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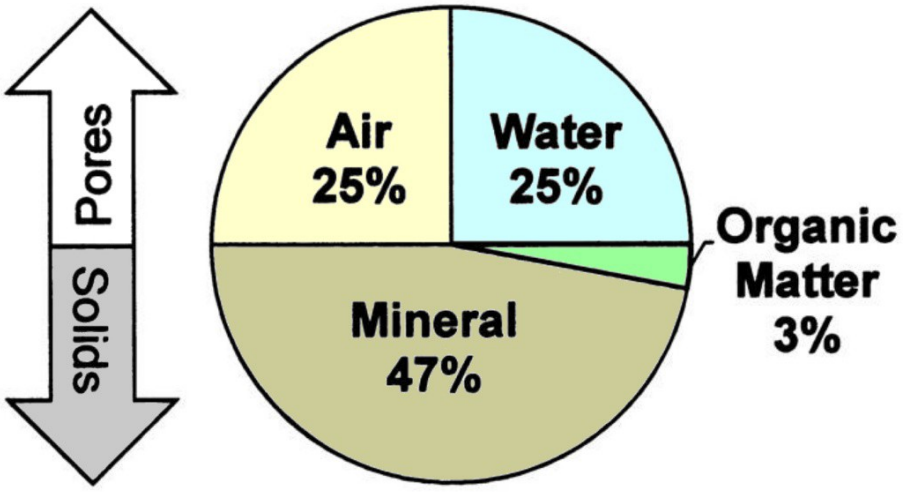
COLORADO STATE UNIVERSITY
EXTENSION




# Soils, Fertilizers, and Soil Amendments

# Learning Objectives

At the end of this unit, 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.

# References

## Colorado State University Extension

### Extension Fact Sheets

- Nitrogen Sources and Transformations – #0.550
- Organic Materials as Nitrogen Fertilizers – CSU-CE #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

### Extension Fact Sheets

- Expansive Soils – Landscaping on Expansive Soils – #7.236
- Landscaping on Expansive Soils – #7.236
- Mulches for Home Grounds – #7.214
- Salt – Diagnosing Saline and Sodic Soil Problems – #0.521
- Salt – Managing Saline Soils – #0.503
- Salt – Managing Sodic Soils – #0.504
- 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

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Soils, Fertilizes, and Soil Amendments curriculum developed by David Whiting (CSU Extension, retired), Carl Wilson (CSU Extension, retired), Catherine Moravec (former CSU Extension Employee) and Jean Reeder, Ph.D., (USDA-ARS, retired). Revised by Eric Hammond and Dan Goldhammer, CSU Extension

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# 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? Give a soil scientist's definition of *humus*. What are the benefits of humus?

8. How does a gardener enhance the *living soil*?

## 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:

    a. Coarse-textured, sandy soil
    b. Fine-textured, clayey soil
    c. 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, and 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 reduce soil compaction.

## Soil Drainage Problems

17. Describe drainage problems as related to *pore space*, *surface runoff*, and *leaching*.

18. Why is it so 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.

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 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: fertilizer, organic fertilizer, certified organic fertilizer, and soil amendment.

39. What does *grade* or *analysis* indicate about a fertilizer? What is a 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 a) ammonium sulfate, 21-0-0, b) ammonium nitrate, 34-0-0, and c) urea, 45-0-0 fertilizers?

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. Define *soil amendment*, *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:

    a. Desired results
    b. Potential for routine application
    c. Longevity
    d. 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.

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*CMG GardenNotes #211*

# Introduction to Soils

Outline:



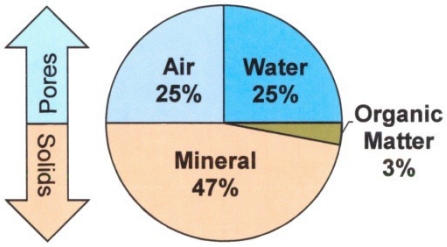
## Soil Attributes

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, etc.) 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% percent 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]

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




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

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 different 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 great 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 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 together 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

## 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.

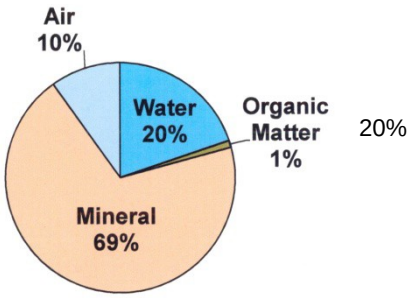
During the construction process, soils in communities are often graded by moving large volumes of soil. This process often removes the A horizon, taking with it the vast majority of organic matter. Furthermore, when construction workers drive large pieces of equipment over soil it becomes compacted. 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 of 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 is 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, water, 1% organic matter, and 69% mineral solids.




Soil conditions contribute to a large number of 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 Soils*.

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.*

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

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Authors: Catherine Moravec (former CSU Extension Employee); David Whiting (Colorado State University Extension, retired); and Jean Reeder, Ph.D., (USDA-ARS, retired). Edited by Dan Goldhamer (CSU Extension). Artwork by David Whiting; used by permission.

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*CMG GardenNotes #212*

# The Living Soil

Outline:

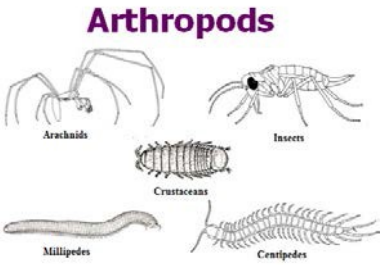


## Soil Organisms Improve Garden Tilth

Rather than being an inert material, soil contains a dynamic living ecosystem. The 1-5% **organic matter found in soils includes living organisms**. The soil is thought to actually have the most bio diverse ecosystems, with only about 1 % of the organisms have been 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 to help 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 central 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:




Insects by Bob Hammon

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

Other organisms that can be found in the soil are 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 affect on plants, and 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 specific fungi that form symbiotic associations with plant roots. Found in most soils, they are very host-specific (i.e., each plant species has specific species of mycorrhizae 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 species 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 http://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. 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 are a large number 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 can't 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 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. 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%). Fourth is the stabilized organic matter (**humus**) remaining after further decomposition by soil microorganisms (50-80%). [Figure 1]

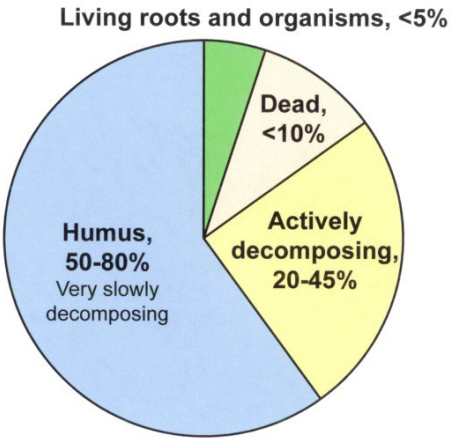



Figure 1. Make-up of soil organic matter

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 that are too chemically complex to be used by most organisms. Humus contains a potpourri of sugars, gums, resins, proteins, fats, waxes, and lignin. This mixture plays an important 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 release 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*. In reality 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 generally 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.

Myccorhizal products are considered highly experimental at this time, and are thus not recommended by CSU Extension for general use.

## 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: 1) bacteria, 2) fungi, 3) protozoa, 4) nematodes, 5) arthropods, and 6) earthworms.

**Bacteria**

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 100 million to 1 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**

Fungi are a diverse group of multi-cellular organisms. The best 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**

Protozoa are microscopic, single-celled microbes that primarily eat bacteria. The bacteria contain more nitrogen than the protozoa can utilize and some ammonium ($NH_4$) is 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**

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**

Soil arthropods 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**

There are three types of earthworms, two of which that live in Colorado soils. Earthworms digest micro-organisms and organic matter. Refer to the *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 a healthy fertile soil supportive to optimum plant growth.

- **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 roto-tilling**, 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.

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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 by permission. Revised by Susan Carter, (CSU Extension), 2015.

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*CMG GardenNotes #213*

# Managing Soil Tilth

## *Texture, Structure and Pore Space*

Outline:



## 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 make-up the soil ecosystem.

Gardening in Colorado can be a challenge due to poor soil tilth. Sandy soils hold little water and nutrients, while some Colorado soils are rocky and shallow.

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.

Many gardeners give attention to the soil's nutrient content by applying fertilizers. However, fertilization is only one of the keys to a productive garden.

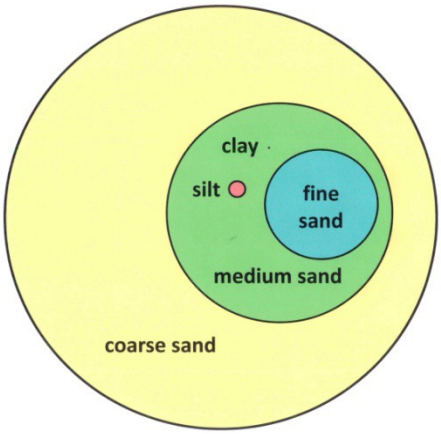
## Texture

***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 and 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 actually less than 0.002 mm (0.00008 inch) with coarse sand up to 1.0 mm(0.04 inch).

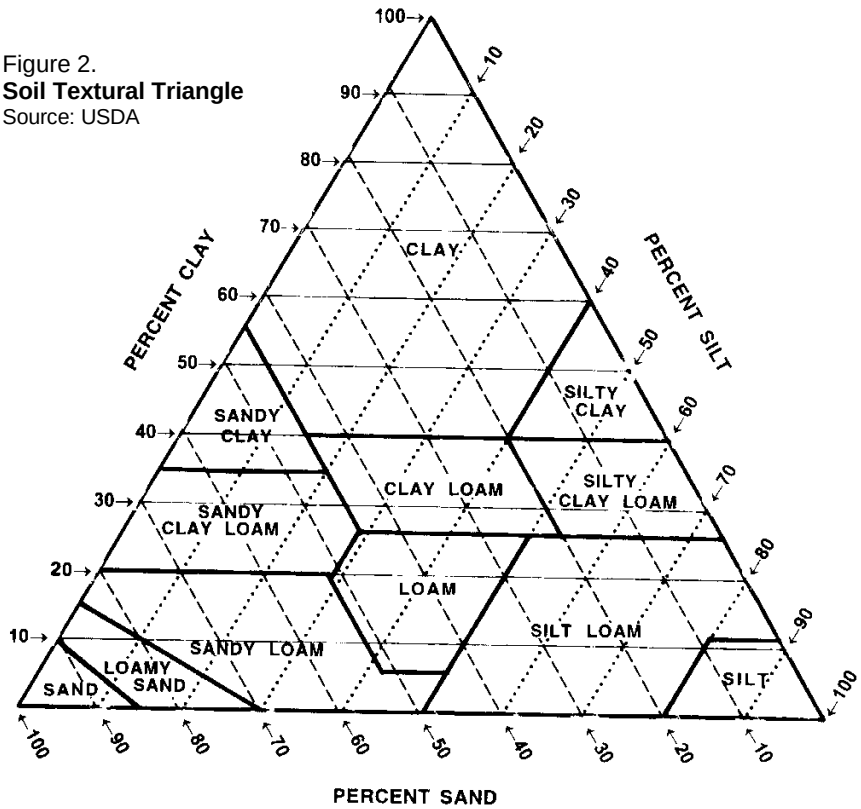



Based on the ***Soil Textural Class Triangle***, (figure 2), the percentage of sand, silt and clay determine the *textural class.* (For example, a soil with 30% clay, 10% silt, and 60% sand is called a *sandy clay loam*. A soil with 20% clay, 40% silt and 40% sand is a *loam.*)

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.

**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. Soils with as little as 20% clay size particles behave like a sticky clayey soil. 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 rather prone to compaction issues.

Figure 2.
**Soil Textural Triangle**
Source: USDA




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.

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

For a soil to take on the characteristics of a sandy soil it needs greater than 50-60% medium to coarse size sand particles. 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 for the soil. Rather they often drain readily, being a droughty soil with low nutrient holding capacity.

Texture directly affects plant growth and soil management as shown in Table 2. Properties of the clay trumps property of the sand in a soil with 20% clay and 80% sand, behaving as a clayey soil. [Table 2]

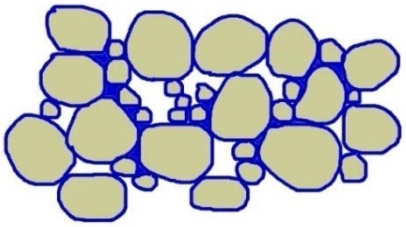
**Table 2. Comparison of Fine-Textured (Clayey) Soil and Coarse-Textured (Sandy) Soil**

| | 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 various 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 & 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.



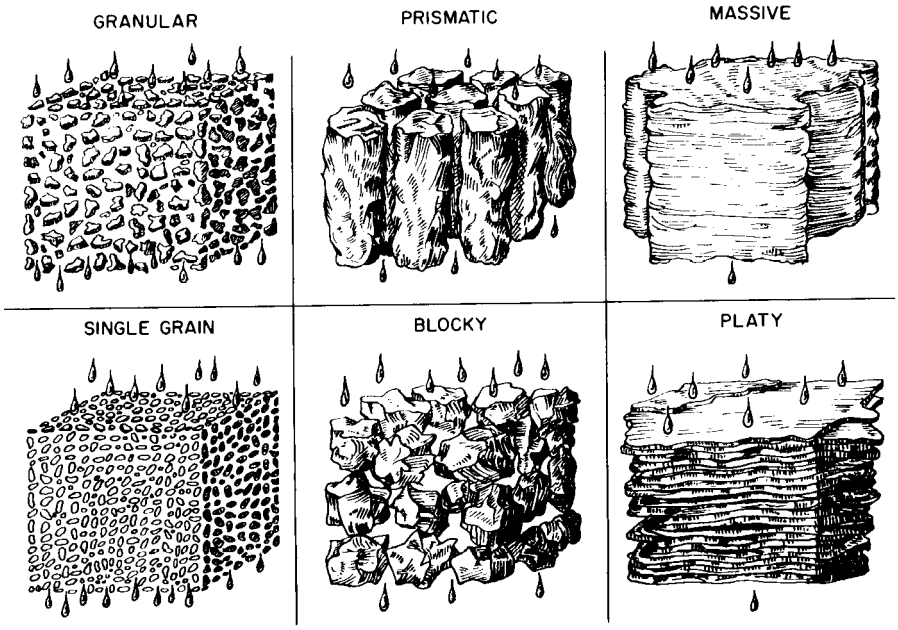



Figure 4. Examples of soil structure types. Line drawing by USDA

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

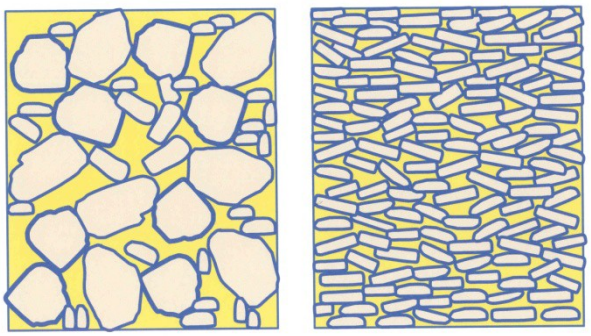
.

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 non-existent to minimal until the sand strongly dominates the soil profile. Organic matter also plays a key role in creating large pore space.

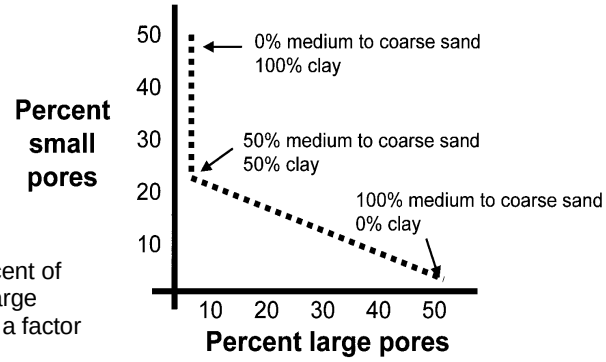



Figure 6. Percent of small versus large pore space as a factor of soil texture.

**The quantities of large and small pore spaces directly affect 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

Soil water coats the mineral and organic particles and is held by the property of ***cohesion*** (the chemical process by which water molecules stick together) in the small pore spaces. Air fills the large pore spaces.

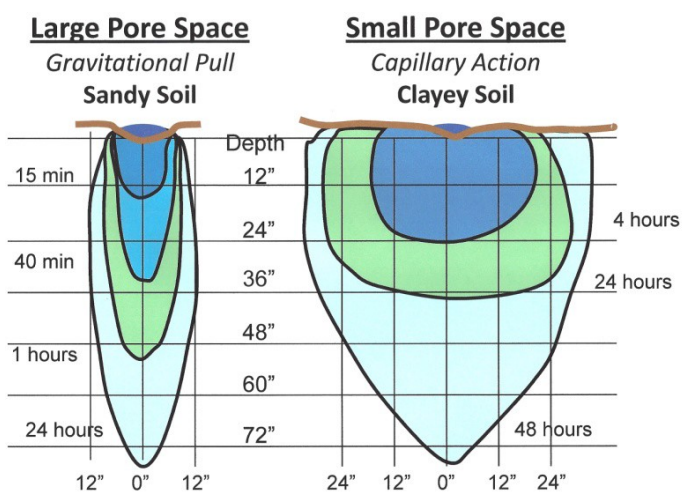



Figure 7. Comparative movement of water in sandy and clayey soils

Water movement is directly related to the size of pores in the soil. In the small pores of clayey soils, water slowly moves in all directions by ***capillary action***. 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]

## 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.

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* (water molecules binding to water molecules).

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.

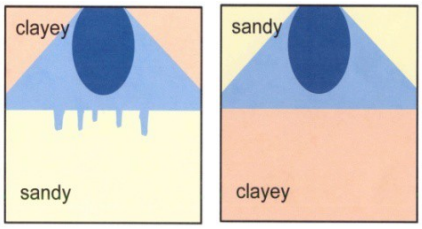



Figure 8. (left) With clayey soil over sandy soil, water is slow to leave to leave the small pore space of the clay. (right) With Sandy over clayey soil, water is slow to move into the small pore space of the clay.

**Perched water table** – This change in water movement creates a ***perched water table*** (overly wet layer of soil) generally 6 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 & 10]

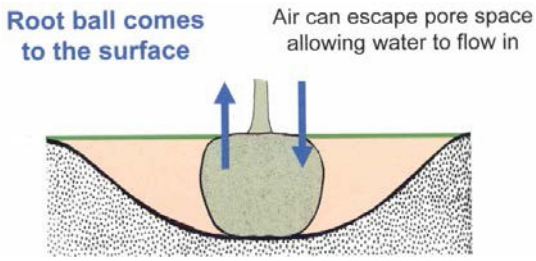
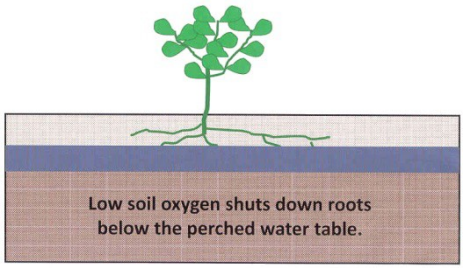



Figure 9. In tree planting, to deal with the texture interface between the root ball soil and the backfill soil it is imperative that the root ball comes to the surface with no backfill soil over top of the root ball.

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.




## 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 10 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, and at this level, additional fertilizer will not be needed. 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 clayey soils. Soil compaction reduces the large pore space, restricting air and water movement through the soil, thus limiting root growth. Soil compaction is the primary factor limiting plant growth in landscape soils. Soils generally become compacted during home construction.

## Gardening on Gravelly and Decomposed Granite Soils

Soils in Colorado foothills and mountains change greatly 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, very 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 greatly 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 home owner 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. <u>First and foremost, understand that without soil improvement the gardener may need to accept less than optimum plant growth and increased maintenance.</u>

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, that have been in for more than some 20 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.

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Authors: David Whiting (CSU Extension, retired), with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), Catherine Moravec (former CSU Extension Employee) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting unless otherwise noted; used by permission.



Revised October 2015

MASTER GARDENER
COLORADO STATE UNIVERSITY
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*CMG GardenNotes #214*

# Estimating Soil Texture

## *Sandy, Loamy or Clayey?*

Outline:



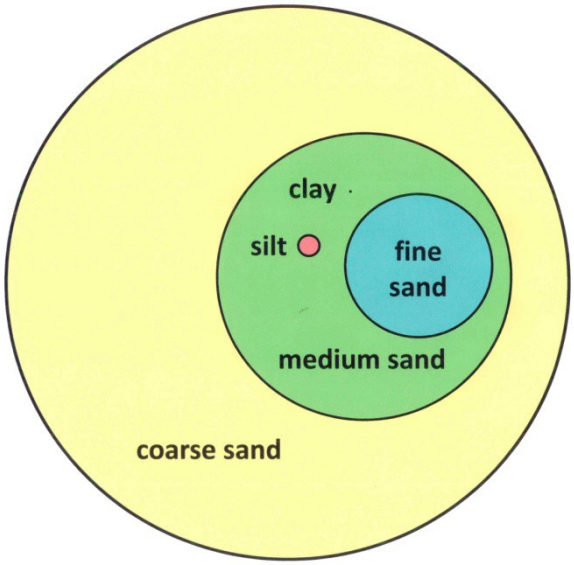
## Sand, Silt and Clay

***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 m (~2 inches) |

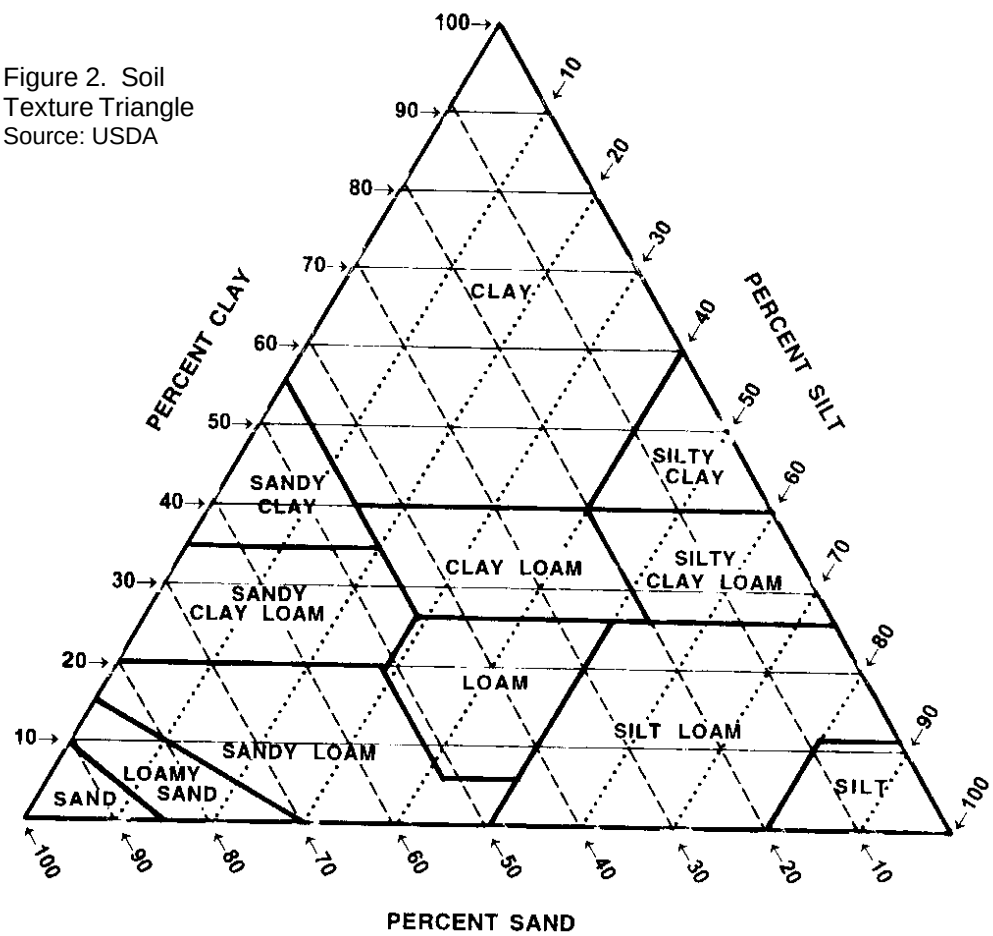
Figure 1. Comparative size of sands, silt and clay. If clay was the size of a dot on the page, silt and sands would be a comparative size.




## 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

1. Spread soil on a newspaper to dry. Remove all rocks, trash, roots, etc. Crush lumps and clods.
2. Finely pulverize the soil.
3. Fill a tall, slender jar (like a quart jar) a one-quarter full of soil.
4. Add water until the jar is theee-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. This 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, but with some soils it may take weeks.

11. Measure the thickness of the sand, silt, and clay layers.
    a. Thickness of sand deposit ____
    b. Thickness of silt deposit ____
    c. Thickness of clay deposit ____
    d. Thickness of total deposit ____

12. Calculate the percentage of sand, silt, and clay.

[clay thickness]
---------- =____percent clay
[total thickness]

[silt thickness]
---------- =____percent silt
[total thickness]

[sand thickness]
---------- =____percent sand
[total thickness]

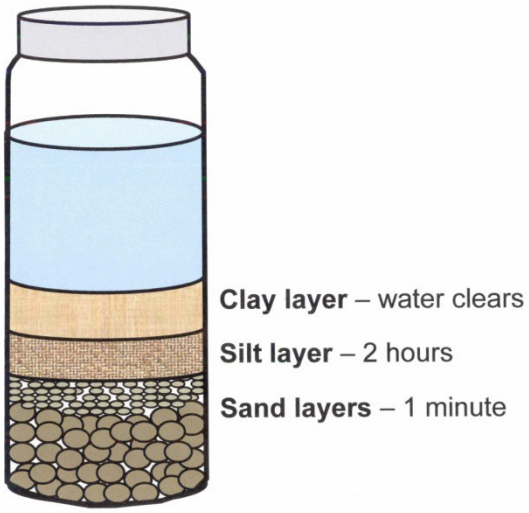



Figure 3. Measuring Soil Texture

13. Turn to the soil texture triangle and look up the soil texture class.

## Identifying Soil Texture by Feel [Figure 4]

**Feel test** – Rub some 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.

- Ribbons less than 1 inch
    - Feels gritty = coarse texture (sandy) soil
    - Not gritty feeling = medium texture soil high in silt
- Ribbons 1 to 2 nches
    - 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.

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Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork 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.
- No endorsement of products mentioned is intended nor is criticism implied of products not mentioned.


Revised 2014; reviewed December 2015

## Figure 4. Soil Texture by Feel

**Start:** Place soil in palm of hand. Add water drop-wise and knead the soil into a smooth and plastic consistency, like moist putty.
**Does the soil remain in a ball when squeezed?**

Yes

No

Add more water

Yes

Is the soil too dry?

No

Add dry soil

Yes

Is the soil too wet?

No

**Sand**

Place ball of soil in the hand, gently pushing the soil out between the thumb and forefinger, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow ribbon to emerge and extend over the forefinger, breaking from its own weight.
**Does the soil form a ribbon?**

Yes

No

**Loamy Sand**

**What kind of ribbon does it form?**

| Moisten a pinch of soil in palm and rub with forefinger | | Forms a weak ribbon less than 1" before breaking<br>**LOAM** | Forms a ribbon 1-2" before breaking<br>**CLAY LOAM** | Forms a ribbon 2" or longer before breaking<br>**CLAY** |
|---|---|---|---|---|
| **Does it feel very gritty?** | Yes | **Sandy Loam** | **Sandy Clay Loam** | **Sandy Clay** |
| **Does it feel equally gritty and smooth?** | Yes | **Loam** | **Clay Loam** | **Clay** |
| **Does it feel very smooth?** | Yes | **Silt Loam** | **Silty Clay Loam** | **Silty Clay** |

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*CMG GardenNotes #215*

# Soil Compaction

Outline:



## 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 the primary factor limiting plant growth in landscape soils.* Soil conditions, primarily soil compaction, contribute to a large portion of plant disorders 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]

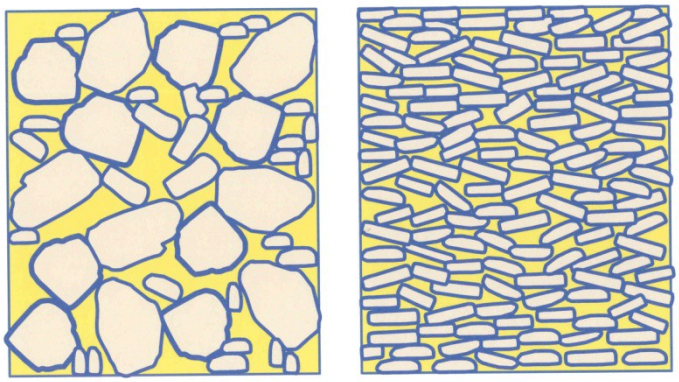
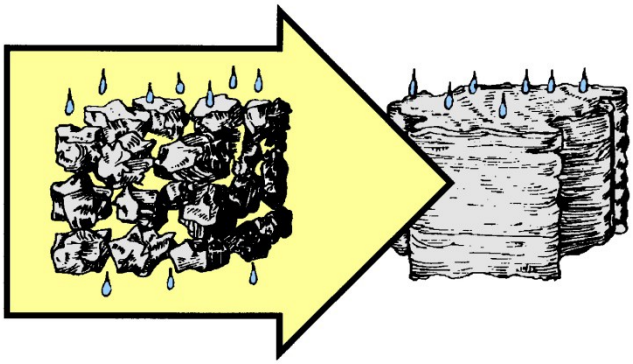


Figure 1. Comparison of large pore space in non-compacted soil (left) and compacted soil (right).

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. Soils generally become compacted during home construction. Foot traffic on moist soils is another primary compaction force 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 plants 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 (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.

## Use 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. [Figure 4]

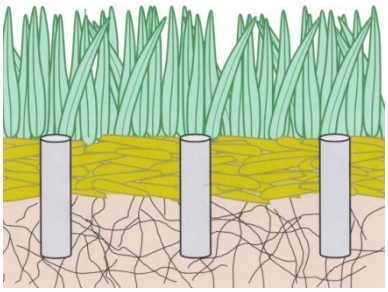


Figure 4. Lawn aeration helps manage the impact of soil compaction if enough passes are made with the aerator to have plugs at two-inch intervals.

## 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.

## Avoid Cultivating Overly Wet or Dry Soils

Never cultivate a 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. 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 a clayey soil may actually 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 actually become 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 a 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 a period of 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). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting (unless otherwise noted); used by permission.

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*CMG GardenNotes #218*

# Earthworms

Outline:



*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: (see Figure 1.)

***Anecic*** (Greek for "up from the earth" or "out of the earth")

- Capable of burrowing to depths of 6'
- Build permanent burrows into the deep mineral layers of the soil
- Drag organic matter from the soil surface into their burrows for food
- Include the familiar bait worm, the nightcrawler or dew worm (*Lumbricus terrestris)*

***Endogeic*** (Greek for "within the earth")

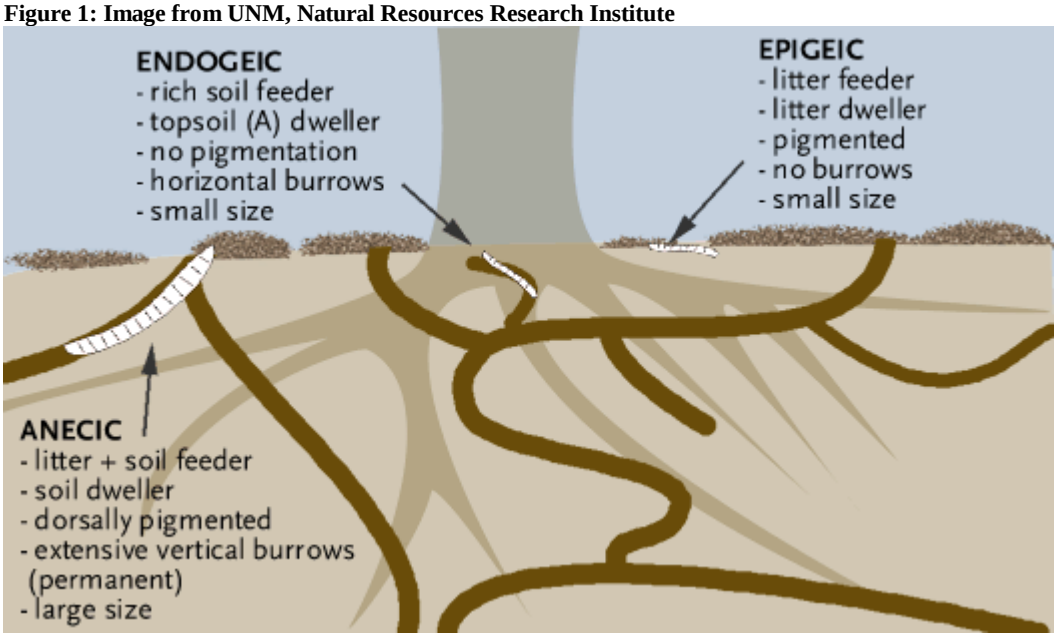
- Build extensive non-permanent burrows in the upper mineral layer of soil
- Feed on the organic matter in the soil
- Live exclusively in soil and usually are not noticed, except after a heavy rain when they come to the surface

***Epigeic*** (Greek for "upon the earth")

- Live on the soil surface
- Form no permanent burrows
- Feed on decaying organic matter
- Common names: red worm, manure worm, brandling worm, red wiggler and compost worm

The anecic (an – ess – ik) and endogeic (in – dough – gee – ik) 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: 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 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 of 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 worms 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 earthworms 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 water logged, oxygen is driven out of the large pore spaces. Without this free oxygen, earthworms cannot breath. 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.

## Practices Detrimental 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.

Author: Adrian Card, Colorado State University Extension, Boulder County, Revised by Susan Carter, CSU Ext, Tri River Area

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*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 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 takes water-soluble pollutants with it. Ground water pollution is a sensitive issue on coarse-textured sandy soils.

In comparison~~, in~~ 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 waterlog.

Roots must have oxygen to survive and root activity shuts down in waterlogged soils. Plants growing on 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 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 surface soil allows 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 12 inches deep and fill it with water. If the water fails to drain in 30 minutes, the soil has a drainage problem. If the hole fails to drain in 24 hours, waterlogged soils may affect plant growth.

# Correcting Drainage Problems

## Managing Soil Tilth

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, attention to organic matter and the "living soil" helps create large pores, 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).

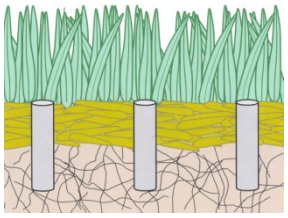
**Compaction** – Compaction is difficult to deal with; so prevention is the key. Soils around new homes are typically compacted from construction traffic. Break up the compacted layer by tilling, adding organic

matter, using cover crops and encouraging earthworms and soil organisms.

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 that plugs are at 2-inch intervals). (See lawn care information for additional details.) [Figure 2]

Figure 2. A heavy thatch layer slows water infiltration. Routine aeration maybe 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. Look at the irrigation schedule; is the area being over-watered or is irrigation running off instead of soaking in (aerate and use multiple shorter irrigation cycles). Fill in the low spot, or install a French or underground drain with a gravity-flow outlet.

**High water table** – Some areas of Colorado have high water tables. The only solution may be to raise the soil level (raised bed 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. 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.

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

**Impervious subsoil layer underlain with permeable soil**

- If less than 2 feet thick, rip or double-dig when soil is dry. Irrigate to settle, and do final grade when soil re-dries.
- If greater than 2 feet thick, bore holes through layer
- Holes are typically 4-6 inches in diameter, at 6 foot intervals. Fill with coarse sand or fine gravel.

**Impermeable subsoil**

- Increase soil depth
- 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. This is a common problem when soils are added to a raised-bed box or applied as a top dressing.

- Cultivate to mix layers

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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 by permission. Revised by Susan Carter, CSU Extension.

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*CMG GardenNotes #221*

# Soil Tests

Outline:



## Value of a Soil Test

In agronomic crops, greenhouse crops and turf, an extensive research base for interpretation of soil test results makes soil testing a key tool in crop management for commercial producers.

In the home garden setting, soil testing is valuable to establish a base line on soil limitations related to pH, salt levels, and the need for phosphate and potash fertilizers. A special lead test would be of concern to homeowners with lead-based paints on older homes.

In some gardening situations, soil testing has limited value. For example, soil testing for nitrogen has limited use for the home gardener because the nitrogen level constantly changes in response to soil organic matter additions, soil microorganism activity, and temperature, moisture levels, leaching and nitrogen consumption by plants and other soil life.

The research base for interpreting results is also lacking for landscape plants. For example, a test for a maple tree, native plants, or a gardener's favorite peony would be difficult to interpret based on standards used for general agronomic crops.

Finally, 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 soil)

    - About two-thirds of 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.
- pH
- Lime ($CaCO_3$ reported by percent)
- 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)
    - Nitrate nitrogen
    - Phosphorus
    - Potassium
    - Micronutrients such as copper, iron, manganese and zinc

Additional tests could be run for special needs like lead content 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 base line 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 dramatic changes are made to the soil (such as addition of larger quantities of manure, biosolids, or compost that may be high in salts) or approximately every 4-8 years to reestablish the base line.

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 the same, the sample should include subsamples taken from each and mixed together. Because garden areas are managed differently from lawns, the garden should be sampled separate from the lawn. Sample various garden beds that receive differing amounts of fertilizers and soil amendments separately.

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. 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 for Soil Tests**

| Crop | Sampling Depth |
|---|---|
| Garden (vegetable and flower) | 0 through 6 inches |
| Lawns, new (prior to planting) | 0 through 6 inches |
| Lawns, established | 0 through 3 inches |
| Lead test | 0 through ¾ inch |

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 10-15 subsamples for larger areas.

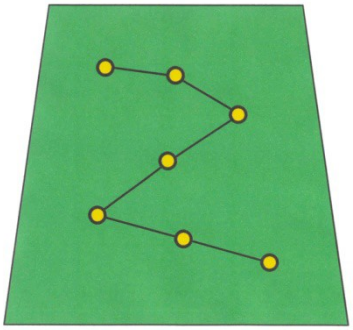

Figure 1. A proper soil sample is a composite of five to fifteen sub samples.

Collect the subsamples in a clean plastic pail, thoroughly mixing the subsamples together. Remove plant debris and break up clods. If possible, air-dry the soil by spreading it out on paper towel. (Do not oven-dry the sample.)

Place about two cups of the soil mix into the sample bag or box. Label the sample container (e.g., front lawn, vegetable garden, or flowerbed) and keep a record of the area represented by each sample taken. Send the samples to the soil-testing laboratory.

Climate and soil vary considerably in different parts of the country so it's important to select a local laboratory that processes for 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 Lab* available online at www.cmg.colostate.edu.

## Soil Test Recommendations

In production agriculture, it is not uncommon 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, fertilizer application will be highest, with increased costs, and higher potential for leaching

of fertilizers into ground water. In another scenario, the crop's net return may be the primary objective, reducing production (fertilizer) costs, or minimizing potential for ground water pollution.

Fertilizer practices may also impact recommendations. For example, is the phosphate fertilizer recommendation based on an annual application or a single application to last several years? For new turf, it is a standard practice to bring the phosphorus to a higher level when the fertilizer can be cultivated through the soil profile before the sod is laid.

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 actual process used in some procedures is based on soil pH. Most home test kits were designed for acid soils, and have questionable accuracy on the alkaline soils of the west.

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.

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Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., USDA-ARS (retired). Revised by Eric Hammond. Artwork by David Whiting; used by permission.



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MASTER GARDENER
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*CMG GardenNotes #222*

# Soil pH

Outline:



## 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 or 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 climate. The quality of irrigation water used can also have an effect on soil pH. Areas of the world with limited rainfall typically have alkaline soils while areas with higher rainfall typically have acid soils.

Soil pH is important to gardeners because it can affect the availability of plant nutrients as well as the soil ecology. In very acid or alkaline soils some plant nutrients convert to forms that are more difficult for plants to absorb. This can result in nutrient deficiencies. Plants which have evolved under such soil conditions often have developed mechanisms to deal with this issue.

In Colorado, many of our soils are alkaline with a pH of 7.0 to 8.3. Soils with a pH of 7.5 to 8.3 generally have a high calcium carbonate content (known as ***free lime***). This is important because it is impractical to lower a soil's pH if it contains free lime. Free lime buffers the soil against pH change by neutralizing acids which are added to the soil. Soils with a pH of 8.3 or higher normally have a very high sodium content (such soils are referred to as sodic). In some mountain soils and older gardens that have been irrigated and cultivated for many years the pH may be in the neutral range (6.8 to 7.2). When possible, select plants which are adapted to your soil pH.

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

**Figure 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 on alkaline soils. |
| **Alkaline soil** | **7.2** | 6.8 to 7.2 – "near neutral"<br>6.0 to 7.5 – acceptable for most plants |
| **Neutral soil** | **7.0** | |
| **Acid soil** | **6.8** | |
| | 6.0 | |
| | 5.5 | Reduced soil microbial activity esp. bacteria |
| | <4.6 | Too acid for most plants |

## Managing Alkaline Soils

Manage Colorado soils with moderate to high alkalinity (pH above 7.5) by increasing soil organic matter content and managing soil moisture through organic mulches and proper irrigation. 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.

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 elements (calcium and magnesium) which contribute to the higher pH. Many fertilizers also add acidity to soil and plant roots secrete weak acids into the soil which may also 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 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 effectively lower the pH.**

On 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 (see Table 1). Incorporate sulfur to a depth of six inches. It may take several months to over a year to react with the soil, lowering the pH. Test soil pH again 3 to 4 months after initial application. If the soil pH is not in the desired range, reapply.**

**Table 1. 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 on fine-textured, clayey soils and soils with a pH 7.3 and above.

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

**Acid sphagnum peat** incorporated into the soil prior to planting will help provide a favorable rooting environment for the establishment of acid-loving plants in near neutral soils. Incorporate peat at the rate of one to two cubic feet per plant. The positive effects of acid peat will last a few years, but unless other measures are used, the pH of the soil will eventually increase. The pH will be driven up with the high calcium in our irrigation water. Soil with a pH above 7.3 and/or with *free lime* cannot be adequately amended for acid-loving plants.

**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. However, do not use these fertilizers at rates greater than those required to meet the nitrogen needs of the plants. For example, ammonium sulfate fertilizer, 21-0-0, at ten pounds per 1000 square feet (maximum rate for crop application) may lower the pH from 7.3 to 7.2.

## Raising the pH in Acid Soil

On acid 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 materials to raise the pH.

A laboratory test called **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.

**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 |
| 5.5–6.0 | 20 | 25 | 35 |
| 5.0–5.5 | 30 | 40 | 50 |
| 3.4–5.0 | 40 | 55 | 80 |
| 3.5–4.5 | 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, crease application rates in the above table by 50% and apply no more than 10 pounds of hydrated or burned line per 1000 square feet of turf.

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 becomes effective in raising pH. **Calcitic lime** mostly contains calcium carbonate ($CaC0_3$). **Dolomitic lime** contains both calcium carbonate and dolomite [$MgCa(CO_3)_2$]. On most soils, both are generally 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.

**Home pH test kits**

In alkaline soils, home pH kits have questionable value. Inexpensive kits do not calibrate closely enough on alkaline soils to be meaningful and small changes in techniques, such as how much water and the pH of the water used in the sample, can change results. Most home soil test kits are designed for acid soils.

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*CMG GardenNotes #223*

# Iron Chlorosis of Woody Plants

Outline:



## Symptoms

The term ***chlorosis*** means a general yellowing of the 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 include ***interveinal chlorosis***, i.e., 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 (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 tolerance to stress conditions. Plants with reduced vigor from iron chlorosis are more prone to winter injury and winter injury may aggravate an iron chlorosis problem. Weakened plants also are 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. Leaves 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 greatly in their susceptibility to iron deficiency.

Chlorosis usually develops as an overall yellowing of needles on junipers, pines, and other evergreens.

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### Similar Symptoms

Iron chlorosis symptoms can be confused with other problems. In the high pH soils of Colorado, an iron chlorosis problem may actually 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. Iron chlorosis appears first on the younger or terminal leaves. Under severe conditions, it may progress into older and lower leaves. By comparison, zinc and manganese deficiencies typically appear first on older, interior leaves.

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

Damage from soil sterilants (i.e., Pramitol, Atrazine, Simazine, Ureabor, and Diuron) used to prevent weeds result 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 and some virus, 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. A number of 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. These factors 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 raise 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 over-watering.

Overly wet or dry soils predispose plants to iron chlorosis. Iron chlorosis is more prevalent following wet springs, and where gardeners over-water in the spring. In western calcareous soils, iron chlorosis can be moderated by eliminating springtime over-watering. Dry soils can also lead to nutrient deficiencies as nutrients are absorbed in solution with water. Severe cases of iron chlorosis involving "acid-loving" 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 receives as much as 40% more water than is needed in the spring and fall. Such over watering can contribute to iron chlorosis.. For details, refer to *CMG GardenNotes* on irrigation management.

## 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. For details on mulching and soil compaction, refer to *CMG GardenNotes* #215, **Soil Compaction**, and #245, **Mulching with Wood/Bark Chips, Grass Clippings, and Rock**.

## 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 20 years after planting.

In tree planting standards, the top of the root ball should rise slightly above grade (i.e., 1-2 inches above grade) for newly planted trees. At least two structural roots should be located in the top 1-3 inches of the root ball. For additional information on tree planting, refer to *CMG GardenNotes* #633, **The Science of Planting Trees**.

On established trees, the trunk-to-root flare should be noticeable. If the trunk goes straight into the ground, suspect 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 a key 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 an 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 (Table 1) on soils prone to iron chlorosis problems (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 rather expensive and give disappointing results.Plant and soil conditions vary greatly so there is no single approach that is consistently best. Focusing on reducing springtime over-watering, soil compaction and other contributing factors is 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 soil factors directly affect the success of any approach. Determine soil pH by 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. 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. **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 and disadvantages. Each procedure 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, ferrous sulfate). Several types of iron chelates are marketed under a variety of trade names. Soil pH dictates the type of chelate to use. Treatment of 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, HiYield 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 drip-line of the tree, as described for chelates (see below). Over time, the sulfur reacts to lower soil pH in a localized area. Broadcast applications, that 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 12-24 inches away from the plant. See specific label directions for application rates. For 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 a couple of 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 1½ to 2 inches in diameter, 6 inches deep and 12 inches apart in rings 2 feet apart. For smaller trees, make 2 to 3 rings of holes. For large trees, create four to five or more rings of holes, and rings may need to extend beyond the drip line. No holes should be made within 2½ to 4 feet of the tree trunk on established trees. [Figure 2]

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, have the area utility-staked before starting. [Figure 2]

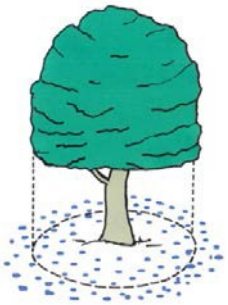

Figure 2. Place soil additive in a ring of holes around the drip line of the tree.

**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 its 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 very 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 quick response, often in a matter of days. However, the treatment is often spotty and only temporary. Multiple applications per season may be needed. 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 generally 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 rather 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. Trunk injections 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.

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*CMG GardenNotes #224*

# Saline Soils

Outline:



## Soluble Salts

The term ***soluble salts*** refers to the salts (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. Others like sodium chloride (table salt0 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 4150'. Some salts such as Boron, chloride and sodium can be toxic to plants.

### 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 any damage being apparent. 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 may or may not 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 the section on Soil Amendments.

### Excessive/Unnecessary Fertilizer Applications

**Unwarranted application of fertilizers (such as phosphate or potash) increases the salt level.** 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** is also a salt problem containing alkaline salts and nitrogen. 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 in light of 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 salinity | sensitive plants are inhibited |
| 4.1 to 8 | moderate~~ly~~ salinity | many plants are inhibited |
| 8.1 to 16 | strong~~ly~~ salinity | most cultivated plants are inhibited |
| over 16 | very strong~~ly~~ salinity | 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 ½ 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) when growing the 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. 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.*

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 by permission. Revised by Susan Carter, (CSU Extension)

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*CMG GardenNotes #231*

# Plant Nutrition

Outline:



## Fertility and Fertilization

Many people confuse plant nutrition with plant fertilization. ***Plant nutrition*** refers to the need for basic chemical elements for plant growth.

The term ***fertilization*** refers to the application of plant nutrients to supplement the nutrients naturally occurring in the soil. Nutrients may be applied as commercially manufactured fertilizers, organic fertilizers and/or other soil amendments. Organic fertilizers and soil amendments are typically low in plant-available nutrient content.

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

From a nutritional perspective, a plant cannot tell if applied nutrients come from a manufactured fertilizer or a natural source. Plants use nutrients in ionic forms. 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 manufactured and organic soil amendments/organic fertilizers is the speed at which nutrients become available for plant use. Manufactured fertilizers release rates are typically, but not always, a few days to weeks. Some are specially formulated as “controlled

release", "slow release" or "time release" products release over a period of months, but some organic fertilizers are quickly available. With natural-organic fertilizer, nutrients typically become available over a period of months or years. However, there are exceptions to this general rule. High salt contents of *some* manufactured fertilizers and *some* organic soil amendments can slow the activity of beneficial soil microorganisms and subsequent nutrient release.

Benefits of organic fertilizers and soil amendments include improvements in soil tilth (suitability of the soil to support plant growth). This should not be confused with "fertilization", a distinctly different soil management objective.

Remember that fertility is only part of the soil's role in supporting plant growth. The organic content of the soil also directly affects plant growth due to its influence on soil tilth and the activity of beneficial soil microorganisms. Relying solely on manufactured fertilizers is not recommended as this does not support good soil tilth.

## Plant Nutrients

Plants need 17 elements for normal growth. Carbon, hydrogen, and oxygen come from the air and water. Soil is the principle source of other nutrients. ***Primary nutrients*** (nitrogen, phosphorus, and potassium) are used in relatively large amounts by plants, and often are supplemented as fertilizers. [Table 1]

***Secondary nutrients*** (calcium, magnesium, and sulfur) are also used in large amounts but are typically readily available and in adequate supply. M***icronutrients*** or trace elements are needed only in small amounts. These include iron, zinc, molybdenum, manganese, boron, copper, cobalt, and chlorine. [Table 1]

**Table 1. Essential Plant Nutrients**

| Nutrient | Ions Absorbed by Plants |
|---|---|
| Structural elements | |
| Carbon, C | $CO_2$ |
| Hydrogen, H | $H_2O$ |
| Oxygen, O | $O_2$ |
| Primary nutrients | |
| Nitrogen, N | $NO_3^-$, $NH_4^+$ |
| Phosphorus, P | $H_2PO_4^-$, $HPO_4^{-2}$ |
| Potassium, K | $K^+$ |
| Secondary nutrients | |
| Calcium, Ca | $Ca^{+2}$ |
| Magnesium, MG | $Mg^{+2}$ |
| Sulfur, S | $SO_4^{-2}$ |
| Micronutrients | |
| Boron, B | $H_2BO_3^-$ |
| 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 primarily 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's water is in a constant state of flux as the variety of ions dissolve in 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. Negatively charged anions (like nitrate, $N0_3^-$) are prone to leaching and can become a water pollution problem. Both ammonium and nitrate are important plant nitrogen sources and are commonly found in salt forms in fertilizers.

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.

# Colorado Soils and Plant Nutritional Needs

## 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 relative need for soil nitrogen. Colorado soils benefit from nitrogen fertilization of the right amount and frequency to meet plant needs. General symptoms of nitrogen deficiency are shown in Table 2 and Figure 1.

**Table 2 and 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 value is constantly changing due to organic content, microorganism activity, and changes in temperature and water.

Nitrogen is useable by plants in two forms, **ammonium** ($NH_4$+), and **nitrate** ($NO_3^-$). Ammonium, being positively charged, is attracted to the negatively

charged soil particles and thus is resistant to leaching (movement down through the soil profile). Soil microorganisms convert ammonium to nitrate. Nitrate, being negatively charged, readily leaches below the root zone with excess rain/irrigation in sandy soils. Prevent water pollution by avoiding over-fertilization of nitrogen, particularly on sandy soils.

Soil microorganisms release nitrogen tied-up in organic matter over a period of time. Release rates from compost are very slow (i.e., over a period of years). The need for nitrogen fertilizer is based on the organic content of the soils. [Table 3]

**Table 3.**
**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

Iron chlorosis refers to a yellowing of leaves caused by an iron deficiency in the leaf tissues. Primary symptoms include interveinal chlorosis (i.e., a general yellowing of leaves with veins remaining green). Symptoms appear first and are more pronounced on younger leaves and on new growth. In severe cases, leaves may become pale yellow or whitish, but veins retain a greenish tint. Angular shaped brown spots may develop between veins and leave margins may scorch (brown along the edge). Symptoms may show on a single branch or on the entire tree. General symptoms of iron chlorosis are shown in Table 3 and Figure 2.

**Table 3 and 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; but rather unavailable for plant uptake due to the soil's high lime (calcium carbonate) content. In western soils, iron chlorosis is a general symptom of other problems, including the following:

- **Springtime over-watering** is the primary cause of iron chlorosis in western soils! Attention to irrigation management, with seasonal changes of the irrigation controller will generally correct iron chlorosis.
- **Soil compaction** and low soil oxygen contributes to iron chlorosis.
- Iron chlorosis is an early symptom of **trunk girdling roots.**
- Iron chlorosis appears as a complication of **winter trunk/bark injury**.

Attention to these contributing factors is much more effective than adding iron products.

## Phosphorus

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 and five atoms of oxygen. The *phosphorus* content of fertilizer is measured in percent *phosphate*.

**Phosphorus may be present in high concentrations, 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 is also *less available* to plants when soil temperatures are cool. In the spring, the use of starter fertilizers with phosphorus may be beneficial to herbaceous flowers and vegetable transplants.

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 composts.

## Potassium

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 and one atom of oxygen. The potassium content of fertilizer is measured in percent potash.

**Potassium levels are naturally adequate and even high in most Colorado soils. 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 fertilizers.

Potassium deficiency is very difficult to diagnose, because other growth factors will give similar symptoms. General symptoms include a marginal and interveinal chlorosis (yellowing), followed by scorching that moves inward. Older leaves are

affected first. Leaves may crinkle and roll upward. Shoots may show short, bushy, zigzag growth, with dieback late in season.

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

## Zinc

Zinc deficiency occasionally occurs in sandy soils containing excessive lime and in soils low in organic matter (typical of new yards where the topsoil has been removed). Excessive phosphate fertilization may aggravate a zinc problem. It will be seen more in years with cold wet springs.

Sweet corn, beans, and potatoes are the most likely vegetables to be affected. 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 generally not extending to the tip.

Occasional manure applications will supply the zinc needs. If a soil test indicates zinc deficiency (less than 1 ppm), apply a zinc-containing fertilizer according to label directions.

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired). Revised by Dan Goldhamer (CSU Extension). Artwork by David Whiting; used by permission.

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*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 percent 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 (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://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 http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program

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 that 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**<br>o Lasts 4-6 weeks | Ammonium sulfate<br>Ammonium nitrate<br>Calcium nitrate<br>Potassium nitrate<br>Urea |
| **Slowly available nitrogen**<br>o Available over weeks to months<br>o Regulated by solubility or microorganism activity | Resin-coated urea<br>Sulfur-coated urea<br>Isobutylidene diurea (IBDU)<br>Methylene urea<br>Urea formaldehyde<br>Manure<br>Poultry wastes<br>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 contains 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 affect 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 #711, Vegetable Garden: 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 and 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 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 wastes 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. Actually, 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 to blow 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]

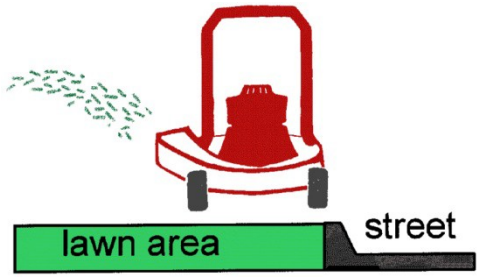


Figure 1. Grass clippings and leaves mowed or blown into the street are the major source of phosphate pollution from the landscape environment. Mow in a direction to discharge clippings back onto the lawn and not into the street.

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 unmowed 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 very 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 time period. 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., MiracleGro, 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 are 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., MiracleGro, Peters, Schultz Plant Food, Fertilome Root Stimulator, etc.). Water soluble fertilizers are mixed with the 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. (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.) Water solubles are the standard in greenhouse production where the fertilizer is injected into the irrigation water.

**For herbaceous transplants** (flowers and vegetables), water soluble fertilizers are recommended at planting and possibly 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.

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Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired). Revised 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 3

## 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

__ ft. long X ft. wide = ____square feet

*Example:*

**40** feet X **100** feet = **4000** square feet

### 2.Calculating fertilizer application rate

__ lb. nutrient per_____sq. ft.
---
__ % nutrient in fertilizer = pounds fertilizer /_____sq. ft.

*Example:*

**1** lb. nutrient per **1000** sq. ft.
---
**20%** nutrient in fertilizer
(.20) = **5** pounds. fertilizer / **1000** sq. ft.

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

| lawn or garden area | X | application rate | = | pound of fertilizer per garden or lawn |
|---|---|---|---|---|
| ____sq. ft. / garden or lawn | X | ___pounds fertilizer / ___sq. ft. | = | __ pounds fertilizer / garden or lawn |

*Example:*

| | | | | |
|---|---|---|---|---|
| **4000** sq. ft. / lawn | X | **5** pounds fertilizer / **1000** sq. ft. | = | **20** pounds fertilizer / lawn |

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Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension) and Carl Wilson (CSU Extension, retired) Reviewed by Eric Hammond (CSU Extension)

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## Table 1. Fertilizer Application Rate Table

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:

**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 1,000 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 1 000 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 sq. ft. and the fertilizer grade selected has a ratio of 18-6-12 (column 1), apply 0.6 lb. of this fertilizer per 100 sq. ft.

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*CMG GardenNotes #234*

# Organic Fertilizers

Outline:



## Terms

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 (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://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 http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program. 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 have no legal claims about nutrient content or other helpful (or harmful) effects it 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.

**Release Time** – Organic products require the activity of soil microorganisms before nutrients are available for plant uptake. Microorganism activity is generally 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.

## 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 trianconatol, 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 1 to 4 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

Used primarily as an animal feed product. Available bagged at many feed stores.

**Soybean Meal**

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

## Animal By-Products

### Bat Guano – High N

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 – 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

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. Difference is that it is processed for high phosphorus content.

| 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 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 with 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 | Highly 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 that have been heat and acid processed from fish waste.

**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 power is dried with heat and turned into water-soluble powder. It is a high source of nitrogen. Many can be mixed into 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 Powders

Rock powders relevant for use in Colorado soils are those that supply phosphorus. Those that serve as a potassium source (greensand, feldspar, potassium sulfate, biotite, etc.) are not necessary as Colorado soils are naturally high in potassium. Similarly, it is not necessary to add calcium (gypsum, lime, etc.) due to naturally high calcium levels in Colorado soils and arid conditions.

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.

Generally, plant or animal sources are the best value for phosphorus in the home garden. **Recent CSU research results concluded that no rock P (regardless of mesh size) is available for plant use unless the soil pH is below 7.0.**

### Colloidal Phosphate – a.k.a. Soft Rock Phosphate

This product is made by surrounding clay particles with natural phosphate. Total phosphate is about 20% while available phosphate is about 2-3%. You can apply large amounts of colloidal phosphate, as it will release slowly over the years (usually more available the second year than the first). For home gardeners the cost/return is adequate to apply colloidal phosphate at rates to supply phosphorus for this season's crops. This product also adds micronutrients to soil.

Micronized (passing through 1000 mesh screen [1000 wires per square inch]) sources may be more available than regular soft rock grinds in soils with a pH below 7.0.

## Seaweed

Kelp is the most common form and is valued not for its macronutrient (nitrogen, phosphorus and potassium) contributions but for 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). Ranked in quality of content and plant availability they are (highest to lowest) 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 micronutrients |
| Cons | Insignificant nitrogen, phosphorus and potassium |
| Application | Till in 1 pound per 100 square feet |

## Kelp Powder

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

**Kelp Powder**

| | |
|---|---|
| Typical NPK analysis | 1-0-4 |
| Release time | Immediate – 1 month |
| Pros | Adds micronutrients |
| Cons | Insignificant nitrogen, phosphorus and 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 – 1 month |
| Pros | Adds micronutrients plus helps plant with stress |
| Cons | Insignificant nitrogen, phosphorus and potassium |
| Application | Mix 1-2 tablespoons per gallon of water |

Authors: Adrian Card (CSU Extension), with David Whiting (CSU Extension, retired), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Revised Dan Goldhamer (CSU Extension)

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*CMG GardenNotes #241*

# Soil Amendments

Outline:



## Terms

The term ***soil amendment*** refers to any material mixed into a soil. ***Mulch*** refers to a material placed on the soil surface. By legal definition, soil amendments make no legal claims about nutrient content or other helpful (or harmful) effects that it 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 microorganism activity.

By legal definition, the term ***fertilizer*** refers to soil amendments that guarantee 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 (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://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 http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program 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 most often do not meet the legal requirements as a "fertilizer" and generally add only small quantities of plant nutrients.

## 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 glues the tiny clay particles into larger chunks or *aggregates* creating large pore space. 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). For additional discussion, refer to the *CMG GardenNotes* #213, **Managing Soil Tilth**.

Using ***organic soil amendments*** is a great way to turn otherwise useless products, like fall leaves and livestock manure, into compost for improving soil tilth.

When using organic soil amendments, it is important to understand that only a portion of the nutrients in the product are available to plants in any one growing season. Soil microorganisms must process the organic compounds into chemical ions ($NO_3^-$, $NH_4^+$, $HPO_4^{-2}$, $H_2PO_4^-$, $K^+$) 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.

# 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, aged manure, and peat. To improve aeration and infiltration (improve structure on clayey soils) select fibrous materials like composted wood chips, peat 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** of the product merits consideration. Produces that decompose rapidly (like grass clippings and manure) give quick results, while products that decompose slowly (like wood chips, bark chips and peat) provide longer lasting results. For quick improvement that last, use a combination of materials.

**Salts** are a primary consideration. Products made with manure and/or biosolids are often very high in salts. Salt levels may actually increase in the composting process, although water moving through the compost pile leaches out the salts. Use with caution! Plant-based products are naturally low in salts.

Routine application rates depend on the salt potential of the material and the depth to which it will be cultivated into the soil. Table 1 gives standard rates.

**Table 1. Routine Application Rate for Soil Amendments**

| 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 inches | 2-3 inches | 1 inch |
| **Annual application** to vegetable and flower gardens – **first three years** | 6-8 inches | 2-3 inches | 1 inch |
| **Annual application** to vegetable and flower gardens – **fourth year and beyond** | 6-8 inches | 1-2 inches | 1 inch |

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 plants to reduced growth, low vigor and low stress tolerance. If the actual incorporation depth is different, adjust the rate accordingly.

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. For a few products in the market with extremely high salt levels, even this low rate may be too high.

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. Voluntary standards for bulk products may help in product evaluation. Use with caution! Many of the soil amendments sold in Colorado are high in salts!

**Need for nitrogen fertilizer** – Soil microorganisms release nitrogen tied-up in organic matter over a period of time. Release rates from compost are very slow,

over a period of years. The need for nitrogen fertilizer is based on the soil organic content. As the soil organic content increases, the need for fertilizer decreases. [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 / 1,000 square feet |
| 2-3% | 1 pound actual N / 1,000 square feet |
| 4-5% | 0 |

### 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 following problems:

- High salts
- High nitrogen
- Low nitrogen (from the tie-up of nitrogen due to a 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 ½ inch particle size; lawn top dressing less than ¼ inch
**Foreign materials** – Less than 1% and smaller than ½ inch size
**Uniformity** Within the batch
**Consistency** 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** – Less than 20 to 1 acceptable; 10-12 to 1 is better

**Ash content** – (This measurement of the mineral portion after the organic matter is burned off will determine if soil was a primary part of the mix.)

- 20-30% common
- Keep below 50%
- If greater than 50-60% it probably contains a lot of soil

**Bulk density** – Less than 1.0 gm/cc

**pH** – 6.0 to 7.8

- May be higher in manure
- Near neutral (6.8 to 7.2) is best

**Salts** – Acceptable levels depend on use

- Potting grade: < 2.5 mmhos/cm
- Potting media amendment: < 6 mmhos/cm
- Top dressing: < 5 mmhos/cm
- Soil amendment in a low salt soil: <10 mmhos/cm

**Sodium** – Sodium adsorption ratio less than 13%

**Ammonium** – Less than 1/3 of total nitrogen. If higher, it may not be finished composting.

**Heavy metals** – A concern with biosolids but regulated by application permits.

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

**Pathogens** – *E-coli* and other human pathogens are a potential in manure.

**Nutrient content** varies greatly from product to product.

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

**Stability (respiration rate) vs. maturity** – Relative measurement of the completeness of microbial activity. If microorganisms are highly active, they may consume oxygen in the root zone causing root problems.

**Bacterial and fungal diversity** – Some compost has been found to suppress plant diseases. This is a high-tech field with commercial applications.

## 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 man-made. Organic amendments include sphagnum peat, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust, and wood ash. Inorganic amendments include vermiculite, perlite, tire chunks, pea gravel, and sand.

**Peat**

**Sphagnum peat** is a good soil amendment, especially for sandy soils, which will retain more water after sphagnum peat application. Sphagnum peat is generally acidic (i.e., low pH) and may help gardeners grow plants that require a more acidic soil. Sphagnum peat is harvested from bogs in Canada and the northern United States. The bogs can be revegetated after harvest and grow back relatively quickly in this moist environment. In recent years however, harvest rates have become so high that it is raising questions on renewability.

**Colorado mountain peat** is not an acceptable soil amendment. It often is too fine in texture and generally has a higher pH. Mountain peat is mined from high-altitude wetlands that will take hundreds of years to rejuvenate, if ever. This mining is extremely disruptive to hydrologic cycles and mountain ecosystems.

## Biosolids

Biosolids (sewage sludge) 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 dS/m (38.3 mmhos/cm), which is considerably above acceptable tolerances for soil amendments. (A soil amendment above 10 dS/m 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

Versatile worm castings can be used in potted plants, soil mixes, and in garden beds. Worm castings pose no threat of burning potted plants. Worms should have digested the batch of vermicompost for 4 months to ensure that microbial oxygen consumption has diminished sufficiently.

Red worm castings are the feces from compost worms. It has a slow release performance due to a mucus covering which is slowly degraded with microorganism activity. It contains highly available forms of plant nutrients that are water-soluble, has a neutral pH, and contains trace elements, enzymes, and beneficial microorganisms. The release time for nutrients is around 4 months. For continual release of nutrients, repeat applications at 4-month intervals.

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.

Castings can be applied as a top dressing, 1/4 inch deep, to potted plants, as 25% of a soil mix (1 to 4 mix) or tilled into a garden at 1 gallon per 13 square feet or 7.5 gallons (1 cubic foot) per 100 square feet. Due to the high cost in Colorado, they 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 has a low water holding capacity.

## Summary: Considerations in Selecting Soil Amendments

There is really not a best amendment to use in each 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:

- Cost
    - Local availability
    - Cost of product
    - Size of area to be treated (quantity needed)
    - Depth of incorporation (application rate / quantity needed)
    - Transportation costs
- Need for fertilizer after amending
    - Soil organic content
- Precautions with specific products
    - Salts (manure and biosolids)
    - Weed seeds (manure and compost)
    - Plant pathogens (compost)
    - Human pathogens (manure)
- Alternatives to amending
    - Potential to incorporate amendments
    - 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 to slowly improve soil over time
    - Container and raised-bed gardening
    - Preventing compaction forces

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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*CMG GardenNotes #242*

# Using Manure in the Home Garden

Outline:



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 transmitting human pathogens, such as *E. coli*, fresh manure should only be used on fruits and vegetables when specific precautions are taken. Apply non composted (fresh) manures in the fall and mix it into the soil. Do not leave it on the soil surface. Wait 120 days from manure application to harvest. Never apply it to growing good crops.

## 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. [Table 1]

**Table 1. Approximate nutrient content of manure***

| Type | | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|
| **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.

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 2. Approximate percentage of organic N mineralized in the 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 builds in organic matter 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 (when cultivated six to eight inches deep) and thoroughly cultivate the manure or compost into the soil. When cultivation is less than six to eight inches deep, adjust 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 the following:

- Potential burning of roots and foliage from high ammonia.
- 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.

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 145ºF 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 supplemented. This could be supplied with blood meal (approximately 1 to 2 pounds per 100 square feet) or with a manufactured fertilizer like ammonium nitrate (2/3 cup per 100 sq. ft) or ammonium sulfate (1 cup per 100 sq. ft.). The ammonia content drops due to volatilization during composting, thereby reducing the burn potential.

Fresh manure without bedding materials is somewhat 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.

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Authors: David Whiting (CSU Extension, retired) with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Revised by Dan Goldhamer (CSU Extension)

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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*CMG GardenNotes #243*

# Using Compost in the Home Garden

Outline:



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

## Compost Products

Home made or commercial compost is a good source of organic matter for the garden. Compost provides a food source for beneficial soil organisms, enhancing the soil food web and releasing nutrients over the long term.

A home compost bin is an environmentally sound method to convert yard wastes into a valuable soil-building resource. Using compost has also been found to suppress some soil borne plant disease pathogens in certain situations.

Home compost has the advantage that the gardener controls what goes into the compost pile and can avoid weed seeds, diseased plants and salt problems.

There are many bagged compost based products available in the retail trade. They can be any combination of plant residues, manure, and/or biosolids. Some products also have added rock minerals or animal by-products. These bagged products are usually more expensive than manure and compost supplies available in bulk. They provide a long-term release of nutrients and add organic matter to soils, improving soil physical properties.

In Colorado, compost is unregulated. Materials sold as “compost” could be anything (plant materials, manure, biosolids, animal by-products, etc.) and could be at any stage of decomposition. Not all “composts” are good for the soil.

## Application Rates and Salt Problems

General application rates for compost are based on the salt content of the compost and soil and on the depth to which it is cultivated into the soil. Ideally, cultivate the compost 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.

Table 1 gives standard application rates 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.

**Table 1. Routine Application Rate for Soil Amendments**

| 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 inches | 2-3 inches | 1 inch |
| **Annual application** to vegetable and flower gardens – **first three years** | 6-8 inches | 2-3 inches | 1 inch |
| **Annual application** to vegetable and flower gardens – **fourth year and beyond** | 6-8 inches | 1-2 inches | 1 inch |

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. In compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor and low stress tolerance.

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. For a few products in the market with extremely high salt levels, even this low rate may be too high.

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.

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 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.

## Nitrogen Release is Slow

Typical nutrient content includes 1.5% to 3.5% nitrogen, 0.5% to 1% phosphate, and 1% to 2% potash, plus micronutrients. Thus compost is more of a soil conditioner than a fertilizer. In gardens where compost is routinely added, phosphorus and potassium levels are likely to be adequate.

As in other organic soil amendments, the nitrogen release rate from compost will be very slow, (i.e., over a period of years). When the organic content is below 4-5%, additional supplemental organic or manufactured nitrogen fertilizer may be needed.

**4-5% Organic Matter** – Soils with 4-5% organic matter from compost will *mineralize* (release to plants) about 0.2 pound of nitrogen per 100 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 100 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.

## Beware of Unfinished Compost

Finished compost is dark and crumbly, does not resemble the original contents and has an earthy smell. Compost that has not thoroughly processed could be “hot” with high ammonia content. This could burn plant roots (when applied to the soil) or plant leaves (when applied as a mulch). If the compost smells like ammonia, it should be processed longer or be worked into the soil at least one month prior to seeding or transplanting in the area.

Compost maturity can be assessed in a laboratory by measuring the carbon dioxide ($CO_2$) production by the microorganisms living in the material. Lower levels of $CO_2$ 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 $CO_2$, they are consuming oxygen ($O_2$). Unfinished compost can consume all of the $O_2$ from the root zone and greatly inhibit root growth. Finished compost should smell earthy, like healthy soil, not like ammonia.
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 45 days before being considered finished. This curing period allows nitrogen and other chemical constituents to stabilize into forms suitable for placement around plants.

## 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 in compost if the animals were fed hay with 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 increases the incidence of nuisance animals rummaging through the compost pile and disease transmission to humans.

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Authors: David Whiting (CSU Extension, retired), with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Reviewed by Dan Goldhamer (CSU Extension)



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MASTER GARDENER
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*CMG GardenNotes #244*

# Cover Crops and Green Manure Crops

Outline:



## Terms: Green Manure and Cover Crop

A ***cover crop*** is simply high numbers of plants, usually specific annual, biennial, or perennial grasses and/or legumes, growing and covering the soil surface which improves the soil. 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 Cover Cropping 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. A thick stand of a cover crop protects the soil surface from wind erosion and as the cover crop's roots hold soil in place against water erosion during heavy downpours.

**Weed suppression** – Cover crops left in place for part or all of a growing season can suppress annual and some perennial weeds. Among the grasses, annual rye has alleopathic properties that prevent weed seeds from germinating and suppress 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 plants sugar in return for the nitrogen. Some of this nitrogen is available as roots die, but the majority becomes available when the legume is tilled under (green manure). Alfalfa is a legume with alleopathic properties towards plants of the same species.

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

**Insect rests reduction** – Cover crops encourage beneficial insect populations, often minimizing or eliminating the need for other insect control measures.

## Why is Green Manuring Beneficial?

Green manuring 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. Nitrogen accumulation is greater with legumes, which have nitrogen-fixing *Rhizobium* bacteria growing in nodules on the legume roots [Table 1]. 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 variations in the activity level of rhizobium.

**Table 2. Potential Nitrogen Fixation Rates of Selected Legumes for Colorado**

| Legume Crop | Pounds N per 1000 $ft^2$ |
|---|---|
| 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 aggregate soil particles, thereby enhancing the tilth, porosity, and water holding capabilities of soil.

## Basic Recipes for Cover Crops and Green Manure Crops in a Garden

### Spring-Planted

Most gardeners do not have enough space to forfeit 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. It also has a definite shelf life, so check the expiration date. Broadcast the seed/*Rhizobium* mix at a specified rate after the last frost with a hand held broadcaster (often used with pelleted fertilizer) into a loose seedbed and incorporate shallowly and water until germinated. Monitor water as you would in a lawn.

Till 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 tilled under as a spring green manure. Seeding dates should be done by mid-October at the latest. Mid-September is ideal on 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 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 a veritable salad-bar to geese and deer. 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 a month before you plan to plant/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 for homeowners. During droughty periods, watering restrictions and the lack of natural precipitation may make turf establishment difficult or impossible. A temporary cover crop or long-term xeric grass may be the answer.

In this scenario, the homeowner has to 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.

### Annual Species Options

These are cool season grains that should be broadcast at 2-3 pounds per 1000 square feet in February or March and later for higher elevations. Natural precipitation may be sufficient to get them established. They are suited for non-traffic areas, as they will grow to 2 feet tall and brown-out in the heat of summer. The Sterile Triticale will not produce viable seeds so may be a good idea for areas that will eventually be put into turf or garden space. Winter rye seeds can be a weed problem in seeded turf grass and gardens. [Table 4]

**Table 4. Annual Species**

| Name | Bunch or Sod | Cool or Warm Season | Annual or Perennial | Turf? | Reseed? |
|---|---|---|---|---|---|
| Winter rye | Bunch | Cool | Annual | No | Yes |
| Pioneer sterile triticale | Bunch | Cool | Annual | No | No |

### Perennial Species Options

These are non-native grasses often used on roadsides for stabilization and cover. They are perennial and will be persistent (i.e., – difficult to kill) once they are established. Water requirements for both are 9-10 inches of precipitation per year. Streambank wheatgrass has a slightly higher water requirement but is tolerant of very clayey soils, unlike Crested wheatgrass. Broadcast in February or March at 3-5 pounds per 1000 square feet. [Table 5]

**Table 5. Perennial Species**

| Name | Bunch or Sod | Cool or Warm Season | Annual or Perennial | Turf? | Reseed? |
|---|---|---|---|---|---|
| Streambank wheatgrass | Sod | Cool | Perennial | Yes | Some |
| Crested wheatgrass | Bunch | Cool | Perennial | Yes | Some |

### Native Species Options

These have the lowest water requirements at 8 inches of precipitation per year and should be considered for areas of a landscape that are being converted to xeric management. This is a long-term management decision as the price of these seeds is more than the other options. These grasses will not feel like Kentucky blue grass and will brown out like other cool season grasses. Seed as per perennial species options specifications. Seed for native species will be available from local seed sources. [Table 6]

**Table 6. Native Species**

| Name | Bunch or Sod | Cool or Warm Season | Annual or Perennial | Turf? | Reseed? |
|---|---|---|---|---|---|
| Indian ricegrass | Bunch | Cool | Perennial | No | Some |
| Squirreltail bottlebrush | Bunch | Cool | Perennial | No | Some |

## 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 area prior to seeding if possible to establish ample soil moisture levels.

Broadcast the correct amount 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.

**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 seed heads.

**Removing cover crops** – For winter rye, either till under, mow and mulch heavily, or spray herbicide before it goes to seed. A seed bank can be sodded over or watered, germinated and killed. Perennial grasses can be either mowed and mulched heavily prior to sodding, or sprayed with herbicide and sodded, or sprayed with herbicide, tilled and seeded.

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- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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MASTER GARDENER
COLORADO STATE UNIVERSITY
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*CMG GardenNotes #251*

# Asking Effective Questions About Soils

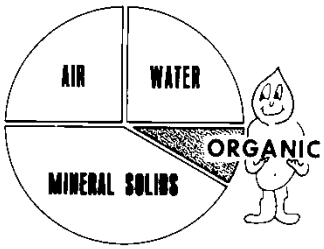
Outline:



## 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 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, but not assessed by a soil test.




Soil physical properties 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 the **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?
- What is your soil like to water?

- How do you care for your soil?
- 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.

## "Piggy Back" Questions

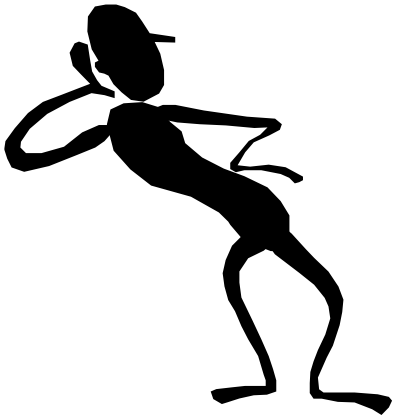
Remember to "piggy back" your new questions on top of the answers already obtained. Example – "O.K., let's talk about your soil in a little more detail. Is it a clayey or a sandy soil?" Avoid negative presuppositions. For example, ask "Have you amended your soil? What amendment did you use?" Do not accusingly 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 O.K. 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 don't insert judgmental overtones into the comments. Examples of neutral comments are:

- You noticed a white substance in the soil.
- You found no 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.

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