics depend on parentage.

Planting Grapes

Grapes need full sun and protection from wind. Space plants six to eight feet apart, in rows six to ten feet apart (depending on trellising system). Strong trellising systems are required to support the heavy vines and fruit. Use treated posts and 12-gauge or heavier wire.

Trellising and Pruning

Grapes fruit on **one-year-old wood** (canes that grew the previous summer). Thus, pruning is a balance between growing fruit and renewing the one-year-old wood. Correct pruning is essential for production. Un-pruned or under-pruned grapes give many small clusters of tiny grapes. Correctly pruned, grapes give high yields of large clusters of large grapes. Over-pruning simply cuts the yield. There are many methods to trellis grapes. A simple method for the home gardener is the Single Curtain System which is explained below.

Pruning at Planting

At planting, prune back to two to three buds. Allow the summer growth to develop what will become the primary trunk.
[**Figure 2**]

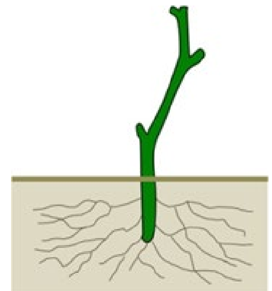


Figure 2. Notice the three buds. This heavy pruning pushes growth of lone canes. One of the canes will become the trunk.

Pruning the Second Spring

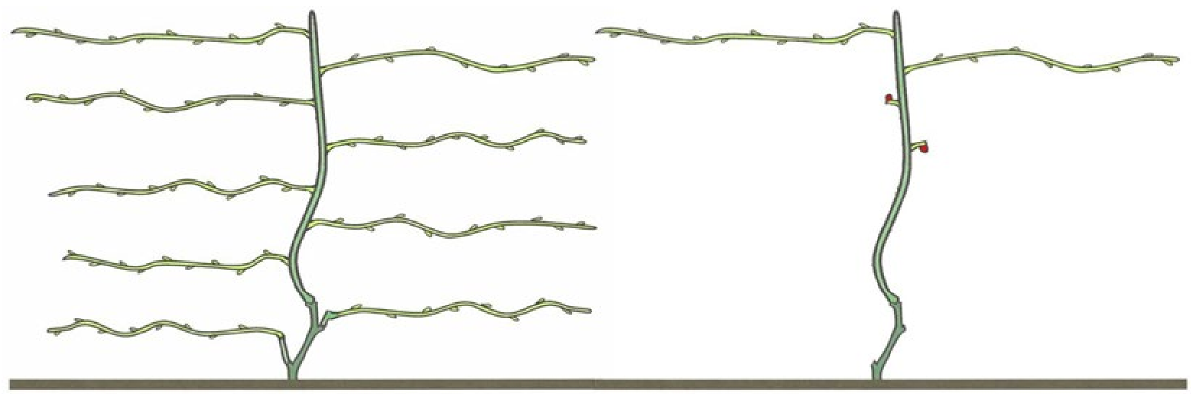
In the spring, select one of last summer's canes to become the trunk. Remove the others, leaving one or two renewal spurs (buds close to the trunk). Renewal spurs allow for replacement growth of potential trunk wood if something damages the trunk. If growth was poor (not generating the desired trunk), start over by pruning back to two to three buds.
[**Figure 3**]

Figure 3. Second spring pruning: **Left:** Before pruning with three canes. **Right:** After pruning with one cane selected to become the trunk and other canes pruned back to a renewal spur (circled in red).

Pruning the Third Spring

1. Select two one-year-old canes (one to the left and one to the right) to become the **fruiting canes** and **cordon arms** along the trellis. The ideal cane is about pencil diameter with moderate spacing between buds. [**Figure 4**]
2. Select two canes (one to the left and one to the right) to become **renewal spurs** by pruning them back to two buds each. The purpose of renewal spurs is to give more options near the trunk in selection fruiting canes in future years.
3. Remove all other canes!
4. Prune the two fruiting canes back to 40-60 buds per plant (more buds for smaller fruit clusters, or less buds for larger fruit clusters).

Figure 4. Pruning the third spring. **Left:** Before pruning. **Right:** After pruning. A one-year-old fruiting cane is selected to go to the left and another to the right. These become the cordon arms along the grape trellis. Another cane to the left and to the right (near the trunk) are pruned back to two buds as renewal spurs. All the other wood is removed. This heavy pruning balances fruit production with renewing the one-year-old wood for next year's crop.



Spring Pruning the Fourth Spring and Beyond

1. Select two, one-year old canes (one to the left and one to the right) to become the new fruiting canes and spread them out along the trellis as cordon arms. The ideal cane is about pencil diameter with moderate spacing between buds. To keep the fruiting wood near the trunk, these could be selected from the first couple of canes on last year's cordon arm or from the renewal spurs. [**Figure 5**]
2. Select two canes (one to the left and one to the right) to become renewal spurs by pruning them back to two buds each. These could be selected from the renewal spurs of the first couple of canes on last year's fruiting cane. The purpose of the renewal spurs is to give options to select future fruiting canes/cordon arms close to the trunk.
3. Remove all other canes! This heavy pruning balances fruit growth with growing new fruiting wood for next year's production.
4. Prune the two fruiting canes back to 40-60 buds per plant (more buds for smaller fruit clusters, less buds for larger fruit clusters).

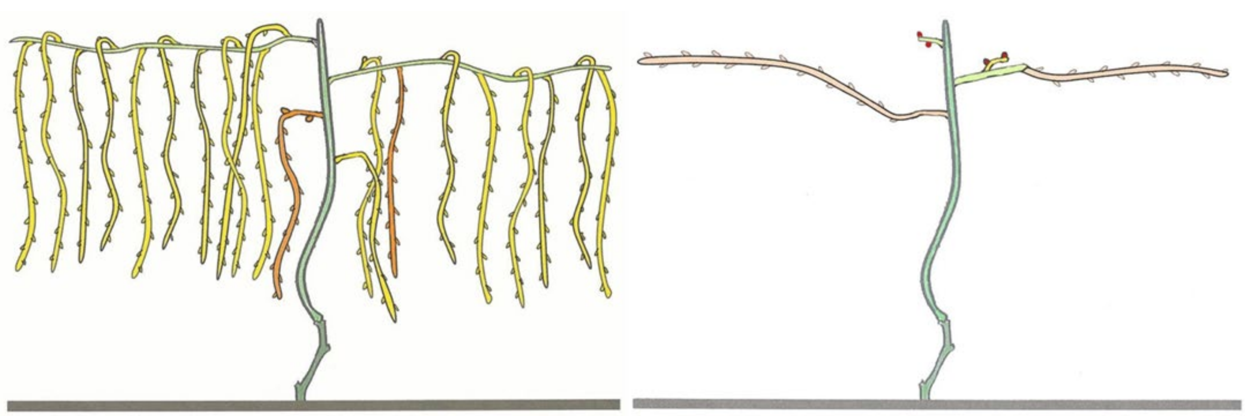


Figure 5. Fourth spring and beyond pruning. **Left:** Before pruning. One-year-old fruiting canes shown in yellow. The one-year-old fruiting canes that have been selected to become the new cordon arm are shown in orange.
Right: After pruning. A one-year-old fruiting cane is selected to go to the left and another to the right. On the left, a cane from the renewal spur was selected. On the right, a cane from last year's cordon arm was selected. These become the cordon arms along the grape trellis. Another cane to the left and to the right (near the trunk) are pruned back to two buds as renewal spurs. All the other wood is removed. This heavy pruning balances fruit production with renewing the one-year-old wood for next year's crop.

General Care of Grapes

- Grapes perform best with a four-foot wide weed-free bark/wood chip mulch strip under the grape trellis. They perform poorly with lawn competition.
- Avoid over-watering. Iron chlorosis is a symptom of springtime overwatering.
- Go light on grape fertilization. Apply one-fourth cup of 21-0-0 (or equivalent) per established plant. Broadcast it under the trellis and water in.
- For home gardeners, flavor is the best method to evaluate harvest time.

Common Grape Pests

Fruit

- **Birds**. Bird netting over the plants may be necessary.
- **Botrytis bunch rot**. Generally becomes a problem with excessively heavy canopy, due to inadequate pruning, and the lack of good air circulation.
- **Spotted wing drosophila flies**. These can affect ripe grapes.

Plants

- **Powdery mildew**. Read more at CSU Extension Fact Sheet #2.902, *Powdery Mildews*.
- **Iron chlorosis**. A symptom of over-watering. Read more at CMG GardenNotes #223 Ir*on Chlorosis of Woody Plants*.
- **Poor soil drainage**. Related to root rot.
- **Inadequate control of weeds and diseases**. Grapes do not tolerate competition.
- **Japanese Beetle**. Damage is probable.

Authors: David Whiting, CSU Extension, retired with Merrill Kingsbury, CSU Extension. Artwork by David Whiting. Used with permission. Reviewed March 2023 by Merrill Kingsbury, CSU Extension.

Reviewed March 2023

MASTER GARDENER
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CMG GardenNotes #260-268

Irrigation Management

Cross Section of Irrigated Root Vegetable Raised Bed
Artwork by Melissa Schreiner © 2023

This Irrigation Management curriculum was developed by David Whiting, CSU Extension, retired; Carl Wilson, CSU Extension, retired; and Catherine Moravec, former CSU Extension employee. Cover art by Melissa Schreiner. Used with permission.

- Colorado Master Gardener GardenNotes are available online at https://cmg.extension.colostate.edu/.
- No endorsement is intended of products mentioned, nor is criticism implied of products not mentioned.
-
- Colorado State University, U.S. Department of Agriculture, and cooperating Colorado counties.

Updated 2023

CMG GardenNotes #260

Irrigation Management

References and Review Material

Reading/Reference Materials

CSU GardenNotes

- https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts/.
- #261, *Colorado's Water Situation*.
- #262, *Water Movement Through the Landscape*.
- #263, *Understanding Irrigation Management Factors*.
- #264, *Irrigation Equipment*.
- #265, *Methods to Schedule Home Lawn Irrigation*.
- #266, *Converting Inches to Minutes*.
- #267, *Watering Efficiently*.
- #268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Checkup*.

CSU Extension Fact Sheets

- https://extension.colostate.edu/topic-areas/yard-garden/.
- #4.702, *Drip Irrigation for Home Gardens*.
- #4.714, *Home Sprinkler Systems: Backflow Prevention Devices*.
- #4.722, *Irrigation: Inspecting and Correcting Turf Irrigation System Problems*.
- #6.702, *Graywater Reuse and Rainwater Harvesting*.
- #7.199, *Watering Established Lawns*.
- #7.239, *Home Sprinkler Systems: Operating and Maintaining*.
- #9.952, *Water Conservation In and Around the Home*.

Plant*talk* Colorado™

- https://planttalk.colostate.edu/.
- #1621, *Watering Colorado Soils*.
- #1903, *Xeriscape-Efficient Irrigation*.
- #2201, *Automatic Sprinkler System Overview*.

Other

- Denver Water: www.denverwater.org.
- Northern Colorado Water Conservancy District: www.ncwcd.org.

Learning Objectives

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

- Describe issues around the current water situation in Colorado and the western United States.
- Describe design criteria for efficient landscape irrigation.
- Describe maintenance criteria for efficient landscape irrigation.
- Describe management criteria for efficient landscape irrigation.
- Perform a lawn irrigation check-up.
- Set a controller for efficient landscape irrigation.

Review Questions

Colorado's Water Situation

1. Describe the western water rights doctrine of "prior appropriation" or "first-in-time, first-in-right." How does it differ from the "riparian" water rights system used in eastern states?
2. What percent of Colorado's water supply is used for landscape irrigation?
3. During the summer irrigation season, what percent of a community's water supply is typically used for landscape irrigation?
4. On a community-wide basis, what percent of the water used for landscape irrigation is wasted due to poor design, maintenance, and management of the irrigation systems?
5. Explain how landscape irrigation affects a community's water infrastructure. What is the primary purpose behind community water schedules, such as every third day or every other day?
6. What is the typical multi-year drought cycle in Colorado's climate?
7. How does population growth play into Colorado's water situation?

Water Movement Through the Landscape

8. List how water enters the landscape. Explain how water is stored in the landscape. List how water leaves the landscape.
9. What is ET?
10. What factors influence ET rates?

Understanding Irrigation Management

11. Describe how these factors influence irrigation management:
    - Location of soil moisture.
    - Type of soil.
    - Water holding capacity.
    - ET.
    - Rooting depth.
12. How does improving a sandy soil with organic matter influence irrigation management? How does improving a clayey soil with organic matter influence irrigation management?
13. Define *water holding capacity*, *saturation*, *field capacity*, *permanent wilting point*, and available *water*.
14. Compare the historical ET for a lawn in spring, summer, and fall.
15. Based on a soil's typical water-holding capacity, describe the amount of water to apply and frequency of irrigation for sandy, sandy loam and loamy/clayey soils with a six-inch, 12-inch and 24-inch rooting depth in the spring, summer, and fall.
16. Describe the textbook amount of water to apply if a lawn requires water every two, three, four, or five days in the typical summer.
17. Describe how these factors influence irrigation management:
    - Exposure.
    - Previous irrigation pattern.
    - Stage of growth.
18. Give examples of mechanisms that plants use to tolerate/escape drought.

Irrigation Equipment

19. Explain basic components of an in-ground sprinkler system, including the following:
    - Point of connection.
    - Pressure regulator.
    - Backflow prevention device.
    - Supply line.
    - Valve box.
    - Valves.
    - Secondary lines.
    - Winter drainage.
20. Describe the advantages and limitations of pop- up spray heads and rotor heads.
21. Describe the strengths and weaknesses of an in- ground sprinkler system.
22. Describe basic components of a drip system, including the following:
    - In-line filter.
    - Pressure regulator.
    - Half-inch tubing.
    - Quarter inch microtubing.
    - Drip emitters.
    - In-line drip tubing.
    - Micro-sprayers.
23. Describe a drip system made with soaker hose or soaker tubing.
24. Describe the strengths and weaknesses of drip irrigation.
25. Describe the strengths and weaknesses of hose-end, hand watering.

Methods to Schedule Irrigation

26. Describe irrigation scheduling by the Type of Sprinkler Method.
27. Describe irrigation by the Precipitation Rate Method. Explain how to do a Precipitation Rate (Catch Can) Test.
28. What is the purpose of cycle and soak? Explain how to add cycle and soak to an irrigation scheduling method.
29. What is an ET controller? What is a soil moisture sensor?
30. Explain how to fine-tune an irrigation schedule.

Watering Efficiently

31. Of the seven principles of water wise gardening, why does watering efficiently have the greatest potential for water conservation in the typical home landscape?
32. With attention to irrigation design, maintenance, and management, what are the potential water savings for a typical home landscape?
33. List factors to consider with irrigation zones.
34. Describe design criteria for uniform water distribution.
35. Describe maintenance techniques for water wise irrigation management.
36. Describe management techniques for water wise irrigation management.

Irrigation Checkup

37. What is the purpose of an irrigation checkup?

CMG GardenNotes #261

Colorado's Water Situation

Western Water Rights – Doctrine of Prior Appropriations

In Colorado and other western states, water rights are based on the ***Doctrine of Prior Appropriation*** or "first-in-time, first-in-right." Rights are established when water is put to beneficial use.

A water right is a property right to use a specified quantity of the state's water for a specified purpose. As a property right, water rights can be sold, leased, or rented (like other personal properties such as a home, apartment, or car). With the *prior appropriation doctrine* used in western states, a property owner does not own the water that rains, snows, or flows across or is adjacent to their property.

By contrast, eastern states follow some form of "riparian" water right (i.e., water rights belong to landowners bordering the water source). Without an understanding of the *doctrine of prior appropriation*, newcomers and residents may fail to realize that the purchase of land does not necessarily include the rights to irrigation water.

Under the *prior appropriation doctrine*, water rights are established by putting the water into ***beneficial use***. The person or organization putting the water to beneficial use requests the water courts to legally recognize the right with a ***decree***.

In the establishment of water rights, the water judge decrees the location at which the water will be withdrawn, the amount to be withdrawn, the use of the water, then assigns a ***priority date***. Claims with earlier priority dates have senior rights; claims with more recent priority dates have junior rights. During times of reduced rainfall or drought, ***senior rights*** (water rights established in early years) take precedence over ***junior rights*** (water rights established in recent years). Water use will be cut off for junior rights, protecting senior rights.

When a water use is changed, the water courts reissue the decree amending the owner, location, amount, or use. The priority date will be based on the previous priority date. Since Colorado's water supply fluctuates continually and the typical available water in a river basin is already owned with established water rights, issues of senior and junior rights become overly complex in drought scenarios.

Colorado's water future – *"As Colorado's water consumption reaches the limits of its allotment under interstate compacts and treaties, intensive water management will become even more critical. Water management decisions will involve examinations of all options. Conversation will become indispensable…. Inevitably, as each generation must learn, the land and the waters will instruct us in the ways of community."* (Citizen's Guide to Colorado Water Law.)

Administration

In Colorado, the Office of the State Engineer, Colorado Division of Water Resources, administers water rights. It monitors the amount of water being taken from surface and underground sources, and oversees distribution based on the priority of water rights.

Interstate water rights are set in federal agreements based on stream flows for the Platte, Colorado, and Arkansas River basins.

Water Quality Terminology

Regulated by the EPA, ***drinking water*** or ***potable water*** is water of sufficiently high quality for safe human consumption. The drinking water in many Colorado communities is of higher quality than most bottled water. Over large parts of the world, humans have inadequate access to potable water, and use sources contaminated with unsafe levels of dissolved chemicals, suspended soils, disease vectors, and pathogens.

> ***Non-potable water*** refers to water not processed to drinking-water standards. ***Raw water*** refers to untreated water taken directly from rivers and lakes.
>
> ***Wastewater*** is any water that has been adversely affected in quality by human activities. This includes domestic, municipal, or industrial liquid waste products disposed of by flushing them with water through a pipe system. ***Sewage*** technically refers to wastewater contaminated with feces and urine. However, in popular usage, sewage refers to wastewater. ***Graywater*** refers to water from the bath/shower and washing machine. ***Black water*** refers to water with feces and urine from the toilet.
>
> ***Reclaimed water*** or ***recycled water*** is former wastewater (sewage) that has been treated to removed solids and certain impurities. In most situations, it is returned to the river system, being the non-consumptive use portion of water rights. That is, the reclaimed water returned to stream flow becomes someone's water right downstream. In Colorado, some parks, golf courses, and industrial properties are irrigated with reclaimed water. Reclaimed water may be high in salt, limiting its use for landscape irrigation.

Sources of Landscape Irrigation Water

In many communities, most landscape irrigation is done with potable, drinking water purchased from the city or community water provider (who owns the water right or purchases the water wholesale). The source of water may be stream flow (from snowmelt with storage in the reservoir system) or wells. During the summer irrigation season, this puts a high demand on water treatment facilities. To deal with this, many communities aggressively market landscape water conservation.

In the west, many larger landscape sites (golf courses, parks, and industrial sites) are irrigated with non-potable water or raw water. In some western communities, homes have a waterline for drinking water and a second, non-potable waterline for irrigation. This creates significant savings in water treatment costs.

Wells

For rural homes, a common water source is groundwater (wells). The Colorado Division of Water Resources also regulates the drilling and use of groundwater. In the past, the lack of strict regulations caused a significant drop in the water table in some communities, creating problems for well users. Today the use of wells is regulated, limiting the amount of water that can be withdrawn. In recent years, new domestic well permits have been very restrictive, prohibiting outdoor irrigation. Folks moving to their rural ranchette are often shocked when they learn that they may not irrigate the landscape with their well water.

On the high plains of eastern Douglas and El Paso Counties, the community water source is non-renewable groundwater (wells). This water supply is not refilled with annual rain and snowmelt. Conservation is extremely critical.

Rainwater and Graywater

Landscape design can be creative in reducing the surface runoff of rain and snowmelt (reducing pollution of surface water). However, in Colorado state law prohibits the intentional interception and diversion of rain and snowmelt (that is, the collection of the water in a retention system for later use), including rain barrels. This is an issue of water rights, as the water already belongs to someone downstream. Collection of rain and snowmelt could interfere with another's water right.

A new exception which went into effect August 1, 2016, allows rain barrels to be installed at single-family households and multi-family households with four (4) or fewer units. A maximum of two (2) rain barrels can be used at each household and the combined storage of the two rain barrels cannot exceed 110 gallons. Rain barrels can only be used to capture rainwater from rooftop downspouts. The captured rainwater must be used on the same property from which the rainwater was captured, only for outdoor purposes, including watering outdoor lawns, plants and/or gardens. Rain barrel water cannot be used for drinking or other indoor water uses.

Colorado House Bill 13-1044, which was passed and signed during the 2013 legislative session, provides municipalities, counties, and groundwater management districts the authority to authorize graywater use and enforce ordinances. Under HB 13-1044, graywater can be used to flush toilets and irrigate landscapes at residential, multi-residential and commercial locations. As of the 2017 revision of this publication, only the City and County of Denver has permitted graywater use for irrigation, and only for sub-surface or drip irrigation of non-food crops.

For additional information on using gray water and harvesting rainwater in Colorado, refer to CSU Extension Fact Sheets #6.702, *Graywater Reuse and Rainwater Harvesting*, and #6.707, *Rainwater Collection in Colorado*, available on the CSU web site at https://extension.colostate.edu/.

Colorado's Water Use

Eighty percent of Colorado's water supply falls on the Western Slope. With the high population along the Front Range and major agriculture in northeastern Colorado, 80% of the water use (that is 80% of the water rights) is along the Front Range and High Plains. **Table 1** gives the breakdown of water use in a typical year.

Table 1. Where does Colorado's water go?

Agriculture	86.7%
Municipal	6.7%
Recreation and Fisheries	5.5%
Large Industrial	1.1%

Citizen's Guide to Colorado Water Conservation, second edition, copyright 2016.

Production agriculture is the primary user of Colorado's water supply, using 85 to 90% for food production. To grow the typical American meal, it takes 500 to 2,000 gallons of water. On an annual basis, it takes 1.6 million gallons of water to grow the food for the typical American diet of 2,000 calories per day. (Source: Michigan State University Institute of Water Research.)

Although the individual farmer can be rather inefficient in use, the runoff water returning to the system is used repeatedly by other farmers down the line, resulting in a 90% system-wide efficiency.

Landscape irrigation – Depending on the year, approximately 7 to 10% of Colorado's water supply is used for landscape irrigation, including home lawns and yards, public and commercial landscapes, parks, and golf courses. During the summer irrigation season, 50 to 75% of a community's water use may be for landscape irrigation. Because it is highly visible, landscape irrigation is often targeted for conservation.

Based on community water use, the average landscape receives twice the amount of irrigation water that plants need. This is due to poor irrigation system design, maintenance, and management. In research of actual yard-by-yard comparisons, most gardeners are rather efficient; however, others may be applying 5 to 10 times the amount of water needed!

With the rapid growth in Colorado's population, some farmers have sold, leased, or rented water rights to communities. This creates a significant shift in water use during periods of drought and creates long-term dynamics between agriculture and urbanization.

Other demands on water flows come with power generation, recreational use, and wildlife habitats. As an important side issue, during periods of drought (decreased stream flow), hydroelectric power generation will also decrease.

A standard unit for measuring large quantities of water is the ***acre-foot***. An acre-foot is the amount of water needed to cover an acre of land to a depth of one foot, or 325,851 gallons. The standard unit of measuring water flow is cubic feet per second, or cfs. One cfs equals 7.48 gallons per second or 448.83 gallons per minute.

Community Water Infrastructure

A community typically invests $30,000 to $60,000 per new household for the water and sewer treatment infrastructure. Due to landscape irrigation, Colorado communities typically experience ten to fifteen days per year when water use greatly exceeds average use. Because peak demand occurs only a few days a year, developing the water processing and delivery infrastructure to adequately meet water needs during these few peak days is very expensive. One Colorado community, for example, is facing a $35 million expansion to its water-processing infrastructure to meet peak demand for just five days a year!

The high cost of meeting peak water demand is why communities often adopt irrigation schedules based on address (like odd/even days or other set irrigation day programs). Schedules are designed to spread the water demand more evenly over the week. Just imagine the water infrastructure that would be required if most residents decided to water the lawn on a Saturday morning during a hot week!

Odd/even or set watering day water restrictions do not effectively reduce total water usage. An underlying fear with gardeners is that they cannot hold off irrigation until their next turn, so the lawn is watered just because it is their turn. Irrigation restrictions that allow for no irrigation on some days of the week more effectively conserve water.

Population Growth and Water Conservation

Colorado's rapid population growth creates growing pains for Colorado's water supply. Due to planning by forefathers, some communities have good water resources, including senior rights. Other communities seriously lack sufficient water rights to support growth. Residents who do not understand western water rights may have strong values and opinions about where water should and should not be used during shortages. Under western water rights, market price to purchase water rights will determine who has water. What are you willing to pay?

Water conservation, both indoors and outdoors, is essential for communities to meet the water demands for growth. Some communities with limited water resources have put restrictions on new building permits. This could be viewed as a form of discrimination aimed at keeping newcomers out of the "white" community.

Other communities, with limited water resources, have allowed for growth by purchasing "surplus" water from water rights holders (such as other communities or farmers). Some of the extreme water restrictions during the drought of 2002 are examples of what happens in years when "surplus" water is not available for purchase.

With growth, water conservation is also critical even for those communities with senior water rights. For example, Denver Water and Colorado Springs Utilities, two of the state's larger water providers, are running out of water resources to support continued growth at current usage rates. Conservation is essential.

Water for growth must come from water conservation. This will be through voluntary conservation and aggressive pricing structures to push conservation. Since Colorado's climate typically has a multi-year drought about every 20 years, water conservation is important to all residents.

CMG GardenNotes on Irrigation Management

- #261, *Colorado's Water Situation.*
- #262, *Water Movement Through the Landscape.*
- #263, *Understanding Irrigation Management Factors.*
- #264, *Irrigation Equipment.*
- #265, *Methods to Schedule Home Lawn Irrigation.*
- #266, *Converting Inches to Minutes.*
- #267, *Watering Efficiently.*
- #268, *Irrigation Management Worksheet: Lawn In-Ground Check-Up.*

Other Resources to Examine

Water Education Colorado has publications available at
https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/.

- Citizen's Guide to Colorado's Interstate Water Compacts, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorados-interstate-compacts/.
- Citizen's Guide to Colorado Water Law, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-water-law/.
- Citizen's Guide to Colorado Groundwater, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-groundwater/.
- Citizen's Guide to Colorado Water Quality Protection, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-water-quality-protection/.
- Citizen's Guide to Where Your Water Comes From, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-where-your-water-comes-from/.
- Citizen's Guide to Colorado's Transbasin Diversions, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorados-transbasin-diversions/.
- Citizen's Guide to Colorado's Water Heritage, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-water-heritage/.
- Citizen's Guide to Colorado Water Conservation, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorado-water-conservation/.
- Citizen's Guide to Colorado's Environmental Era, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-colorados-environmental-era/.
- Citizen's Guide to Denver Basin Groundwater, https://www.watereducationcolorado.org/publications-and-radio/citizen-guides/citizens-guide-to-denver-basin-groundwater/.

Authors: David Whiting, CSU Extension, retired. Revised September 2017 and reviewed August 2022 by Kurt M. Jones, CSU Extension.

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CMG GardenNotes #262

Water Movement Through the Landscape

Soil-Plant-Water System

Water constantly moves in and out of landscapes. Scientists use the concept of the soil–plant–water system to explain the complex ways water moves in landscapes. The ***soil–plant–water system*** describes water entries, storage and exits in a landscape from the plant's perspective. Understanding how water moves through a landscape is important when designing or using an irrigation system.

Most plants constantly use water, but store little in their tissues. Therefore, plants rely on soil water reserves being periodically replenished through entries of water into the soil–plant–water system.

Water Entries

Water enters the landscape in several ways.

- First, water enters through **precipitation**, such as rain or snow.
- Second, gardeners may add water through **irrigation**.
- Third, water may run over the surface of the landscape from a neighboring area **run-on**.
- Fourth, water may enter as **seepage** from groundwater.

In different landscapes, some entry methods are more important than others. For example, in a wet climate most water enters through precipitation. Alternatively, in dry climates like many areas of Colorado and the West, most water enters via irrigation. If a landscape is located below a heavily irrigated property or below a melting snowfield, run-on or seepage may be the most important entry. Taking water entries into account helps gardeners determine how much water must be added through irrigation to keep plants healthy.

Water Storage

In most landscapes, soil is the major water storage site for plants. Once water has entered the landscape through precipitation, irrigation, run-on, or seepage, water penetrates the soil surface through **infiltration**.

Water infiltrates into sandy soils much more quickly than into clayey soils. For example, a sandy soil may take in four inches per hour, but a clayey soil may take in only half an inch of water per hour –

that is eight times more slowly. To prevent water waste via runoff, gardeners should take the soil's infiltration rate into account when scheduling landscape irrigation.

Once water infiltrates the soil surface, it **percolates** downward and sideways through the soil profile. Water moves rapidly through large soil pores, and slowly through small pores. Therefore, sandy soils with primarily large pores will accept and release water readily, holding little. On the other hand, clayey soils with primarily small pores will wet and dry slowly.

After water percolates through the soil profile, some of the water will be stored in small pores, and in water film surrounding soil particles. Plants can use some of the stored water (called **plant-available water**) by extracting it with their roots. However, some of the water is held so tightly by small pores or particle surfaces that plant roots cannot extract it, so it is **unavailable** to plants.

When plants need more water than is available in the soil, they experience **water stress**. Because water is a component of photosynthates, photosynthesis stops and growth stops. Furthermore, water stress compromises plant defense systems, making them more susceptible to insect and disease problems and abiotic stress factors.

Some soils store more water than others. The amount of water held in the soil and available to plants depends on the following factors:

- Clay content (the amount of small pore space) to hold water.
- Soil organic content – Organic matter holds ten times more water than sand.
- Rooting depth – Plants with deeper roots reach a larger water supply.

Water Exits

Water eventually leaves the landscape. Water may exit by running over the land surface (**runoff**). It may leave the system through **off-target application**, such as sprinklers that apply water to the sidewalk rather than the soil. Sometimes, water percolates below the plant's root zone (**leaching**).

Water **evaporates** from the soil surface, causing soils to dry from the top downwards. Mulches help ameliorate water loss by reducing evaporation from the soil surface. Mulches also improve plant growth by helping to maintain moisture in the top layer of soil, thereby stabilizing soil moisture around roots.

Some water is taken up by plant roots, transported through plant tissues and used in photosynthesis for plant growth. Most of the water taken up by plants **transpires** out of the leaf's surfaces. Because evaporation and transpiration are often the two most important water exits in landscapes, scientists combine these two pathways into one term called ***evapotranspiration***.

Evapotranspiration (abbreviated as **ET**) is a measurement of water use combining water used by plants for transpiration, photosynthesis, and growth, plus water lost from the soil surface evaporation. It is most often defined as a <u>rate of water loss</u>, such as ¼ inch per day. In this example, an ET of ¼ inch per day means that a ¼ inch depth of water was lost from the soil–plant–water system through evaporation and transpiration.

ET measurements help gardeners make informed decisions about how much irrigation water to add. In some Colorado communities, ET rates are available on-line through weather stations or water utilities.

ET rates change daily through the growing season. High ET rates occur when there is bright sunshine, high wind, high temperature, and/or low humidity.

Summary

Water entries and exits are summarized in **Figure 1**. To maximize plant health in the dry climates of Colorado and the West, gardeners can take two approaches. First, they can apply soil management practices to increase soil water storage. This helps ensure adequate water supplies for plants when needed. Second, gardeners can use effective irrigation management practices to ensure that irrigation water is made available to plants and not wasted.

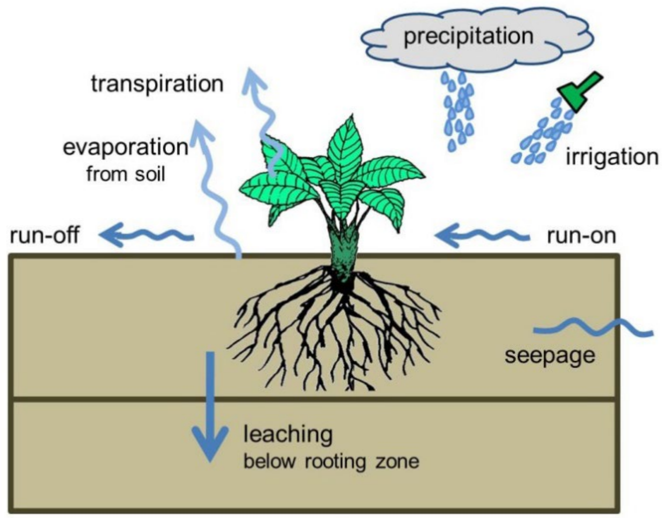

Figure 1.
Typical water entries and exits in the soil-plant-water system.

Authors: Catherine Moravec, former CSU Extension employee and David Whiting, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed October 2022 by Marvin Reynolds, CSU Extension.

Reviewed October 2022

MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #263

Understanding Irrigation Management Factors

Poor watering practices lead to many common landscape problems, including iron chlorosis, low plant vigor, foliar diseases, root rot, and water pollution. On a community-wide basis, landscape irrigation typically uses twice the amount of water that the plants require, **adding unnecessary demand to a limited and valuable natural resource, water.**

Several complex factors work together in irrigation management, including the following:

- The soil's ***water-holding capacity*** (the quantity of water held by the soil).
- ***Evapotranspiration, ET,*** (a measurement of actual water used by the plant and lost from the soil by evaporation). ET is a factor of weather (temperature, wind, humidity, and solar radiation) and plant growth.
- Rooting depth.
- The plant's ability to extract water from the soil.
- The plant's water need.

Location of Soil Moisture

Following dry winters or summer droughts, soils may be dry in the top layers with moisture only in deeper layers. Following extended drought, it is possible that soils may be dry in deep layers and wet only in the top few inches following a light rain or irrigation.

Dry soils tend to resist wetting. Alternating irrigation applications with shutoffs to allow water to soak in (cycle and soak irrigation) may be necessary to wet a dry soil profile.

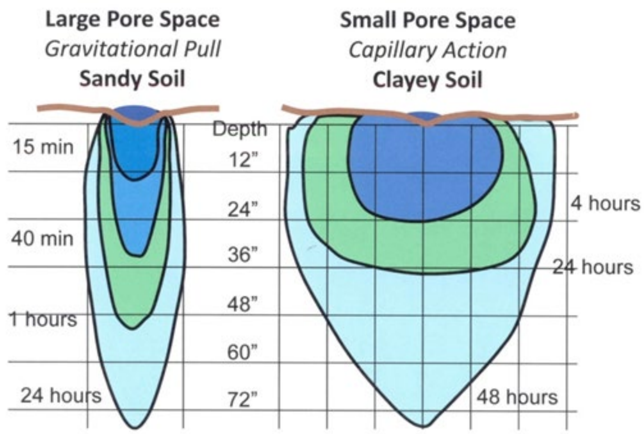
Irrigation management is applying the correct amount of water at the correct frequency to supply the water needs of the plants. Additional water would be wasted as it would leach below the rooting zone.

Type of Soil

Soil texture, structure, and organic matter content determine the soil's water-holding capacity and water movement in soil. Water coats the soil particles and organic matter, and is held in small pore space by cohesion (chemical forces by which water molecules stick together). Air fills the large pore space.

In large pore space, water readily moves downward by **gravitational pull**. In small pore space, water moves slowly in all directions by **capillary action**. **Figure 1** illustrates water movement in a sandy soil with large pore space and clayey soil with small pore space.

Figure 1. Comparative movement of water in sandy and clayey soils.



Sandy Soil

Large pore space dominates sandy soil, giving it rapid drainage. Thus, surface runoff of irrigation water is generally not a concern with sandy soil. Water movement is primarily in a downward direction by gravitational pull in the large pore space with limited sideward and upward movement by capillary action in the small pore space. Thus, in drip irrigation the emitters must be placed closer together than in clayey soils.

Sandy soils have a low water-holding capacity due to the lack of small pore space. Organic matter, which holds ten times more water than sand, significantly improves the water-holding capacity of sandy soils.

As a point of clarification, plants on sandy soils do not use more water than plants on clayey soils. **With the limited water holding capacity, sandy soils simply need lighter and more frequent irrigations than clayey soils.** Water readily moves below the rooting zone when too much is applied at a time.

Clayey Soil

Small pore space dominates clayey soil, giving it high water holding capacity. However, the lack of large pore space limits water movement. Water is slow to infiltrate into clayey soil, often leading to surface run-off problems. Cycle and soak irrigation is appropriate on clayey soils to slow application rates and reduce surface runoff.

In clayey soils, soil ***structure*** (creating secondary large pore space) also directly influences water movement and soil oxygen levels. Compaction (a reduction in pore space) further limits water movement and reduces soil oxygen levels, resulting in a shallow rooting depth. The total water supply available to plants is reduced by shallower rooting.

With higher water-holding capacity but limited drainage, clayey soils need heavier, but less frequent irrigations than sandy soils. Watering too often can aggravate low soil oxygen levels. Because water moves slowly in all directions by capillary action, drip emitters may be placed further apart than in sandy soils.

For additional discussion on texture, structure, and pore space, refer to CMG GardenNotes #213, *Managing Soil Tilth: Texture, Structure, and Pore Space*.

Water Holding Capacity

The terms, ***saturation, field capacity***, ***wilting point***, and ***available water*** describe the amount of water held in a soil. [**Figure 2**]

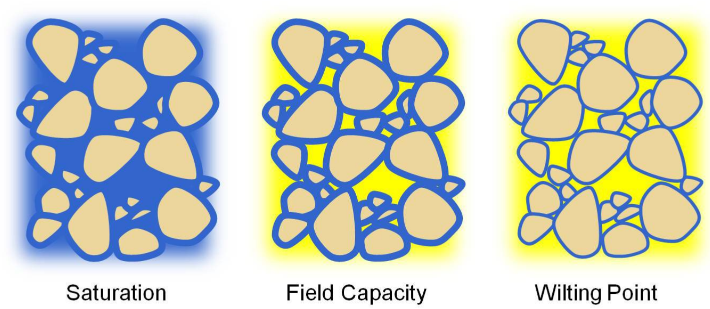


Figure 2.
At ***saturation*** water fills the pore spaces. At ***field capacity*** air occupies the large pore spaces while water fills the small pore spaces. At the ***wilting point***, plants cannot extract additional water from the soil.

Saturation refers to the situation when water fills both the large and small pore spaces. With water replacing air in the large pore spaces, root functions temporarily stop (since roots require oxygen for water and nutrient uptake).

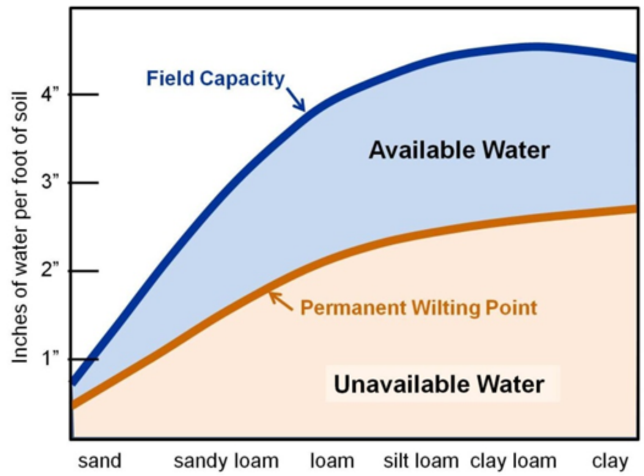
Prolonged periods without root oxygen will cause most plants to wilt (due to a lack of water uptake), to show general symptoms of stress, to decline (due to a lack of root function) and to die (due to root dieback). During summer flooding of the Mississippi River in Iowa and Illinois it was observed that healthy trees were tolerant of a short-term flooding period, whereas trees under stress or in a state of decline were very intolerant.

Field capacity refers to the situation when excess water has drained out by gravitational pull. Air occupies the large pore space. Water coats the soil particles and organic matter and fills the small pore space. A handful of soil at or above field capacity will glisten in the sunlight. In clayey and/or compacted soils, the lack of large pore space slows or prohibits water movement down through the soil profile, keeping soils above field capacity for a longer period of time and limiting plant growth.

Permanent wilting point refers to the situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point, the soil feels dry to the touch. However, it still holds about half of its water; the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil.

Available water is the amount of the water held in a soil between *field capacity* and the *permanent wilting point*. This represents the quantity of water "available" or usable by the plant. Note from **Figure 3**, that the amount of *available water* is low in a sandy soil. Loamy soils have the largest amount of *available water*. In clayey soils, the amount of *available* *water* decreases slightly as capillary action holds the water so tightly that plants cannot extract it.

Figure 3.
Relationship between soil texture and available water.



Evapotranspiration, ET

Evapotranspiration, ET, is the rate at which a plant uses water for transpiration and growth plus evaporation from the soil surface. Primary influences on ET include weather factors (temperature, wind, humidity, and solar radiation) and the stage of plant growth.

On hot, dry, windy days, ET will be higher. On cool, humid days, ET will be lower. In the summer, ET changes significantly from day to day. To illustrate seasonal variations, the typical irrigation requirement for cool season turf in Colorado is given in **Table 1**.

Table 1.
Weekly Water Requirements for Cool Season Lawns in Colorado

Inches of water (irrigation and rain) per week

Late April	May	June	July	August	September	Early October
0.75”	1.0”	1.0”	1.5”	1.5”	1.0”	0.75”

Rooting Depth

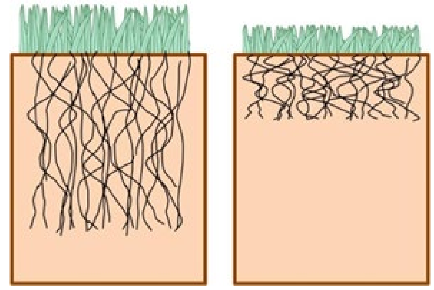
Irrigation management should consider the rooting depth, adding water to the actual root area. Root systems may be contained or spreading. Annual plants tend to have contained root systems, whereas woody trees and shrubs have more wide-reaching roots.

A newly planted annual flower or shallow-rooted plant cannot obtain water from deeper soil depths. Deep watering of these plants is wasteful.

Roots only grow where there are adequate levels of soil oxygen. In clayey or compacted soils, where a lack of large pore space restricts oxygen levels, roots will be shallow. Plants with a shallow rooting depth simply have a smaller profile of soil water to use. [**Figure 4**]

A plant with deeper roots will need less frequent but heavier irrigation than the same plant with shallow roots. This, however, should not be interpreted as necessarily using less water. For example, turf-type fall fescue may root more deeply than Kentucky bluegrass (if soil oxygen levels allow). With deeper rooting, it requires less frequent irrigations, but irrigations must be heavier to recharge the rooting zone. Actual water-use rates of Kentucky bluegrass and tall fescue are similar.

Figure 4.
Plants with deeper rooting systems reach a larger supply of water and can go longer between irrigations. With deeper rooting, irrigations will be less frequent but heavier to recharge the larger rooting zone. In compacted or clayey soils, low levels of soil oxygen limit rooting depth, thus reducing the supply of available water.



Irrigation: How Much? How Often?

Table 2 illustrates the relationship of the soil water-holding capacity, ET, and rooting depth.

These textbook figures make a good starting point for understanding irrigation management. Most automatic sprinkler systems are set to keep the lawn green in the summer. (i.e., set for the higher summer water need). Without seasonal adjustments on the irrigation controller the lawn will be over-irrigated in the spring and fall time by about 40%. This springtime over-irrigation is a primary contributing factor to iron chlorosis.

Table 2. Irrigation Summary of a Textbook Soil

	Soil Type		
	Sandy	**Sandy Loam**	**Loamy & Clayey**
Available water per foot of soil	0.5”	0.75”	1”
6-inch rooting depths			
Inches of available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone)	**0.25”**	**0.38”**	**0.5”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	1.8 days	2.7 days	3.6 days
Summer (at 1.5 inches/week)	1.2 days	1.8 days	2.4 days
12-inch rooting depth			
Inches of available water, and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone)	**0.5”**	**0.75”**	**1”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	3.6 days	5.3 days	7.1 days
Summer (at 1.5 inches/week)	2.4 days	3.6 days	4.8 days
24-inch rooting depth			
Inches available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone)	**1”**	**1.5”**	**2”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	7.1 days	10.7 days	14.2 days
Summer (at 1. 5 inches/week)	4.8 days	7.1days	9.5days

Fine-Tuning for the Site

These textbook figures are a good starting point to understand irrigation management. When coupled with careful observations, a gardener can quickly fine-tune their irrigation schedule to the site-specific irrigation demands.

On a typical July day, if the lawn is using an average of 0.20 inch per day, you can estimate the water-holding capacity and rooting depth by observing irrigation needs. For example:

- **If the lawn will go five days on one-inch of water**, and additional water will not extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is one inch. <u>One inch would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be one inch of water every five days.
- **If the lawn will go four days on 0.80 inch of water**, and additional water will not extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.80 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be 0.8 inches of water every four days.
- **If the lawn will go two days on 0.40 inch of water**, and additional water will not extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.40 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone</u>. Irrigation options include the following: The ideal irrigation would be 0.4 inches of water every two days.

These textbook figures do not consider exposure, wind, or irrigation system efficiency. They make a good starting point but **will need adjustments to fine-tune it to the specific site.** For example:

- In full shade (not under large trees), water use could be 30% lower.
- In unusually hot weather or in open, windy sites, water use could be 20% to over 50% higher.
- In the rooting area of large trees, water use could be 30% to 50% higher as the tree is pulling water as well as the plants in the shade under the tree.

For example, in one landscape, the front lawn (open site with constant summer wind) uses 20% more water than the normal ET. While the back lawn (sheltered from the wind by the house and wood fence) uses the normal ET.

The trick for efficient irrigation is to start with the textbook numbers then fine tune them based on observation. **Based on actual observations for each zone, adjust the run time up/down in 10% increments to fine-tune the irrigation.**

These examples are based on typical July weather. <u>For cooler spring and fall seasons, the amount of water to apply generally remains the same, with a longer interval between irrigations.</u>

Other Factors Influencing Irrigation Management

Other factors also have a direct influence on the <u>actual</u> water-holding capacity and irrigation demand:

- **Exposure** – The plant’s exposure influences water demand. Sun, heat, and wind increase water demand. Shade decreases water demand. Water use for a lawn on a windy, southwest-facing slope could be double the water use for a lawn in full sun but sheltered from wind and extreme heat.

- **Soil organic matter content** – Since organic matter holds over ten times more water than sand, a sandy soil with good organic content (around 4% to 5%) will hold more water than indicated in the table above. Over time, clayey soils with good organic content may have an improved soil structure, supporting a deeper rooting depth.
- **Previous irrigation pattern** – Plants adjust rooting depth (to the extent that soil oxygen levels allow) to where soil water is available. Frequent irrigation eliminates the need for plants to develop a deep rooting system. A shallow rooting system makes the plant less resilient to hot, dry weather.
- **Stage of growth** – The stage of growth also influences ET. Water needs increase as a plant grows during the season and peaks during flowering and fruit development.
  - Compared to the rooting system of a mature plant, newly planted or seeded crops do not have the root systems to explore a large volume of soil for water. Recently planted and seeded crops will require frequent, light irrigations. In our dry climate, even "xeric" plants need regular irrigation to establish.
  - Confusion about plant water requirements can arise from changing needs as plants move through their life cycles. For example, newly planted trees are extremely intolerant of water stress. Established trees in good health are tolerant of short-term water stress. Older trees in decline are intolerant of water stress. General statements about the ability of trees to tolerate dry situations need to consider life-cycle stages.
- **Water demand of a plant** – Plants vary in the demand for water to 1) support growth, and 2) survive dry spells. (Note that the two are not necessarily related.)
- **Ability to extract water** – Plants vary in their ability to extract water from the soil. For most plants, the *available water* is about 50% of the soil's total water supply before reaching the *permanent wilting point*. Onions are an example of a crop that can only extract about 40%.
- **Drought mechanism** – A similar, <u>but unrelated</u>, issue is the plant's ability to survive on dry soil. Plants have evolved with a variety of drought mechanisms:
  - Small leaves, waxy leaves, hairy leaves, and light-colored leaves are characteristics of many plants with lower water requirements.
  - Some plants, like cacti, have internal water storage supplies and waxy coatings.
  - Many plants, like impatiens, readily wilt as an internal water conservation measure.
  - Trees close the stomata in the leaves, shutting down photosynthesis, during water stress.
  - Some plants, like Kentucky bluegrass, can go dormant under water stress.
  - Kentucky bluegrass slows growth as soils begin to dry down. (Does your irrigation management capitalize on this dry-down, also reducing your mowing?)
  - Tall fescue is an example of plants that survive short-term dry soil conditions by rooting more deeply (if soil conditions allow) to reach a larger water supply. But tall fescue cannot go dormant.

Tools to Evaluate Soil Moisture

Gardeners have several tools available to evaluate the amount of moisture in their soil.

Plant observation is a good guide to soil moisture. Look for color change and wilting. For example, Kentucky bluegrass will change from a blue green to gray blue with water stress. Footprints in the lawn that do not rebound within sixty minutes are another symptom to watch for. Use of an indicator plant in a perennial flower bed is also useful. Certain perennials such as *Ligularia stenocephala* 'The Rocket' and *Eupatorium rugosum* (White Snakeroot) often wilt before other perennial flowers, indicating irrigation will shortly be required.

The **hand feel method** used when digging in soil is more evidence of moisture content. Is the soil powder dry, medium moist or even muddy?

The ease with which a **probe** can be inserted can be telling. A screwdriver will punch into the soil more easily when wet than when dry. However, this can be very misleading, as a clayey soil may be difficult when wet and impossible when dry. A sandy soil may be easy when dry and easier when wet.

Soil moisture meters are available. A simple houseplant water meter can be used outdoors. Although the exact number reading may give little information, the overall indication of wet or dry is useful. It will read on the wet side when the soil has high nutrients or salts, and on the dry side when the soil is low in nutrients and salt. Permanently buried soil moisture sensors are available to automatically activate irrigation systems when the soil has dried.

CMG GardenNotes on Irrigation Management

- #260, *Irrigation Management: References and Review Materials.*
- #261, *Colorado's Water Situation.*
- #262, *Water Movement Through the Landscape.*
- #263, *Understanding Irrigation Management Factors.*
- #264, *Irrigation Equipment.*
- #265, *Methods to Schedule Home Lawn Irrigation.*
- #266, *Converting Inches to Minutes.*
- #267, *Watering Efficiently.*
- #268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Checkup.*

Authors: David Whiting, CSU Extension, retired; with Carl Wilson, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed Augst 2023 by Chris Hilgert, CSU Extension.

Reviewed Augst 2023

CMG GardenNotes #264

Irrigation Equipment

Equipment for delivery of landscape irrigation water ranges from automated in-ground sprinkler systems and drip irrigation systems to hose-end watering. A basic outline of each with their strengths and limitations follows.

In-Ground Sprinklers

Variations of plantings in the personal garden landscape require diverse types of irrigation equipment. For lawns, sprinkler irrigation with pop-up spray heads and rotor heads are generally used. Because each type of sprinkler delivers water at a different rate, do not mix sprinkler types in a zone.

All sprinkler systems must comply with local building codes, requiring building permits and inspection. All in-ground sprinkler systems have the following basic components:

Point of Connection – The system starts at the point of connection where the supply line connects to the water supply, usually in the basement of the typical house. The size of the pipe and water pressure determines water flow and thus influences the design of the system (how many heads can run at one time). [**Figure 1**]

Pressure Regulator – A pressure regulator provides uniform, lower water pressure for uniform water delivery. This is typically found just before the point of connection. It should be set at 30 to 40 psi for the landscape irrigation system and household water use. Sprinkler systems have maintenance problems and values may fail to shut off when the pressure is above 80 psi. Pressure regulators are typically not found in older homes. Due to increased uniformity of water delivery, adding a pressure regulator may result in significant water savings in landscape irrigation.

Figure 1. Point of connection with pressure regulator and shut-off valve for outdoor line and drain valve that drains the outdoor line to the backflow prevention device (located just outside the house).

Backflow Prevention Device – Local building codes require a backflow prevention device to protect the community's water supply. This is typically placed where the water line comes out of the house. Some valves have a backflow prevention device built into the valve. The type to use depends on local building codes. [**Figure 2**]

Figure 2.
Required by local building codes, backflow prevention devices are typically located where the line comes outside from the house.

Main Supply Line – The main supply line is the line holding water under pressure throughout the summer. It splits in the valve box, providing a valve for each zone. To minimize maintenance headaches, use Schedule 40 PVC pipe for below-ground supply lines and copper pipe for any above-ground pipe. PVC fittings are connected with special glue. Copper pipefittings are soldered. [**Figure 3**]

Figure 3.
Valve box with two zone valves.

Secondary Lines – Beyond the valve, secondary lines (lines that have water only when the zone is running) go to sprinkler heads. Being easy to work with, these are generally made of flexible black poly pipe. Connect poly pipe fitting with pinch clamps. The size of the pipe and the water pressure determine the number of sprinkler heads that can be used per zone. Various brands of sprinkler equipment have planning booklets with specific details for their product lines.

Controller – A controller (timer) runs the system from a central location (typically in the garage). In the home garden market, there are many styles of controllers with a variety of features. [**Figure 4**]

Figure 4.
Many brands of controllers offer a variety of features.

End of Season

In climates where the soil freezes, the lines need to be **drained** in the winter. This starts by turning off the water with the valve near the point of connection and opening the internal drain line. This drains the line to the backflow prevention valve (which is outdoors at the high point in the system).

Depending on how the system was designed, there are several methods to drain the supply line and secondary lines. Some systems are “blown out” by connecting an air compressor. Other systems have valves that are manually opened, allowing for drainage by gravity. In some systems, secondary lines have self-draining valves that automatically drain the line each time the water is turned off.

Pop-Up Spray Heads

This is a generic name for sprinklers that automatically “pop up” with a fan-shaped spray pattern and do not rotate when running. The head retracts by spring action when the water is turned off. [**Figure 5**]

Figure 5.
Pop-up spray heads are used for small areas, up to fifteen feet.

Delivery Pattern – Pop-ups spray heads are best suited for small to moderate sized home lawn areas (larger than seven to ten feet wide up to thirty to forty-five feet wide) and irregular or curvilinear areas.

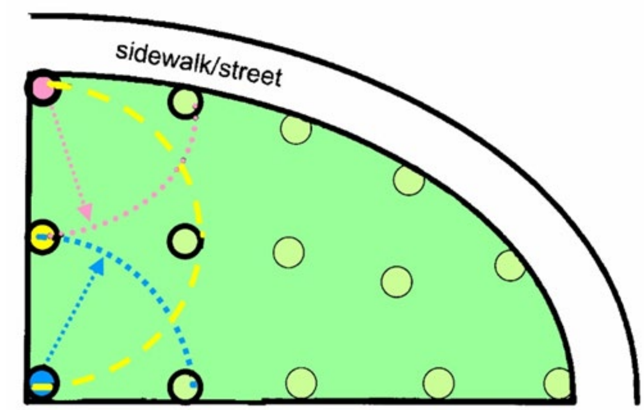
Pop-up spray nozzles are most common with fifteen-, twelve-, ten-, and eight-foot ranges. The radius can usually be adjusted down about 30%, using the nozzle’s adjustment screw. Therefore, a commonly available ten-foot nozzle can be adjusted down to seven feet. Any greater adjustment would significantly distort the pattern, resulting in poor application efficiency.

The spray pattern of a pop-up spray head depends on the nozzle’s ability to water quarter circles, half circles, or full circles. Some manufacturers offer adjustable arch nozzles that can be set at any angle. However, do not use adjustable nozzles where a fixed nozzle would work, as the uniformity of water delivery is not as high.

Some specialty patterns to manage narrow, rectangular turf areas are available (often called “end-strip,” “center-strip” or “side-strip” nozzles). However, nozzle performance is not as uniform compared to quarter-circle, half-circle, or full-circle nozzles.

Within any given brand, spray nozzles have “match precipitation rates.” That is, a half-circle head uses half the amount of water per hour as a full-circle head. With match precipitation rates, full, half and quarter circles may be used in the same zone. It is also acceptable to mix a combination of nozzle radii in a zone.

Figure 6.
For uniform water distribution, the spray head needs to release water above the grass height.



Pop-Up Height – For uniform water distribution, the sprinkler heads should rise above the grass height, making the four inch pop-up style most popular. High pop-up heads, with a twelve inch rise, are suitable for ground-cover areas and lower flowerbeds. [**Figure 6**]

Pressure – Pop-up spray heads work best with water pressure around 30-40 psi. The water pressure at some homes may be significantly higher, and an in-line pressure regulator will be needed in these cases. A sprinkler producing a “mist cloud” around the head is a common symptom of excessive pressure. This gives a distorted distribution pattern, significantly increases water use, and leads to increased maintenance problems.

In addition, a grade change of more than eight vertical feet on a single zone will result in significantly higher pressure at the lower end, creating distribution problems.

Small Areas – Small areas less than seven to ten feet wide are difficult to irrigate efficiently with pop-up spray heads. Consider landscape alternatives. For example, that small side yard between houses may be an excellent site for a low maintenance, non-planted, non-irrigated mulch area. Alternatively, the small area could be a shrub/flower bed watered with drip irrigation. A narrow lawn strip may be watered efficiently with the new sub-surface drip for lawns.

Precipitation Rate – Pop-up spray heads have a high-water delivery rate (precipitation rate) of 1 to 2½ inches per hour. At the typical rate of 1½ inches per hour, the zone would apply ½ inch of water in just twenty minutes.

Rotor Head

Rotor heads mechanically rotate to distribute the spray of water. Impact and gear-driven heads are two common types in the home garden trade. [**Figures 7** and **8**]

Rotor heads in the home garden trade are best suited for larger lawn areas, generally eighteen-to-twenty-four-foot radius and greater. Some rotor-type heads in the commercial line have a radius of thirty to ninety feet.

Figure 7.
Impact or impulse heads rotate as the water stream coming from the nozzle hits a spring-loaded arm. Impact heads tend to experience fewer problems with marginal (dirty) water quality.

Figure 8.
Gear-driven heads use the flowing water to turn a series of gears that rotate the head. Gear-driven heads are quieter to operate than impact heads.

The spray pattern depends on the head. Most can be set at any angle from 15º up to a full circle. Some are adjusted at 15º increments. Others are designed for a quarter-circle, half-circle, or full-circle spray pattern.

In rotor head design, <u>do not mix quarter, half, and full circle patterns in the same zone</u>. The water flow is the same for each head, but the area covered will be different. For example, a full circle (covering twice the area of a half circle) will have half the precipitation rate of a half circle. The full circle will need to run twice as long to apply the same amount of water as the half circle.

Pressure – Rotor heads typically operate at 30 to 90 psi, 30 to 40 psi being most common for heads in the home garden trade. Better quality heads have built-in pressure regulators.

Precipitation Rate – Rotors are more uniform in water distribution than pop-up spray heads and take much longer to water. As a rule of thumb, rotor heads deliver water at a rate of ¼ to ¾ inch per hour. At the typical precipitation rate of ½ inch per hour, it would take sixty minutes to apply ½ inch of water. The slower precipitation rate can be an advantage on clayey or compacted soils where water infiltration rates are slow.

Multi-Stream Rotors

The newer multi-trajectory rotating streams provide unmatched uniformity in water distribution for significant water savings. They have a lower application rate, reducing runoff on compacted, clayey soils and slopes. The streams of water are large enough to resist wind disturbance, so they reduce the amount of water blowing onto driveways, sidewalks, and roads.

Several manufacturers offer multi-stream rotors in today's market, including Hunter MP Rotator, Toro Precision Series, Rainbird R-VAN, and others. Generally used by landscape contractors, multi-stream rotors are less common in the home garden trade. For the personal gardener, they may be found online.

Almost any type of sprinkler head can be retrofitted with an MP Rotator® sprinkler, including spray heads and traditional rotors. MP Rotators® can apply water to distances ranging from four to thirty feet. They can also be used to water narrow planting strips, which are often difficult to water effectively with traditional sprinkler heads.

Depending on the head, they perform best at 30 to 40 psi. With matched precipitation rates, quarter, half, and full heads may be mixed in a zone.

Strengths and Weaknesses of In-Ground Sprinklers

Strengths of in-ground sprinklers include the following:
- Convenience.
- Saving Time.
- Ability to irrigate small areas.
- Efficient if well-designed, maintained, and managed according to plant water needs.

Weaknesses of in-ground sprinklers include the following:
- Inefficient if poorly designed, maintained, or managed.
- Being too convenient, gardeners give them little attention, which can cause significant water waste.

Bubblers

Small groupings of flowers and other small plants can be efficiently watered with bubblers, which flood an area and rely on the natural wicking action of the soil to spread the water.

They are ideal for level shrub and ground cover areas. Heads are typically placed at three to five feet intervals or placed by individual plants for spot watering. Stream bubblers are directional and come in a variety of spray patterns.

Bubblers deliver water faster than drip emitters and are used to water trees and shrubs. Refer to manufacturers' literature for design and management criteria related to various models.

Drip Systems

For flower and shrub beds, small fruits and vegetable gardens, drip emitters, drip lines, micro-sprayers, and soaker hoses are popular.

Water use rates, weed seed germination, and foliar disease problems are reduced in drip systems that do not spray water into the air and over the plants and the soil surface. As a rule of thumb, a drip system coupled with mulch can reduce water needs by 50%.

Figure 9. In-line filter and pressure regulator going to drip line poly tubing.

Drip emitters, micro-sprayers, and drip lines require clean water, which is free of soil particles, algae, and salts. In-line filters are part of the system. Water quality is generally not a problem when using potable water sources. However, with non-potable water sources, the filtering system required may be expensive and high maintenance, making drip impractical.

Drip systems work with lower pressures (typically around 20 psi), usually with in-line pressure regulators. The system snaps together with small fittings. No gluing or bands are required. It is much easier to work with if the tubing has been warmed by the sun for an hour. [**Figure 9**]

The system is put together with half-inch and quarter-inch poly tubing, fittings, and emitters. For the main line and branch lines, half-inch poly tubing is used. The quarter-inch micro-tubing serves as feeder line to individual drippers or micro-sprinklers. Ideally, the tubing is on the soil surface under the mulch.

Specifications on design and management vary among manufacturers and types selected. Refer to the manufacturer's literature for details. Typical run times are sixty to ninety minutes.

Figure 10. Drip emitter on ½" poly tubing.

Drip systems are easy to automate by connecting the zones to valves and a controller (like an in-ground system for a lawn). For ease of programming to the specific watering needs of the drip system, use a dedicated controller for multiple drip zones. In small yards, a single zone or two could be added to the controller used for the lawn, but they would run on a different program than the lawn to match the different watering needs.

When connected to the garden hose, the zone can be automated with single-zone controllers that connect with hose-end fittings at the tap. Some simple models turn the water off after a set number of minutes or gallons. More elaborate battery-operated models turn the water on and off at the day and time interval set by the gardener.

Like any irrigation system, drip systems require routine maintenance. They are not an install-and-forget type of system.

For additional information on drip irrigation, refer to CSU Extension Fact Sheet #4.702, *Drip Irrigation for Home Gardens.*

Drip Emitters deliver water at a slow, consistent rate, such as one-half gallon, one gallon, or two gallons per hour. Emitters can connect to the branch line or extend on micro-tubing out to individual plants or pots. Small annuals and perennials typically have one emitter per plant. Several would be used spaced around larger perennials, shrubs, and small trees. [**Figure 10**]

As a point of clarification, some gardeners mistakenly think that using half, one, and two gallon per hour drippers is an effective method to manage differing water needs. Although this works to a small degree, the concept is basically flawed. The two-gallon per hour drippers will have significantly larger wetting zones than the half-gallon per hour dripper. However, plants with the higher water needs (two-gallon/hour drippers) do not necessarily have a larger root spread. Likewise, plants with lower water needs (half-gallon/hour dripper) will not necessarily have a smaller root spread (in fact, a large root spread is what makes some plants more xeric). The factor missing here is irrigation frequency to match the water needs.

In-line Drip Tubing is a quarter-inch micro-tubing with built-in emitters spaced at six, twelve, or twenty-four-inch intervals. The twelve-inch spacing is readily available in the home garden trade. These are great for snaking through a bed area. For sandy soils, the spacing of the tubing should be at twelve inches. For clayey soils, spacing may be at eighteen to twenty-four inches for perennial beds.

Micro-Sprayers often held up on a spike, covering a radius of two to thirteen feet. Delivery rates vary from 0.1 to 10 inches per hour, depending on the head selected. Because water is sprayed in the air, drift and water waste in wind resembles sprinklers more than ground-applied drip. Micro-sprayers work with a very small droplet size that readily evaporates. For this reason, their efficiency in Colorado's low humidity is questionable.

Soaker Hose and Soaker Tubing

The **soaker hose** is a different type of drip system that allows water to seep out the entire length of a porous hose. They are great for raised bed gardens and flower beds. In sandy soils, space runs at twelve inches. For flower and shrubs beds on clayey soil, space runs at eighteen to twenty-four inches. In a raised bed vegetable garden (where uniform delivery to small vegetables is important), make three to four runs up and down a four-foot-wide bed. Typical run time is ten to twenty minutes.

Quarter-inch Soaker Tubing – Quarter-inch soaker tubing is available in the drip irrigation section at garden stores. Cut the soaker tubing to desired length and connect with drip system components. An in-line pressure regulator [**Figure 9**] is required; otherwise, the fitting may pop or leak.

Half-Inch Soaker Hose – Some brands (like Swans Soaker Hose) are a ½-inch hose that connect with a standard hose fitting. These are found in the garden hose section. It can be cut to any length and connected with garden hose fittings.

A small plastic disc fits inside the female hose connection as a flow regulator. To water the garden with the reduced water flow, it may need to run for around an hour. For better performance, use the pressure regulators with hose-end fittings found with the drip irrigation supplies see **Figure 11**. To adequately water the garden with this type of regulator, the drip line runs ten to twenty minutes. Without a pressure regulator of some type, the soaker hose tends to rupture, sending out streams of water at spots rather than dripping along the line.

Figure 11.
Tap, pressure regulator, hose connection, and half-inch drip hose in a raised bed garden.

This half-inch hose style is more tolerant of tiny amounts of dirt, algae, or salts in the water than other types of drip systems and may be successful on some non-potable water sources. Periodically, open the end of the hose and flush out soil deposits.

Because the soaker tubing has a higher delivery rate, it cannot be on the same zone as other in-line drip tubing, button emitters, or bubblers.

Strengths and Weaknesses of Drip Irrigation

Strengths of drip irrigation include the following:

- Convenience.
- Water savings.
- Operates with low water pressure.
- Easy to change when the plantings change.

- Does not require trenches for installation.
- Readily automated on a multi-zone controller or single-zone controllers that connect to the faucet.

Weaknesses of drip irrigation include the following:
- Requires good-quality water and filtration.
- Difficulty seeing if systems are operating.
- Water delivery to individual plants needs to be checked.
- For large areas, the cost will be significantly higher than a sprinkler system.
- Unsuitable for watering large trees.

Subsurface Drip

Subsurface drip is a recent way to water lawns and flowerbeds. Tubes are permanently buried below ground. Water soaks upward and laterally so subsurface drip works in clay-containing soils, but not well in sands.

Generally installed by a trained and experienced professional, subsurface drip requires very exact installation depth and spacing. Without proper attention to installation, the lawn becomes striped with green and dry strips. Studies being conducted by the Northern Colorado Water Conservation District find that water use is similar to a well-designed sprinkler system.

Strengths and Weaknesses of Subsurface Drip

Strengths of subsurface drip include:
- Convenience.
- Operation at low pressure.
- Equipment located out of sight, where it is less prone to damage.
- Easy to water anytime day or night, even when the lawn is being used.
- Application of water directly to the root zone.
- Easy to automate with soil moisture sensors.
- Potential to inject fertilizers with the irrigation water.

Weaknesses of subsurface drip include:
- Requires high-quality water.
- Unable to see if it is operating correctly.
- Needs to be dug up if not operating properly to correct issue(s).
- Unable to insert stakes in the ground.
- Requires professional installation.
- Relatively high cost.
- Evolving technology has not stood the test of time yet.

Hose-End and Hand Watering

Hose-end watering devices include several types of spray heads, water wands and water breakers, soaker hoses, and soil needles. Such devices are commonly used for temporary situations and where permanent installations are impractical or not desired.

Hose-end watering is inefficient in uniformity of water delivery, resulting in high water use. However, significant water savings *may* occur if gardeners do not water until the lawn/garden show signs of being dry.

A frequent problem with hand-held water wands is that folks tend to only water the surface, rather than deep watering of the root system. Avoid soil needles because they apply the water below the primary root system of trees, shrubs, and flowers.

A hand-moved sprinkler can be automated with single-zone controllers that connect with hose-end fittings at the tap. Some simple models turn the water off after a set number of minutes or gallons. More elaborate battery-operated models turn the water on and off at the day and time interval set by the gardener. [**Figure 12**]

Figure 12. Single-zone controllers connect to the hose line.
Left: This style is manually turned on and automatically turns off after a set number of minutes.
Right: This battery powered controller turns water on and off at the day and time intervals set by the gardener.

Strengths and Weaknesses of Hose-End and Hand Watering

Strengths of hose-end and hand watering include the following:

- Relative low cost of equipment.
- Ability to water plants differently and is useful for spot watering.
- Allows for close observation that may result in more timely care of plants.
- Being outside in the yard encourages neighborhood relationships.

Weaknesses of hose-end hand watering include the following:

- Time-consuming.
- Poor uniformity of water distribution with hand-placed sprinklers, leading to high water use.
- Hand-held watering often leads to surface watering rather than effectively watering the root zone.
- Water can be wasted by allowing it to run too long.

Summary

Any type of irrigation system (in-ground sprinklers, drip, or hand watering) can be very efficient if installed and maintained properly. Likewise, any type of irrigation can be inefficient, wasting water. What makes a system efficient or inefficient is not the equipment, but the attention given to it by the gardener.

CMG GardenNotes on Irrigation Management

- #260, *Irrigation Management: References and Study Questions*
- #261, *Colorado's Water Situation*
- #262, *Water Movement Through the Landscape*
- #263, *Understanding Irrigation Management Factors*
- #264, *Irrigation Equipment*
- #265, *Methods to Schedule Home Lawn Irrigation*
- #266, *Converting Inches to Minutes*
- #267, *Watering Efficiently*
- #268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Check-Up*

Authors: David Whiting, CSU Extension, retired and Carl Wilson, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed October 2022 by Brian Kailey, CSU Extension.

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CMG GardenNotes #265

Methods to Schedule Home Lawn Irrigation

Irrigation Scheduling

In many areas of the semiarid West, gardeners cannot count on natural precipitation to deliver moisture at the right times or in sufficient amounts to grow most introduced landscape plants. Supplemental irrigation is necessary unless the plant pallet is limited to species tolerant of natural precipitation levels. Due to limited precipitation and periodic droughts that limit available water supplies, using efficient irrigation is of interest to all.

Scheduling landscape irrigation is a critical part of lawn and garden care. When irrigating, gardeners have two goals: 1) water enough to keep plants healthy, and 2) minimize water waste.

Irrigation management comes down to two basic questions: 1) "How much?" and 2) "How often?" Gardeners often hear recommendations such as "water deeply and infrequently" or "water to adequate depth without runoff." Such advice is usually too broad to translate into effective irrigation management practices.

Rather than using broad generalizations, this CMG GardenNotes looks at several management approaches with differences in the time investment and potential water savings. **The textbook figures will need to be fine-tuned to the specific site needs, considering soils, exposure, heat, wind, and other water-use factors.**

Methods focus on cool-season turf, such as Kentucky bluegrass and turf-type tall fescue. Xeric and dry-land plants may need significantly less water.

Sprinkler-Type Method

One of the easiest ways to schedule an irrigation system is based on sprinkler type. Different types of sprinklers deliver vastly different amounts of water in the same amount of time. By considering sprinkler type, gardeners can begin to match their watering practices to the lawn's water needs. Pop-up spray heads typically apply 1-2½ inches of water per hour, whereas rotor heads only deliver ¼ to ¾ inch of water per hour. Therefore, zones that have pop-up spray heads can run for a short time, while zones with rotors will need to run longer to deliver the same amount of water.

A gardener could estimate that a zone with pop-up spray heads applies 1¾ inches of water per hour, and zones with rotor head apply about ½ inch per hour on average. **Table 1** estimates run time based on historical water use. The typical Colorado soil requires that this be split between a couple of irrigations.

Table 1.
Estimated Sprinkler Run Time Based on Sprinkler Type for Cool-Season Lawns

	Late April	May & June	July & August	September	Early October
Inches of water per week (Irrigation plus rain)	0.75"	1.0"	1.5"	1.0"	0.75"

Run Time (minutes/week)	Late April	May & June	July & August	September	Early October
Pop-up Spray Head[1]					
Irrigated 1 time per week[3]	**26**	**34**	**52**	**34**	**26**
Irrigated 2 times per week[4]	**13**	**17**	**26**	**17**	**13**
Irrigated 3 times per week	9	11	17	11	9
Irrigated every 6 days	22	29	45	29	22
Irrigated every 5 days	19	24	37	24	19
Irrigated every 4 days	15	19	30	19	15
Irrigated every 3 days	11	15	22	15	11
Irrigated every 2 days	7	10	15	10	7
Rotor Head[2]					
Irrigated 1 time per week[3]	**90**	**120**	**180**	**120**	**90**
Irrigated 2 times per week[4]	**45**	**60**	**90**	**60**	**45**
Irrigated 3 times per week	30	40	60	40	30
Irrigated every 6 days	77	103	154	103	77
Irrigated every 5 days	64	86	129	86	64
Irrigated every 4 days	51	69	103	69	51
Irrigated every 3 days	39	51	77	51	39
Irrigated every 2 days	26	34	51	34	26
Percent of July/August	**50%**	**67%**	**100%**	**67%**	**50%**

[1] Pop-up spray head estimated at 1 ¾" per hour.
[2] Rotor head estimated at ½" per hour.
[3] Recommended for most Colorado soils in the spring and fall.
[4] Recommended for most Colorado soils in the summer.

An easy tool for making seasonal adjustments is the **Percent Key** found on most controllers. The controller would be set for the July/August irrigation schedule. The percent key would be set at 50%, 67% or 100%, based on the season.

This method will need fine-tuning as described below to match the actual water need for the site based on soil, exposure, heat, wind, etc.

Although this method outlines a starting point for gardeners who want an easy approach, it does not factor in the actual water application rates for each zone.

Precipitation Rate Method

A far better approach is to do a **Precipitation Rate (Catch Can) Test** on each zone to determine the actual water delivery rate (known as ***precipitation rate***). The actual precipitation rate is determined by the sprinkler type and brand, water pressure, and head spacing. It may be slightly different for each zone.

To do the calculations you will need six identical, straight-sided, flat-bottomed cans such as soup, fruit, or vegetable cans. (Do not use short cans like tuna cans as they are too shallow, and water may splash out.) You will need a ruler, a watch and paper/pen to record your findings. Many water providers and sod growers have calibrated plastic cups specifically designed for this test. Again, six are needed.

Precipitation Rate (Catch Can) Test

Step 1. Place six identical, straight-sided, flat-bottomed cans randomly around the area between sprinkler heads in the same zone.
Step 2. Turn on the sprinklers for exactly ten minutes.
Step 3. Pour all the water into one can.
Step 4. With a ruler, measure the depth of the water in the can. **This is your precipitation rate in inches per hour.** Write it down for future reference.
Step 5. Repeat steps 1 and 2 for each irrigation zone.
Step 6. Use **Tables 2** and **3** to calculate the run time for each zone.

Note: If the amount of water in some containers is significantly more or less than others, the system is poorly designed, or head(s) are malfunctioning.

In many lawn sections, one zone waters the area from the left while another zone waters the same area from the right. In this situation, cut run times for zones in half, so that each applies half of the needed water.

An easy way to make seasonal adjustments is with the **Percent Key** found on most controllers. The controller would be set for the July/August irrigation schedule. The percent key would be set at 50%, 67% or 100% based on the season.

This method will need fine-tuning as described below to match the actual water need for the site based on soil, exposure, heat, wind, etc.

Tables on next page.

Table 2.
Minutes to Run Sprinklers PER WEEK Based on Precipitation Rates for Cool-Season Turf in Colorado

	Late April	May & June	July & August	September	Early October
Inches of water per week (Irrigation plus rain)	**0.75"**	**1.0"**	**1.5"**	**1.0"**	**0.75"**
Precipitation Rate					
1/4	180	240	360	240	180
3/8	120	160	240	160	120
1/2	90	120	180	120	90
5/8	72	96	144	96	72
3/4	60	80	120	80	60
7/8	52	69	103	69	52
1	45	60	90	60	45
1 1/8	40	53	80	53	40
1 1/4	36	48	72	48	36
1 3/8	33	44	65	44	33
1 1/2	30	40	60	40	30
1 5/8	28	37	55	37	28
1 3/4	26	34	51	34	26
1 7/8	24	32	48	32	24
2	23	30	45	30	23
2 1/8	22	28	42	28	22
2 1/4	20	27	40	27	20
2 3/8	19	25	38	35	19
2 1/2	18	24	36	24	18
2 5/8	17	23	34	23	17
2 3/4	16	22	33	22	16
2 7/8	16	21	31	21	16
3	15	20	30	20	15
Percent of July/August	**50%**	**67%**	**100%**	**67%**	**50%**

Table 3.
Conversion of Run time PER WEEK to Run Time PER IRRIGATION

Irrigations Per Week	Conversion to Run Time Per Irrigation
1 time per week[1]	minutes per week
2 times per week[2]	minutes per week / 2
3 times per week	minutes per week / 3
Every 6 days	minutes per week X 0.86
Every 5 days	minutes per week X 0.71
Every 4 days	minutes per week X 0.57
Every 3 days	minutes per week X 0.43
Every 2 days	minutes per week X 0.29

[3] Recommended for most Colorado soils in the spring and fall.
[4] Recommended for most Colorado soils in the summer.

Determining the number of irrigations per week becomes complex as soil water-holding capacity and rooting depth are factored in. For details, refer to CMG GardenNotes #263, *Understanding Irrigation Management Factors.*

However, many gardeners know by experience how often they need to irrigate. For most Colorado soils, irrigating once per week works in the spring and fall, and twice a week works in the summer.

Watering as infrequently and deeply as the soil allows gives better resilience during hot spells and helps reduce many weed species.

Adding Cycle and Soak Features

On slopes or compacted, clayey soils, water is generally applied faster than it can soak into the soil, resulting in water being wasted as it runs off-site. The ***cycle and soak*** approach cuts the irrigation period into multiple short runs with soak-in time in between. Programming a controller for cycle and soak is simply a matter of using multiple start times.

Adding Cycle and Soak

Step 1. From your catch can test information, calculate the total run time for the irrigation.
Step 2. Using **Table 4**, figure the number of cycles and soaks desired. For example, if the run time is twenty-six minutes, three cycles are suggested.
Step 3. Divide the run time per irrigation by the number of cycles to get the run time per cycle. For example, if the run time is twenty-six minutes and three cycles will be used, run time per cycle is nine minutes (26 / 3 = 8.67, rounded to 9).
Step 4. Set program with multiple start times, as needed. Generally, the controller is set to cycle again after all the zones have run. If the controller only has a few zones, keep in mind that the start times need to be at least one hour apart.

Table 4.
Estimated Number of Cycles to Reduce Surface Runoff

Type of Sprinklers	Run Time Per Irrigation	Number of Cycles
Pop-up Spray Heads	Greater than 16 minutes	2
	Greater than 24 minutes	3
Rotor Heads	Greater than 48	2
	Greater than 72	3

Observation and Manual Control Method

A simple method to manage lawn irrigation and conserve water is to manually activate the controller as needed. With careful attention, this method can maximize plant health and water savings since the gardener continually adjusts the irrigation system to actual weather and lawn needs. The downside of this method is that it takes daily attention to the lawn's water needs.

Run times on the controller are set as previously described. The difference is that the controller is turned to the "off" position. It is **manually activated** when the lawn shows signs of water stress (color change from bluish green to grayish-blue and footprints are still visible an hour or more later). After the zones run through, the controller is turned back to "off."

Using Emerging Technology

Advances in irrigation technology have led to several innovations. Emerging technology controllers and soil-moisture sensors are examples. Even though they may be more expensive or require professional installation, these products can be used to further improve water delivery to a landscape. Because they automate the irrigation controller, they can potentially reduce the amount of effort needed to water effectively.

Emerging Technology Controller

The **emerging technology controller** is a relatively new piece of equipment that automatically adjusts the irrigation to the daily **ET** (**evapotranspiration**). Emerging technology controllers are designed to water only enough to fulfill the lawn's water need, thereby reducing over and under watering.

Some models use "Historical ET," which is a multi-year average for the day. With these, dry spots will pop up with extreme heat over multiple days. They do not take into account actual rain received locally.

For a small annual fee, other models connect by cell phone, Wi-Fi, or satellite communication networks to download actual ET and rainfall from a local weather station system. On a day-by-day basis, they adjust the irrigation to match actual water needs.

For additional information on emerging technology controllers and the use of ET in irrigation management, refer to the Northern Colorado Water Conservancy District website at https://www.northernwater.org (Efficient Water Use).

Soil-Moisture Sensors

Soil-moisture sensors measure the water content of the soil, allowing the controller to run only when soil dries down to a threshold level. One of the advantages of a soil-moisture sensor is that it uses on-site soil conditions to control the irrigation system. Usually, one sensor is buried in the home landscape in a "representative" area. Run times for reduced irrigation zones or shady zones are programmed into the controller relative to the representative zone.

Rain Shut-off Sensors

Rain shut-off devices, also known as **rain sensors**, interrupt the schedule of an irrigation controller when a specific amount of rain has fallen. They are wired into the irrigation controller and placed in an open area where they are exposed to rainfall. They save water by preventing an irrigation system from running during moderate and heavy rains. Many states, but not Colorado, require rain shut-off sensors on automated systems.

Fine-Tuning Any Scheduling Method

Any scheduling method will need fine-tuning to match the actual water need of the site based on soil type, exposure, wind, heat, rooting depth, etc. This is done by careful observation of the lawn.

When adjusting all zones, the Percent Key on most controllers provides an easy method to fine-tune for the actual site by adjusting the percentage up or down in 10% increments, as needed. It can also be adjusted by increasing or decreasing the run time for each zone in 10% increments, as needed.

When adjusting a single zone, adjust the run times for that zone up or down in 10% increments, as needed.

In typical summer weather, if the lawn starts to become dry between irrigations, increase the run time in 10% increments, as needed. By trial and error, it is easy to fine-tune each irrigation zone. **On multiple days of unusually hot weather, dry spots should pop up if the controller is precisely**

fine-tuned. In unusually hot weather, if dry spots do not pop up, the lawn is over-watered. Cut back the time in 10% increments, as needed, to fine-tune each zone.

Many water providers encourage homeowners to water their yards between 9 p.m. and 9 a.m. Winds are typically less at night, and evaporation loss will be lower.

Authors: David Whiting, CSU Extension, retired. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed April 2023 by Marvin Reynolds, CSU Extension.

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CMG GardenNotes #266

Converting Inches to Minutes

Gardeners often wonder, how long should my sprinklers run in order to apply the right amount of water? The difficulty is that water is usually measured in inches while the irrigation controller (timer) works in minutes. The challenge is to convert minutes to inches so that sprinkler run times provide the correct amount of water that is applied to the lawn or garden. It's easy to make the conversion using the following process. First, calculate the precipitation rate for each irrigation zone, then convert inches to minutes using the formulas given in **Tables 1**, **2**, and **3**.

Calculate the Precipitation Rate

The following steps need to be done for each irrigation zone (or each location you placed the sprinkler(s) if you are manually attaching and dragging a hose). To do the calculations you will need six identical straight-sided flat bottom containers, such as soup cans, fruit or vegetable cans, or coffee mugs. (Do not use short cans like tuna cans as they are too shallow, and water may splash out.) You will need a ruler, a watch, and paper/pen to record your findings. Many sod growers and local water providers give out small rain gauges with a ruler on the side for this measurement. You will need six of the same type.

Steps

1. Place six identical rain gauges, or straight-sided, flat-bottomed cans/mugs between sprinkler heads in the zone.
2. Turn on the sprinklers for exactly ten minutes.
3. Pour all the water into one rain gauge or container.
4. With a ruler, measure the depth of the water in the rain gauge or container. This is your precipitation rate in inches per hour.
5. Write down the number near your controller for future reference.
6. Repeat Steps 1 - 5 for each irrigation zone.

Table 1. Conversion of Fractions to Decimals

1/16	=	.06	9/16	=	.56
1/8	=	.13	5/8	=	.63
3/16	=	.19	11/16	=	.69
1/4	=	.25	3/4	=	.75
5/16	=	.31	13/16	=	.81
3/8	=	.38	7/8	=	.88
7/16	=	.44	15/16	=	.94
1/2	=	.50			

Convert Inches to Minutes

Once you know the precipitation rate for each zone, you can look up the run time in the table or calculate it by using the following formula:

$$\text{Run Time (minutes)} = \frac{\text{Water to apply (inches)}}{\text{Precipitation rate (inches/hour)}} \times 60 \text{ minutes/hour}$$

Example: You have done the above steps and calculated that this sprinkler zone has a precipitation rate of 1 ½ inches per hour. You desire to apply ½ inch of water.

$$\text{Run Time} = \frac{0.5 \text{ inches}}{1.5 \text{ inches/hour}} \times 60 \text{ minutes/hour} = 20 \text{ minutes}$$

You need to calculate this for each zone. A common mistake is assuming that all zones have the same water needs or that all zones run the same. In the typical yard, they do not!

Table 2. Sprinkler Run Timetable (in Minutes) by 1/8th Inch

Precipitation Rate (Inches per hour)	**Water to be Applied** (inches) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
1/4	48	72	96	120	144	168	192	216	240	264	288	312	336	360
3/8	32	48	64	80	96	112	128	144	160	176	192	208	224	240
1/2	24	36	48	60	72	84	96	108	120	132	144	156	168	180
5/8	19	29	38	48	58	67	77	86	96	106	115	125	134	144
3/4	16	24	32	40	48	56	64	72	80	88	96	104	112	120
7/8	14	21	27	34	41	48	55	62	69	75	82	89	96	103
1	12	18	24	30	36	42	48	54	60	66	72	78	84	90
1 1/8	11	16	21	27	32	37	43	48	53	59	64	69	75	80
1 1/4	10	14	19	24	29	34	38	43	48	53	58	62	67	72
1 3/8	9	13	17	22	26	31	35	39	44	48	52	57	61	65
1 1/2	8	12	16	20	24	28	32	36	40	44	48	52	56	60
1 5/8	7	11	15	18	22	26	30	33	37	41	44	48	52	55
1 3/4	7	10	14	17	21	24	27	31	34	38	41	45	48	51
1 7/8	6	10	13	16	19	22	26	29	32	35	38	42	45	48
2	6	9	12	15	18	21	24	27	30	33	36	39	42	45
2 1/8	6	8	11	14	17	20	23	25	28	31	34	37	40	42
2 1/4	5	8	11	13	16	19	21	24	27	29	32	35	37	40
2 3/8	5	8	10	13	15	18	20	23	25	28	30	33	35	38
2 1/2	5	7	10	12	14	17	19	22	24	26	29	31	34	36
2 5/8	5	7	9	11	14	16	18	21	23	25	27	30	32	34
2 3/4	4	7	9	11	13	15	17	20	22	24	26	28	31	33
2 7/8	4	6	8	10	13	15	17	19	21	23	25	27	29	31
3	4	6	8	10	12	14	16	18	20	22	24	26	28	30

Select the precipitation rate of your sprinkler zone along the left column and move right until you are in the column of the amount of water to be applied. This is the number of minutes to run your sprinkler. Example: Your sprinkler applies water at 1 ½ inches per hour and you want to apply ½ inch, it takes 20 minutes.

Table 3. Sprinkler Run Timetable (in Minutes) by 1/10th Inch

Precipitation Rate (Inches per hour)	Water to Be Applied (inches)													
	0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
0.20	60	90	120	150	180	210	240	270	300	330	360	390	420	450
0.30	40	60	80	100	120	140	160	180	200	220	240	260	280	300
0.40	30	45	60	75	90	105	120	135	150	165	180	195	210	225
0.50	24	36	48	60	72	84	96	108	120	132	144	156	168	180
0.60	20	30	40	50	60	70	80	90	100	110	120	130	140	150
0.70	17	26	34	43	51	60	69	77	86	94	103	111	120	129
0.80	15	22	30	37	45	52	60	67	75	82	90	97	105	113
0.90	13	20	27	33	40	47	53	60	67	73	80	87	93	100
1.00	12	18	24	30	36	72	48	54	60	66	72	78	81	90
1.10	11	16	22	27	33	38	44	49	55	60	66	71	76	82
1.20	10	15	20	25	30	35	40	45	50	55	60	65	76	75
1.30	9	14	18	23	28	32	37	42	46	51	55	60	65	69
1.40	9	12	17	21	26	30	34	39	43	47	51	56	60	64
1.50	8	12	16	20	24	28	32	36	40	44	48	52	56	60
1.60	8	11	15	19	22	26	30	34	37	41	45	49	52	56
1.70	7	11	14	18	21	25	28	32	35	39	42	46	49	53
1.80	7	10	13	17	20	23	27	30	33	37	40	43	47	50
1.90	7	9	13	16	19	22	25	28	32	35	38	41	44	47
2.00	6	9	12	15	18	21	24	27	30	33	36	39	42	45
2.10	6	9	11	14	17	20	23	26	29	31	34	37	40	43
2.20	6	8	11	14	16	19	22	25	27	30	33	35	38	41
2.30	5	8	10	13	16	18	21	23	26	29	31	34	37	39
2.40	5	7	10	12	15	17	20	22	25	27	30	32	35	37
2.50	5	7	10	12	14	17	19	22	24	26	29	31	34	36

Select the precipitation rate of your sprinkler zone along the left column and move right until you are in the column of the amount of water to be applied. This is the number of minutes to run your sprinkler. Example: Your sprinkler applies water at 1 ½ inches per hour and you want to apply ½ inch, it takes 20 minutes.

Authors: David Whiting, CSU Extension, retired. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed August 2023 by Chris Hilgert, CSU Extension.

Reviewed August 2023

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #267

Watering Efficiently

Between 40% and 50% of annual domestic water use in Colorado (about 318 billion gallons a year) is used to water landscaping. According to Colorado Water Center, outdoor residential use in the state is nearly double outdoor park and commercial use—individual gardeners in the state, working together, can make a substantial difference in water supplies! According to the US EPA, as much as half of residential outdoor water is wasted through evaporation or runoff due to poor irrigation design, installation, operation, and maintenance.

Irrigation Zones Reflect Water Need

Irrigation zones are not always aligned with plant water needs. Irrigation zones may be installed poorly planned, or a landscape might change over time so that it no longer aligns with the originally intended watering patterns. A foundational step of irrigation efficiency is to be sure that the plants watered by any particular zone have similar water needs. For example, a lawn zone should water only lawn, not lawn plus flower beds, trees, or vegetable gardens, etc.

Because exposure to sun, heat, and wind play a significant role in water requirements, irrigation zones should also reflect exposure to these elements. For example, lawn on an open, windy, southwest-facing slope will have higher water requirements than the average lawn. Design this slope as an independent irrigation zone.

Areas in full or partial shade from a fence or building may have up to 50% lower irrigation needs than areas in full sun. If the shady area is in the rooting zone of large trees, water use will be similar to full sun, or even higher (the tree pulling water from the soil is not in the shade). Irrigation zones should reflect site needs.

Drip irrigation: Flower and shrub beds, small fruit gardens, and vegetable gardens can reduce water usage by 50% when coupled with organic mulch. For details on drip irrigation, refer to CMG GardenNotes #263*, Understanding Irrigation Management Factors*.

Sprinkler Design Criteria for Uniform Water Distribution

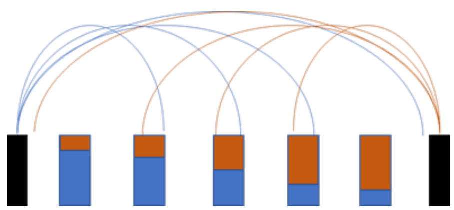
Unfortunately, in the design of many home and commercial sprinkler systems, little attention is given to design criteria for water conservation.

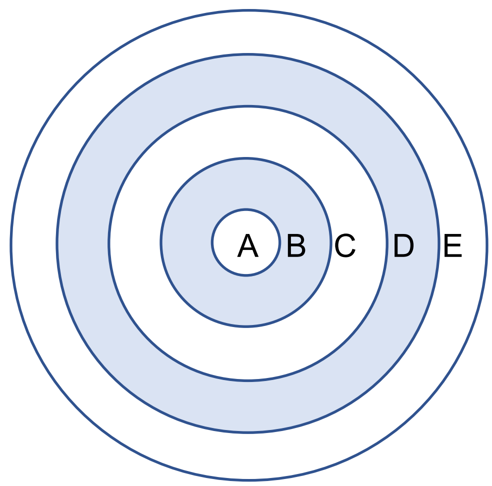
Sprinklers do not deliver a uniform quantity of water over their distribution area; areas close to the irrigation head receive more precipitation than those farther away. If irrigation systems are not designed to account for this unevenness, land managers are likely to overwater much of the lawn in order to keep the drier spots green. Designing sprinkler layouts to provide a more uniform water delivery can reduce water use by 25% to 50%. Most home lawn sprinkler systems have a 30% to 40% efficiency rating, whereas a 70% to 80% rating is achievable with attention to design and management.

Sprinkler design criteria for uniform water distribution includes the following:

Head-to-head coverage. In most residential and small commercial irrigation systems, irrigation heads should never be placed more than the distance of their throw *radius*, or half of the throw *diameter,* apart. Under no circumstance should heads be placed more than 60% of the throw diameter apart. For example, if the radius of a pop-up spray head is fifteen feet, the ideal spacing would be fifteen feet. Even if sprinkler heads apply water evenly, the areas farther from the head receive less water because they are larger. [**Figure 1**] If the sprinkler head is in the center of circle “A”, circle “E” would receive about half as much water than “C”, and nine times less than spots closest to the head (Irrigation Association).

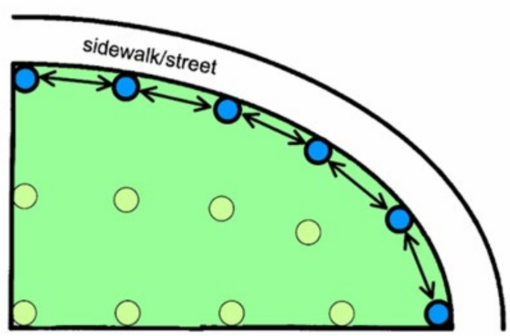
Figure 1.
Because areas far from an irrigation head receive less water than those closer, head-to-head coverage ensures even water application. The two heads below, working together, apply water evenly in the area between them (water from the sprinkler on the left appears blue, from the right, orange).





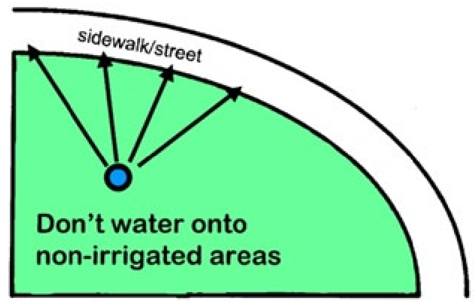
Watering from the edge. Sprinklers should be lining out the edges of the zones (i.e., run a line of sprinkler heads down the edge of the lawn or irrigated area), spraying onto the lawn but not onto the sidewalk, street, or non-irrigated area. [**Figure 2**]

Figure 2.
An efficient layout for irrigation is heads lined-out on the edge of the zone or irrigated area, evenly spaced at a distance of half their throw diameter.



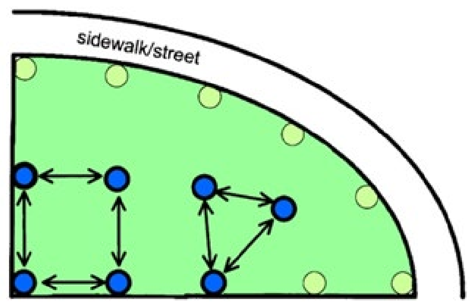
In sprinkler design, avoid layouts where sprinkler heads spray from the center of the lawn area out onto the sidewalk. It either wastes water as it sprays onto the sidewalk or creates a dry lawn area along the edge. [**Figure 3**]

Figure 3.
Spraying from the center out onto a sidewalk or non-irrigated area is unacceptable in water-wise landscaping.



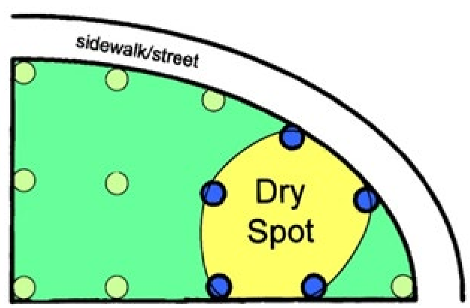
Arrange heads in square or triangular patterns. In the next step of the irrigation design process, fill in larger areas with sprinkler heads in regular square or triangular patterns. Spacing at no more than half of the throw diameter should take precedence over regular patterning. [**Figure 4**]

Figure 4.
For uniform water delivery, fill in heads in square and triangular patterns.



In irregularly shaped areas, heads easily fall into pentagon (five-sided) patterns. Avoid these as it creates an area that receives less water than other parts of the lawn. [**Figure 5**]

Figure 5.
Avoid pentagon-shaped head layout. The area receives less water, creating a dry spot. Add another head, maintaining head-to-head coverage.



Avoid irrigating small, irregularly shaped areas. It is impractical to irrigate small lawns (less than eight feet wide) and irregularly shaped patches of turf without applying water where it is not needed. In small or irregularly shaped areas, consider replacing lawns with plantings that can be watered with drip irrigation, or consider non-irrigated options. For example, in the narrow side yards around urban homes, a ground cover requiring low water, or a non-irrigated mulch area are water-efficient options.

Use recommended water pressure. Water distribution patterns change with pressure. Use the pressure recommended for the specific sprinkler head in use. Most sprinklers in the home garden trade are designed to operate at 30 to 40 psi. Commercial heads typically operate at 40 to 100 psi, and some heads have built-in pressure regulators.

New homes typically have a pressure regulator where the water line enters the home. In older homes, adding a pressure regulator may significantly reduce landscape water use.

Sprinkler Maintenance Checklist for Uniform Water Distribution

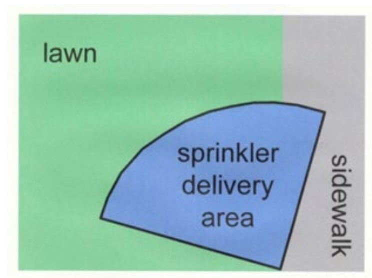
We have all noticed that blown sprinkler head down the street that goes unfixed for weeks. A problem with automatic sprinkler systems is that the gardener may not be aware of a system malfunction. Check the irrigation system's operations frequently.

As water-wise gardening concepts spread in our community, we need to adapt the practice of alerting neighbors to popped sprinkler heads and other system malfunctions. With an automated sprinkler system, many residents or landscape managers may be unaware of the mechanical failure.

Regular sprinkler maintenance issues for uniform water distribution includes the following:

Arc adjustment. Sprinkler heads, particularly rotor-type heads, frequently require adjustment of delivery angle to keep water on the irrigated areas and off non-irrigated areas. [**Figure 6**]

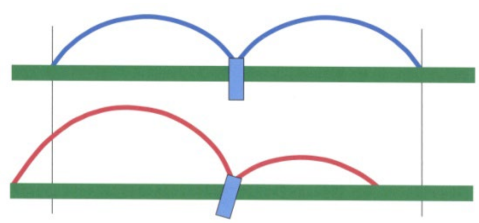
Figure 6.
Heads frequently shift their delivery arc. Frequent adjustment is required.



Adjust radius of throw. As discussed in design, water from one sprinkler head needs to reach adjacent heads for uniform delivery. Occasional adjustment on the radius of throw may be needed. This is done with a screw adjustment on the nozzle or changing out the nozzle to one with a different radius.

Adjust sprinkler heads vertically. Distribution patterns change when the head tilts off vertical alignment. To correct it, remove a donut shape of sod around the head with a shovel. Carefully loosen the soil around the head. Realign the head to vertical, and then firmly pack soil around the base of the head before replacing the sod. [**Figure 7**]

Figure 7
Heads require frequent adjustment back to vertical. Tilted heads change the distribution pattern.



Adjust head height. When water flow does not clear the grass height, the distribution pattern can be distorted. Raise heads to release water above grass height. On the other hand, sprinkler heads set excessively high can be a trip hazard and can interfere with mowing. [**Figure 8**]

To correct this, remove a donut shape of sod around the head with a shovel. Carefully loosen the soil around the head. Adjust head to the correct height, and then firmly pack soil around the base of the head before replacing the sod.

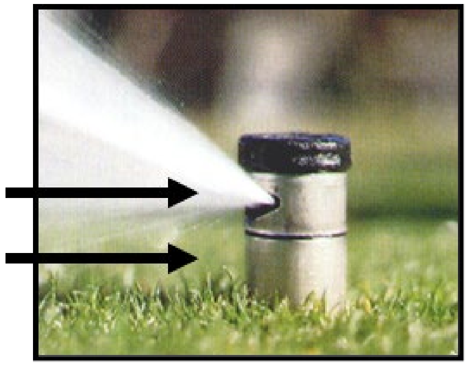
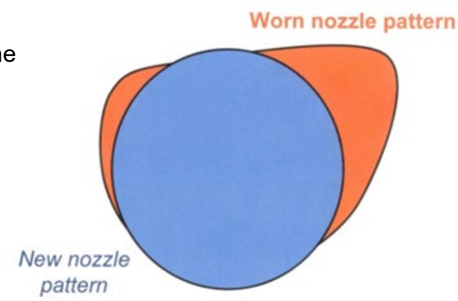


Figure 8.
Raise height of head to a point where water is released well above the grass height.

Replace worn nozzles: As sprinkler nozzles wear, distribution patterns change, giving a less uniform water delivery. Periodically replace old, worn nozzles. [**Figure 9**]

Figure 9.
Worn nozzles distort the delivery pattern.



Adjust pressure. A mist cloud around the sprinkler head indicates that the water pressure is too high for the head. Reduce pressure to avoid wasting water. A pressure regulator can be added to the main supply line. When adjusting pressure, slowly drop the pressure until you see water flow just start to drop, then up the pressure just a touch.

Replace leaky valves. In an irrigation valve, the rubber diaphragm that turns water on and off ages over time. Valves that do not shut off completely need the diaphragm or entire valve replaced. Valves often fail to shut off if the pressure is above 80 psi.

Sprinkler Management Criteria for Water-Wise Irrigation

Sprinkler management addresses two primary questions: how much to water and how often to water? Irrigation scheduling is discussed in more detail in CMG GardenNotes #265, *Methods to Schedule Home Lawn Irrigation.*

Know the *precipitation rate* for each irrigation zone and adjust run time to match water needs of each zone. The first step in irrigation management is to calculate the precipitation rate for each zone. Once the precipitation rate is known, the controller can be set to deliver the desired amount of water. Because distribution patterns and precipitation rates vary from zone to zone, run times should be set for each irrigation zone based on precipitation rates.

Most irrigation controllers are set with all zones receiving the same run time. This results in zones that need less water being overwatered.

Adjust irrigation controller for the season. As summer temperatures increase, water use goes up; as cooler fall weather moves in, water use goes down. Unfortunately, most gardeners have their controllers set for the summer and never adjust the controllers for the season. Without seasonal adjustment, lawns and gardens are overwatered in the spring and fall. Iron chlorosis is a common symptom of springtime overwatering. Several methods can be used for irrigation scheduling. For details, refer to CMG GardenNotes #265, *Methods to Schedule Home Lawn Irrigation*.

Water bluegrass at 80% evapotranspiration. When water is available, Kentucky bluegrass uses significantly more water than what it needs to remain green. Bluegrass also slows its water use and growth rate as soil moisture decreases. Watered at 80% ET, a home bluegrass lawn will remain thick and green. Watered at 60% ET, a home bluegrass lawn will remain green, but may show signs of stress like thinning, and will tolerate less foot traffic.

Summer-dormant Kentucky bluegrass. Where appropriate for the use of the site, allowing Kentucky bluegrass to go dormant in summer is very water efficient. Summer-dormant bluegrass requires only about fourteen inches of rain and irrigation per year (applied in the spring and fall). For additional details, refer to CMG GardenNotes #412, *Water-Wise Landscape Design: Selecting Turf Options*.

Turn off sprinklers in rainy weather. Manually shutting off the sprinkler system during rainy weather is another effective management tool. An inexpensive investment (around $25) to help manage the irrigation system is a rain shut-off sensor. In many parts of the country local ordinances require rain shut-off sensors.

Use cycle-and-soak timing. On slopes and on compacted or clayey soils water can be applied much faster than it can infiltrate into the soil, leading to surface run-off. To deal with this, use multiple short-run cycles that allow the water to soak in between cycles. Most controllers readily accommodate this with multiple start times.

On clayey soil with pop-up spray heads, apply about one quarter inch per cycle (about eight to ten minutes) with two or three cycles to apply one-half-inch to three-quarters, inch of water per irrigation. Runs are typically spaced an hour apart or, more commonly, after all the zones have run their cycles again.

Determine the reason for dry spots. The common approach for managing dry spots is to increase the amount of water applied. Although it may green up the dry spots, it also overwaters the rest of the lawn, wasting water.

To evaluate a dry spot, first place some identical, straight-sided, flat-bottomed cans (like soup, vegetable cans, or coffee mugs) out to measure the water applied. Compare the amount of water received in the dry spot to the amount of water received in green areas. If the dry spot receives significantly less water, it is a water delivery problem (like a malfunctioning head or design problem). If similar amounts of water are being received, the problem is soil or plant related (like compaction, thatch, and root damage).

> **Note:** As the gardener fine-tunes the management of their irrigation system, dry spots will show up in hot weather. This indicates that they are successfully walking the edge on ideal irrigation management, applying nearly exactly what the turf needs, not more.

Aeration. This is a primary tool to increase water infiltration. Aeration may be useful in the spring and fall on lawns with a lot of traffic (children and dogs), compacted, clayey soils, and slopes. For details refer to CMG GardenNotes #551 *Basic Turf Management*.

Water deeply and infrequently. This develops a deep root system that gives the plants more resilience in hot, dry weather.

Water at night or early morning hours. To reduce water loss from evaporation, water between 9:00 p.m. and 9:00 a.m. In many areas, wind drift is less in the early morning hours.

CMG GardenNotes on Irrigation Management

- #260, *Irrigation Management: References and Study Questions.*
- #261, *Colorado's Water Situation.*
- #262, *Water Movement Through the Landscape.*
- #263, *Understanding Irrigation Management Factors.*
- #264, *Irrigation Equipment.*
- #265, *Methods to Schedule Home Lawn Irrigation.*
- #266, *Converting Inches to Minutes.*
- #267, *Watering Efficiently.*
- #268, *Irrigation Management Worksheet: Lawn In-Ground Sprinkler System Check-Up.*

Authors: David Whiting, CSU Extension, retired. Artwork by David Whiting. Used with permission. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed August 2023 by John Murgel, CSU Extension.

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CMG GardenNotes #268

Irrigation Management Worksheet:

Lawn In-Ground Sprinkler System Checkup

To complete this irrigation checkup, you will need the following items:

- Six identical straight-sided, flat bottom cans or cups.
- Watch/Timer.
- Ruler.
- Colored flags or other markers to mark sprinkler heads by zone (optional but helpful).
- Calculator.
- 10" Screwdriver and/or soil probe.

Why Do an Irrigation Checkup?

Of all the principles of water wise landscaping, attention to irrigation efficiency has the greatest potential for water conservation.

A lawn irrigation checkup is a systematic evaluation of the irrigation system design, maintenance, and management. It will identify areas where adjustments will make either a minor or major impact on water conservation and lawn quality. After performing the checkup you will be able to:

1. Recommend appropriate run times for each sprinkler zone, calculated based on the precipitation rate of each zone.
2. Recommend maintenance, such as replacing or adjusting nozzles, moving, or adding heads, or adjusting water pressure.
3. Recommend lawn care practices such as fertility management and core aeration to improve turf quality.

This checkup is only a tool to help identify where the system is working adequately and where adjustments need to be made. Knowing that action is required does not save water. Actual water conservation comes when findings are put into action!

Important Note: Perform a normal watering the day before doing the checkup.

Step 1. Evaluate the Lawn

A. How does the lawn look? Visual indicators of lawn quality show where to look for potential problems.

- ☐ Green (high input lawn)
- ☐ Green (moderate input lawn)
- ☐ Green (low input lawn)
- ☐ Dry spots: ______% of lawn
- ☐ Dry/Dormant
- ☐ Thick
- ☐ Thin
- ☐ Weed-free
- ☐ Few weeds
- ☐ Weedy

B. **Check the soil conditions.** Since the lawn was watered the day before the checkup, probing the soil can show where compaction or drought from uneven watering are issues.

1. Stick a screwdriver in the ground to get a sense of soil compaction. The ease or difficulty at which the screwdriver can be pushed into moist soil gives a grasp of soil compaction.

2. If possible, use a soil probe to get a sense of soil texture, compaction, soil layers, rooting depth, and thatch layer. Note: On compacted or rocky soil, it may be impossible to push a soil probe into the soil. On extremely compacted soils, it may even be impossible to push a screwdriver into the soil.

- **Soil compaction:**
  - ☐ Little to no compaction.
  - ☐ Moderate compaction (recommend core-aeration of three-inch centers).
  - ☐ Severe compaction (recommend core-aeration of three-inch centers or other remediation).

- **Soil texture (use the soil texture by feel method found in GardenNotes #214, *Estimating Soil Texture*). Based on the soil texture expected speed of soil water infiltration is:**
  - ☐ High.
  - ☐ Moderate.
  - ☐ Low.

- **Soil profile:**
  - ☐ Changes in soil texture evident.
  - ☐ Hardpan layer present at ______ depth.
  - ☐ Evidence of drainage problems (such as surface pooling).

- **Thatch layer:**
  - ☐ Less than ½ inch.
  - ☐ Greater than ½ inch (may require core-aeration on three-inch centers).

- **Runoff potential:**
  - ☐ Low potential.
  - ☐ High potential (use cycle and soak application).
    - ☐ Due to slope.
    - ☐ Due to soil conditions (compaction and clayey soils).
    - ☐ Due to heavy thatch.

C. **Current irrigation pattern:**

- During the summer, July/August, the lawn is typically watered ______ (days) for ______ minutes.
- During the typical July/August weather, the lawn can go ______ days between irrigation before getting dry.
  - Multiply the number of days (maximum) between summer irrigations by 0.20 to estimate the water holding capacity for the soil at rooting depth at this site. This is the maximum amount of water to apply per irrigation.
    ______ days x 0.20 inches = ______ inches per irrigation (maximum).

D. Notes & Recommendations:

Step 2. Current Controller Settings

Record the current settings from the controller including watering days, start time(s) and run times. Note: Precipitation rates and inches applied may be calculated later if unknown. This will be used to document water-saving potential from the checkup.

Controller is set for ___________________ (month).

Step 2. Current Setting and Inches Applied						
Zone	**Zone Identity**	**Watering day(s)**	**Start time(s)**	**Run time**	**Precipitation Rate**	**Inches Applied**
1						
2						
3						
4						
5						
6						

Step 3. Identify and Evaluate Irrigation Zones

A. **Identify the location of each sprinkler head in each zone (a group of sprinkler heads that come on at the same time).** Using different colors of landscape flags or other marking devices (like screwdrivers or sticks pushed in the ground near each head) is helpful. Sprinklers may need to be turned on to find and identify sprinkler heads by zone.

B. **Evaluate the following:**

Step 3. Irrigation Zones	**OK.** Concept incorporated.	**Minor**. Benefits with minor adjustments or implementation.	**Major**. Benefits with major adjustments or implementation.	**Not applicable** to site.
Irrigation Zones				
1. Lawn zones separate from flower and shrub bed zones.				
2. Lawn areas zoned by irrigation demand (e.g., high input, moderate input, and low input areas on separate irrigation zones).				
3. Zone by exposure (e.g., extreme exposures, full sun, partial shade, full shade, and slopes on separate irrigation zones).				
4. Drip or bubblers used in flowerbeds, shrub beds, small fruits, and vegetable gardens.				
5. Design avoids sprinkler irrigation on small, irregular shaped areas (generally areas less than 10 feet wide).				

If the current system design fails to meet one or more of the above criteria, consider upgrading the irrigation system.

C. **Notes:**

Step 4. Evaluate Sprinkler Performance

Turn on sprinklers and evaluate sprinkler performance as outlined below, repeating steps for each zone. Refer to GardenNotes #267, *Watering Efficiently* for more details.

A. Design criteria for even water distribution.

1. **Head-to-Head Coverage** – Does the water from each head reach neighboring heads?

Step 4A 1. Head-to-Head Coverage						
Zone	1	2	3	4	5	6
Yes = OK						
No = adjustments needed*						

* In some situations, adjusting heads or changing nozzles may correct the problem. In other situations, the system design may need to be upgraded for water conservation.

2. **Head Position** – Are sprinkler heads "lined-out" along the edge of non-irrigated areas (watering from the outside in)?

Step 4A 2. Lined-Out						
Zone	1	2	3	4	5	6
Yes = OK						
No = upgrade needed*						

* If "No," consider upgrading the sprinkler system for improved water conservation.

3. **Head Layout** – Are sprinkler heads arranged in even pattern, equal distance without gaps?

Step 4A 3. Head Layout						
Zone	1	2	3	4	5	6
Yes = OK						
No = upgrade needed*						

* If "No," consider upgrading the sprinkler system for improved water conservation.

4. **Zone Uniformity** – Are all heads/nozzles in a zone the same brand and type?

Step 4A 4. Zone Uniformity						
Zone	1	2	3	4	5	6
Yes = OK						
No = adjustments needed*						

* In some situations, replacing heads or nozzles may correct the problem. In other situations, the system design may need to be upgraded for water conservation.

5. **Pressure** – Is there a mist cloud around sprinkler heads? Refer to GardenNotes #267, *Watering Efficiently*.

Step 4A 5. Pressure / Mist Cloud						
Zone	1	2	3	4	5	6
Yes = OK						
No = adjustments needed*						

* A mist cloud indicates excessive pressure. Lower pressure to conserve water. In some situations, this may involve installation of an in-line pressure regulator.

6. **Notes:**

B. Maintenance criteria for even water distribution.

1. **Delivery Arc** – For each head, does the delivery angle need adjustment (to avoid spraying the sidewalk, driveway, or other areas outside the zone)?

Step 4B 1. Delivery Arc						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed						
Identify heads needing adjustments						

2. **Vertical Adjustment** – Do heads need adjustment to vertical (are the heads and risers straight up and down)?

Step 4B 2. Vertical Adjustment						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed*						
Identify heads needing adjustments						

* Heads off vertical will distort the delivery pattern. Adjust vertically to conserve water.

3. **Height** – Is nozzle releasing water above grass height and un-blocked by obstacles (trees, mailboxes, boulders, etc.)?

Step 4B 3. Height						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed*						
Identify heads needing adjustments						

* When water doesn't clear grass height, distribution pattern may be distorted. Raise head.

4. **Worn Nozzles** – Look at the fan created by the water spray for each head. Is it uniform around the arc? Rotating nozzles can become stuck in place.

Step 4B 4. Worn Nozzles						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed*						
Identify heads needing adjustments						

* Replace worn nozzles to improve distribution pattern.

5. **Replace Leaky Valves** – In the irrigation valve, the rubber diaphragm that turns water on and off, degrades over time. Valves that do not shut-off completely need the diaphragm or entire valve replaced. Valves may also fail to open fully, reducing available water pressure for the system.

Step 4B 5. Leaky Valves						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed*						
Identify heads needing adjustments						

6. **Evaluate Dry Spots** – If the lawn has obvious dry spots, place five to ten identical containers on the lawn, in the dry spot and on the green areas. After running the sprinkler for their normal time, compare the amount of water collected in each can (measure to at least 1/10-inch accuracy if measuring by depth).

Step 4B 6. Evaluate Dry Spots						
Zone	1	2	3	4	5	6
No dry spots						
Dry spot(s) receiving less water than the green areas[1]						
Dry spot(s) receiving similar amounts of water as green areas[2]						

1. When the amount of water received in dry area cans is significantly less than the green area cans, poor water distribution is a primary contributor. Evaluate irrigation design and maintenance issue.
2. When the amount of water received in both the green area cans and dry area cans are similar, the problem is not directly related to sprinkler performance. Evaluate other growth factors, including soil compaction, thatch, run-off, insect or disease problems, etc.

Adjustments identified in Step 4 need to be performed before continuing to step 5.

Step 5. Perform Precipitation Rate (Catch Can) Test

Perform a precipitation rate test (catch can test) for each zone, recording the precipitation rates in Table **6A,** ***Run Times***.

Precipitation Rate (Catch Can Test)

To do the calculations you will need six identical, straight-sided, flat bottom containers, such as soup cans, fruit or vegetable cans, or even coffee mugs. (Do not use short cans like tuna cans as they are too shallow, and water may splash out.) You will need a ruler, a watch, and paper/pen to record your findings.

Steps:

- Place six identical, straight-sided, flat bottom containers randomly around the area between sprinkler heads in the zone.
- Turn on the sprinklers for exactly ten minutes.
- Pour all that water into one container.
- With a ruler, measure the depth of the water in the can. This is your precipitation rate in inches per hour.
- Write down the rate for each zone in ***Step 8***.
- Repeat the first five steps for each irrigation zone.

Note: if the amount of water in some containers is significantly more or less than others, it indicates that the system is poorly designed, or head(s) are malfunctioning.

Step 5. Precipitation Rate						
1. Zone	1	2	3	4	5	6
2. Precipitation Rate (inches/hour)						

Step 6. Calculate System Run Times for Each Zone

A. Working down through the table, calculate the run time per irrigation.

Step 6A. Run Times						
Zone	1	2	3	4	5	6
1. Historical Summer ET. Amount of water to apply.	1.5 inches weekly					
2. Precipitation Rate – inches/hour.						
3. Run time per week (July/August) Based on Precipitation Rate for the zone.						
4. Number of Irrigations/Week Refer to Step 1-3 above.						
5. Run Time Per Irrigation Convert the Run Time per Week (line 4) to Run Time per irrigation.						

Note: ET, or evapotranspiration, is a term used to describe the amount of water consumed by plants over a period of time. In landscapes that provide complete ground cover, like lawns, ET is almost entirely made up of water that is transpired through plants as they pull water through the soil and release it into the air through stomates on leaves. For up-to-date and local ET data throughout Colorado, visit coagmet.colostate.edu.

B. Adding cycle and soak.

Most clayey and/or compacted soils cannot absorb water as quickly as pop-up spray sprinkler nozzles apply it. Many clayey soils, typical of the Front Range, absorb about ¼ inch of water per hour. Therefore, the most effective watering schedule on these soils would be to set each zone to deliver no more than ¼ inch per cycle with multiple cycles. For example, if the lawn is to have ½ inch of water, set controller to apply ¼ inch and cycle back an hour later to apply the second ¼ inch. If the lawn were to have ¾ inch, set the controller to apply ¼ inch per cycle with three cycles.

Cycle and soak are particularly helpful on slopes to avoid wasteful surface runoff.

Step 6B. Cycle and Soak						
Zone	1	2	3	4	5	6
1. Need for Cycle and Soak? Yes or No						
2. Run Time Per Irrigation from Step 6A, line 5.						
3. Number of Cycles.						
4. Run Time Per Cycle Divide Run Time (line 2) per Irrigation by Number of Cycles (line 3).						

Step 7. Start Time(s)

A. Determine the first start time.

Most communities suggest nighttime irrigation, between 9 p.m. and 9 a.m. Winds are typically less in the early morning, and evaporation loss will be lower. However, many communities experience peak water use from 4 a.m. to 6 a.m. as many sprinklers come on. If you have low-pressure issues, take advantage of the whole watering window and use a less popular time.

Enter your first start time into the table for **Step 7A & B. Start Time(s)**, row #1.

B. Add additional start times for Cycle and Soak (if needed).

1. Add all the Run Times per CYCLE together.
2. Cycle Time – Round this up to the next ¼ or ½ hour (depending on what start time intervals are used in your controller start options). This is the time to run through all the zones. Add this to table **Step 7A & B. Start Time(s)**, Rows 2 and 3. Or add one hour if the total run time is less than 60 minutes.
3. Add this to the first start time for the second start time. Record your second start time in table **Step 7A & B. Start Time(s)**, Start Time 2.
4. Likewise, if a third cycle is needed, add this to the second start time to get the third start time. Record this in the table **Step 7A & B. Start Time(s)**, Start Time 3.

Step 7A & B. Start Time(s)	
1. Start time 1	
Total cycle time	
2. Start time 2 (if needed, add line 1 to line 2.)	
Total cycle time	
3. Start time 3 (if needed, add line 3 to line 4.)	
Total cycle time	

Step 8. Set the Controller for July/August Run Time

A. **Set the run times for each zone** as listed in table **Step 6B. Cycle and Soak**, if Cycle and Soak is not used, or **Step 6B. Cycle and Soak**, line 4 if Cycle and Soak is used.

B. **Set the start time(s)** as given in table **Step 7A & B. Start Time(s)**.

Step 9. Seasonal Adjustment

A simple way to adjust for the season is to use the **Percent Key** found on most controllers.

- For Late April and early October, set the percentage to 50%.
- For May/June and September, set the percentage to 67%.

An alternative method is to repeat **Steps 6 to 8** for the spring/fall season.

Step 10. Fine-Tune to Match Site Specific Needs

These textbook figures are a good starting point in irrigation management. However, any scheduling method will need fine-tuning to match the actual water need of the site based on the exposure, wind, heat, and shade. This is done by careful observation of the lawn.

- **When adjusting all zones**, using the *Percent Key* on most controllers is an easy method to fine-tune for the water delivery by adjusting the percentage up/down in 10% increments. Adjustments can also be made by changing the run time of each zone up/down in 10% increments.
- **When adjusting a single zone**, adjust the run time for that zone up/down in 10% increments, as needed.

In typical summer weather, if the lawn starts to become dry between irrigations, increase the run time in 10% increments, as needed. With experience, it becomes easy to fine-tune each irrigation zone. During multiple days of unseasonably hot weather, dry spots should begin to pop up provided the controller has been precisely fine-tuned. Otherwise, if dry spots do not pop up during unseasonably hot weather, the lawn is overwatered. Cut back the time in 10% increments, until each zone has been fine-tuned.

The following guidelines may help you understand some needs for adjustments:

- In full shade (not under a large tree), water use (ET) could be 30% less.
- In hot and/or windy sites, water use (ET) could be 20% to over 50% higher.
- In the rooting area of large shade trees, water use (ET) could be 30% to 50% higher.

Authors: David Whiting, CSU Extension, retired. Revised September 2017 by Kurt M. Jones, CSU Extension. Reviewed August 2023 by John Murgel, CSU Extension.

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