



## **SOIL AMENDMENTS CLASS OUTLINE**

1. Flip chart list of amendments
2. What is soil?
3. Soil profile
4. Physical properties of soil
  - a. Color
  - b. Texture
    - i. Rocks and gravel
    - ii. Sandy or coarsely textured soil
    - iii. Loamy or medium textured soil
    - iv. Clayey or fine textured soil
    - v. Compaction
    - vi. Erosion
  - c. Structure
  - d. Water holding capacity
5. Organic matter
6. Chemical properties
7. Soil testing
8. Plant nutrition and fertilization
9. Biology

CSU Extension Websites

Extension.colostate.edu

Cmg.colostate.edu

Planttalk.org

Soil data from website

<https://websoilsurvey.nrcs.usda.gov/app/>



CMG GardenNotes #214

# Estimating Soil Texture

## *Sandy, Loamy or Clayey?*

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Outline: Sand, silt, and clay, page 1  
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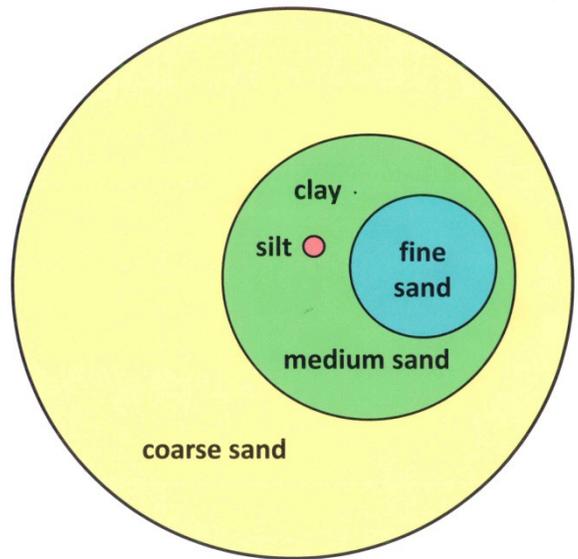
### Sand, Silt and Clay

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

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

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

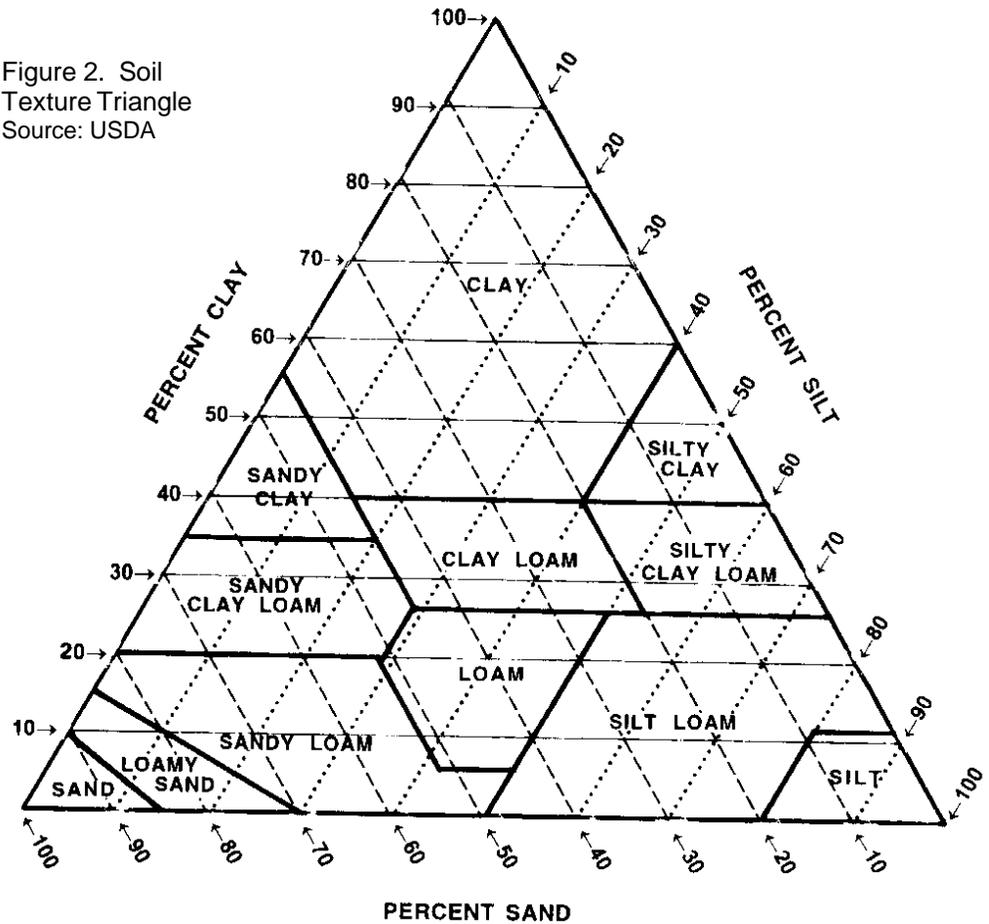
Figure 1. Comparative size of sands, silt and clay. If clay was the size of a dot on the page, silt and sands would be a comparative size.



## Soil Texture Triangle

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

Figure 2. Soil Texture Triangle  
Source: USDA



## Identifying Soil Texture by Measurement

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 three-quarters full.
5. Add a teaspoon of powdered, non-foaming dishwasher detergent.
6. Put on a tight fitting lid and shake hard for 10 to 15 minutes. 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.

$$\frac{[\text{clay thickness}]}{[\text{total thickness}]} = \text{____ percent clay}$$

$$\frac{[\text{silt thickness}]}{[\text{total thickness}]} = \text{____ percent silt}$$

$$\frac{[\text{sand thickness}]}{[\text{total thickness}]} = \text{____ percent sand}$$

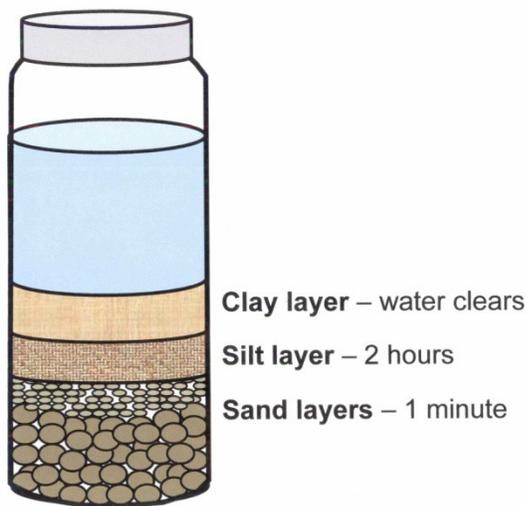


Figure 3. Measuring Soil Texture

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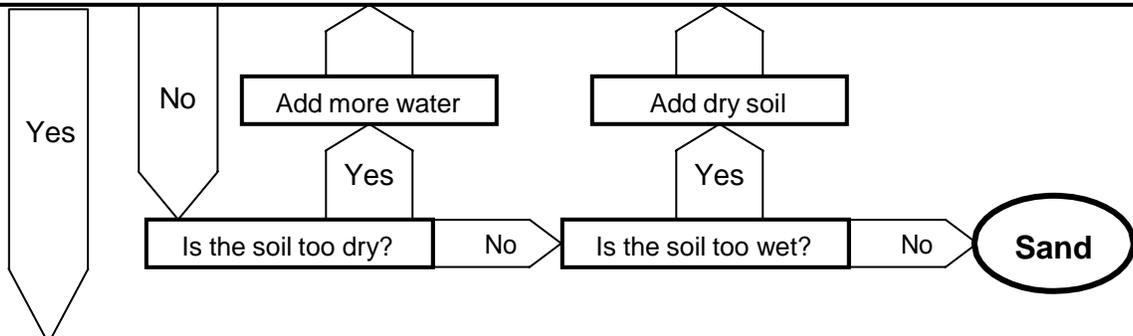
Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting; used by permission.

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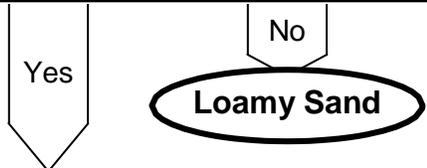
Revised 2014; reviewed December 2015

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?**



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?**



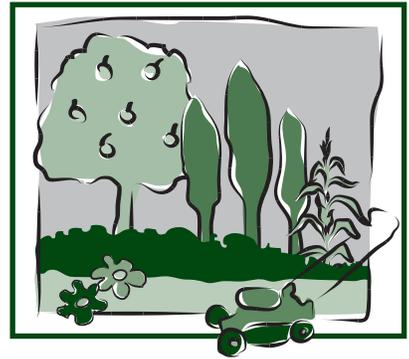
**What kind of ribbon does it form?**

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

# Choosing a Soil Amendment

Fact Sheet No. 7.235

Gardening Series | Basics



by J.G. Davis and D. Whiting\*

A soil amendment is any material added to a soil to improve its physical properties, such as water retention, permeability, water infiltration, drainage, aeration and structure. The goal is to provide a better environment for roots.

To do its work, an amendment must be thoroughly mixed into the soil. If it is merely buried, its effectiveness is reduced, and it will interfere with water and air movement and root growth.

Amending a soil is not the same thing as mulching, although many mulches also are used as amendments. A mulch is left on the soil surface. Its purpose is to reduce evaporation and runoff, inhibit weed growth, and create an attractive appearance. Mulches also moderate soil temperature. Organic mulches may be incorporated into the soil as amendments after they have decomposed to the point that they no longer serve their purpose.

## Organic vs. Inorganic Amendments

There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that 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.

Not all of the above are recommended by Colorado State University. These are merely examples. Wood ash, an organic amendment, is high in both pH and salt. It can magnify common Colorado soil problems and should

not be used as a soil amendment. Don't add sand to clay soil — this creates a soil structure similar to concrete.

Organic amendments increase soil organic matter content and offer many benefits. Over time, organic matter improves soil aeration, water infiltration, and both water- and nutrient-holding capacity. Many organic amendments contain plant nutrients and act as organic fertilizers. Organic matter also is an important energy source for bacteria, fungi and earthworms that live in the soil.

## Application Rates

Ideally, the landscape and garden soils are improved to 4-5% organic matter. At this level, the *mineralization* (release) of nitrogen from the organic matter will be adequate for most plants without additional fertilizers. Many cities now require that the landscape soils be brought up to this level in new developments as a water conservation technique. With the improved aeration and deeper rooting, plants are more efficient in capturing rain events.

Table 1 gives the routine application rates. Where the soil amendments may be high in salts, the rate is limited due to the salt problem. Salt burn of roots and death of landscape and garden plants is common from over application of salty soil amendments.

## Wood Products

Wood products can tie up nitrogen in the soil and cause nitrogen deficiency in plants. Microorganisms in the soil use nitrogen to break down the wood. Over several months to years, as microorganisms complete the rapid decomposition process, the nitrogen is released and again becomes available to plants. This hazard is greatest with sawdust, because it has a greater surface area than wood chips.

Compost wood products, before using them as soil amendments. For these products to decompose rapidly, add a nitrogen

## Quick Facts

- On clayey soils, soil amendments improve the soil aggregation, increase porosity and permeability, and improve aeration, drainage, and rooting depth.
- On sandy soils, soil amendments increase the water and nutrient holding capacity.
- A variety of products are available bagged or bulk for soil amendments. However, soil amendments are not regulated. Many are extremely high in salts.
- With Colorado's large livestock industry, manure and manure-based compost are readily available. These are often high in salts, limiting application rates. Use with caution.
- Plant-based composts are low in salt. These may be applied at higher application rates, more effectively improving the soil. Plant-based composts are typically higher in price.

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\*J.G. Davis, Colorado State University Extension specialist and associate professor, soil and crop sciences; and D. Whiting, Extension specialist. 2/2013

source to the compost pile. This could be plant residues high in nitrogen (such as grass clippings or manure), or a nitrogen fertilizer. Do not use uncomposted wood products or sawdust as a soil amendment. It is slow to break down, ties up nitrogen, interferes with seedbed preparation, and interferes with soil and water movement through the soil profile.

### Sphagnum Peat vs. Mountain Peat

Sphagnum peat is an excellent soil amendment, especially for sandy soils, which will retain more water after sphagnum peat application. Sphagnum peat is generally acid (i.e., low pH) and can 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 in this moist environment. However, the harvest rate greatly exceeds the vegetation rate of the peat bogs, so it is considered a semi-renewal resource.

Colorado mountain peat is not a good 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.

### Are Biosolids Safe?

Biosolids are byproducts of sewage treatment. They may be found alone or composted with leaves or other organic materials.

The primary concerns about biosolids are heavy metal content, pathogen levels and salts. Use only Class A biosolids, it has been treated to reduce the bacterial content. Class A biosolids are approved for use in production agriculture. However, it is advisable to avoid application to vegetable gardens due to the potential for heavy metals (such as cadmium and lead).

Some cities sell or give away biosolids or compost made with biosolids. It is often extremely high in salts. Ask about the salt content. Use with caution.

### Manure

Fresh manure can harm plants due to elevated ammonia levels. To avoid this problem, use only aged or composted manure.

**Table 1: Routine application rate for soil amendments.**

| Site   |                        | Depth of soil amendment prior to incorporation <sup>A</sup><br>(based on an incorporation depth of 6-8 inches) <sup>B</sup> |  |
|--|------------------------|---|--|
|  |                        | Plant-based composts and other soil amendments low in salts <sup>C</sup>  | Manure, manure-based compost, biosolids, biosolid-based compost and other soil amendments that may be high in salts <sup>D</sup> |
| One-time application to new landscapes prior to planting trees, shrubs, perennials, and lawns. |                        | 2-3 inches  | 1 inch <sup>E</sup>  |
| Annual application to vegetable garden and annual flowerbeds                                   | First three years      | 2-3 inches  | 1 inch <sup>E</sup>  |
|  | Fourth year and beyond | 1-2 inches  | 1 inch <sup>E</sup>  |

<sup>A</sup> Three cubic yards (87 bushel) covers 1,000 square feet approximately 1 inch deep.  
<sup>B</sup> Cultivate the soil amendment into the top 6-8 inches of 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. Rate should be adjusted if incorporation depth is different.  
<sup>C</sup> Plant-based compost are derived solely from plant materials (leaves, grass clippings, wood chips, and other yard wastes). Use this application rate for other soil amendments known to be low in salt.  
<sup>D</sup> Use this application rate for any soil amendment with manure or biosolids, unless the salt content is actually known, by soil test, to be low. Excessive salts are common in many commercially available bagged and bulk products. Use with caution.  
<sup>E</sup> For soil amendments with high salts, this routine application rate may be too high. Use with caution.

Human pathogens, including *E. coli*, are another potential problem with fresh manure, especially on vegetable gardens. For vegetables with direct contact with the soil, fresh manure must be applied at least four months prior to harvest. For other fruits and vegetables, fresh manure must be applied at least three months prior to harvest. In simple words, fresh manure would be only fall applied for the spring garden. For additional information on *E. coli*, refer to fact sheet [9.369 Preventing E. coli from Garden to Plate](#).

Aged manure refers to manure that has been piled for at least six months. Excessive ammonia will have escaped. Salt levels may be higher as the salts concentrate in the decomposing material, or may be leached out with high rainfall. Weed seeds will be viable.

Composted manure technically refers to manure that has been through multiple active heating cycles and turned in between. If heated above 145 degrees F, it will kill pathogens and weed seeds. In composted manure, the organic matter is stabilized

**Table 2: Permeability and water retention of various soil types.**

| Soil Texture | Permeability | Water Retention |
|--------------|--------------|-----------------|
| Sand         | high         | low             |
| Loam         | medium       | medium          |
| Silt         | low          | high            |
| Clay         | low          | high            |

**Table 3: Permeability and water retention of various soil amendments.**

| Amendment   | Permeability               | Water Retention                       |
|---|----------------------------|---------------------------------------|
| <b>Fibrous</b><br>Peat<br>Wood chips<br>Hardwood bark | low-medium<br>high<br>high | very high<br>low-medium<br>low-medium |
| <b>Humus</b><br>Compost<br>Aged manure                | low-medium<br>low-medium   | medium-high<br>medium                 |
| <b>Inorganic</b><br>Vermiculite<br>Perlite            | high<br>high               | high<br>low                           |

(through the rapid decomposition process) making it an ideal soil amendment. Salt level may be concentrated or may be leach out with high rainfall.

As a point of clarification, composts and manures are not regulated. Many commercially available products are labeled as “composted.” However, this does not mean that it has been through the active decomposition process.

## Compost

Compost refers to decomposed organic matter. It is not regulated, so there is no standard about the state of decomposition. In commercially available products the term “compost” is often used generically, and does not infer that the product has been through the actively heating, decomposition process.

In Colorado, a wide variety of compost products are available in bagged and bulk products. These may be a combination of plant-based compost, manure-based composts, biosolids, and other agriculture by-products (such as chicken feathers).

With the large livestock industry in Colorado, manure-based composts are most common. These are often high in salts. Use with caution.

Compost made solely from plant-based products (such as wood chips and yard wastes) are low in salts. These are preferred over manure based composts which are often higher in salts. However, they are generally more expensive.

Working with Dr. Jean Reeder, the Colorado Master Gardener Program had soils tests done on samples of locally available, bagged, manures and composts. The majority had high salts. Use with caution!

## Factors to Consider When Choosing an Amendment

There are at least four factors to consider in selecting a soil amendment:

- how long the amendment will last in the soil,
- soil texture,
- soil salinity and plant sensitivities to salts, and
- salt content and pH of the amendment.

Laboratory tests can determine the salt content, pH and organic matter of organic amendments. The quality of bulk organic amendments for large-scale landscape uses can then be determined.

## Longevity of the Amendment

The amendment you choose depends on your goals.

- Are you trying to improve soil physical properties quickly? Choose an amendment that decomposes rapidly.
- Do you want a long-lasting improvement to your soil? Choose an amendment that decomposes slowly.
- Do you want a quick improvement that lasts a long time? Choose a combination of amendments.

## Soil Texture

Soil texture, or the way a soil feels, reflects the size of the soil particles. Sandy soils have large soil particles and feel gritty. Clay soils have small soil particles and feel sticky. Both sandy soils and clay soils are a challenge for gardeners. Loam soils have the mixture of different size soil particles.

When amending sandy soils, the goal is to increase the soil’s ability to hold moisture and store nutrients. To achieve this, use organic amendments that are well decomposed, like composts, peat, or aged manures.

With clay soils, the goal is to improve soil aggregation, increase porosity and permeability, and improve aeration and drainage. Fibrous amendments like peat, wood chips, tree bark or straw are most effective in this situation.

Use Tables 2 and 3 for more specific recommendations. Because sandy soils have low water retention, choose an amendment with high water retention, like peat, compost or vermiculite. Clay soils have low permeability, so choose an amendment with high permeability, like composted wood chips, composted hardwood bark or perlite. Vermiculite is not a good choice for clay soils because of its high water retention.

## Soil Salinity and Plant Sensitivity to Salts

Many forms of compost made with manure, and biosolids are high in salts. Avoid these amendments in soils that are already high in salts (above 3 mmhos/cm) or when growing plants that are sensitive to salts. Raspberry, strawberry, bean, carrot, onion, Kentucky bluegrass, maple, pine, viburnum and many other landscape plants are salt sensitive. In such cases, choose plant-based composts or sphagnum peat.

## Salt Content and pH of the Amendment

Always beware of salts in soil amendments. High salt content and high pH are common problems in Colorado soils. Therefore, avoid amendments that are high in salts or that have a high pH. Amendments frequently high in salts and/or pH include wood ash, Colorado mountain peat and manures, and manure-based compost, biosolids, and biosolid-based compost.

An amendment with up to 10 mmhos/cm total salts is acceptable if mixed well into low-salt soils (less than 1 mmhos/cm). Amendments with a salt content greater than 10 mmhos/cm are questionable. Choose a low-salt amendment for soils testing high in salts.

Sphagnum peat and compost made from purely plant sources are low in salts and are good choices for amending Colorado soils.

Ask for an analysis of the organic amendments that you are considering, and choose your amendments wisely. If no analysis is available, test a small amount of the amendment before purchasing a large quantity.

Use caution as the salt content in compost may vary from batch to batch.

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# Colorado Gardening: Challenge to Newcomers

Fact Sheet No. 7.220

Gardening Series | Basics

by J.E. Klett and R. Cox\*

Gardening in Colorado can be challenging. The average elevation of the state is 6,800 feet above sea-level. Three-fourths of the nation's land above 10,000 feet is within its borders. Due to the high elevation, sunlight is frequently of high intensity and the humidity generally is low. These features, along with rapid and extreme weather changes and frequently poor soil conditions, make for challenges in growing plants.

## Newcomer's Dilemma

Newcomers to Colorado often have trouble getting plants to survive, let alone thrive. More often than not, they previously gardened where "you stick a plant in the ground and it grows." Typically, those from northern states such as Minnesota or Michigan are puzzled why certain trees that did well for them there do poorly in Colorado.

Winter cold is not the only factor that determines plant survival. Low humidity, drying winds and physical properties of the soil also influence how well plants perform here.

## Soil Properties

Many of our population centers are on heavy clay soil. These soils have poor aeration that limits root growth. Thus the ability of plants to replenish water loss brought about by low humidity and wind is limited. Adding more water to such soils further complicates the problem because the water added reduces the amount of air in the soil, causing oxygen starvation to the roots. Little can be done to modify humidity and wind, so the obvious solution is to improve the soil. See fact sheet [7.235, \*Choosing a Soil Amendment\*](#).

\*Colorado State University Extension landscape horticulturist and professor, department of horticulture and landscape architecture; R. Cox, horticulture agent, Arapahoe County Extension. Revised from original fact sheet authored by J.R. Feucht, retired. 3/2013

High soil pH can also negatively affect plant growth. Basically, pH can be described as the measure of acidity or alkalinity of soil. pH is measured on a scale of 1 to 14 where 7, which is neutral, is the optimal level for most plants. Numbers lower than 7 are considered acidic and numbers higher than 7 are considered alkaline or calcareous (high in calcium carbonate). Colorado soils that have never had amendments added may have a pH value of up to 8.5, which is higher than most plants can tolerate — especially acid-loving plants such as rhododendrons.

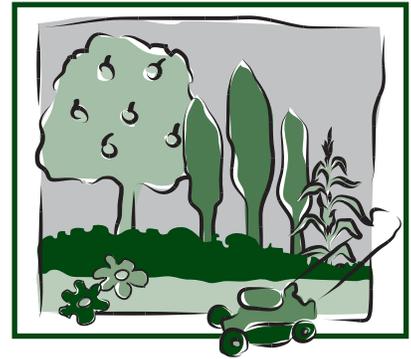
## Why Not Rhododendrons?

Newcomers, particularly those from coastal states such as California, Oregon, New York and the Carolinas, frequently express surprise and disappointment in the lack of broad-leaved evergreen plants such as mountain laurel, rhododendron, pittosporum and similar plants. Our highly calcareous soils and rapid changes in our winter temperatures are partly responsible for this. However, the primary limiting factors are low humidity, drying winds and intense winter sunlight.

Mountain laurel, rhododendrons and similar types of plants can grow in Colorado if the soils are carefully amended to make them more acidic and where the plants are protected from winter wind and sun. Even broadleaved evergreens that can tolerate alkaline soils and lower humidity, such as wintercreeper, English ivy, kinnikinnick and Oregon grape-holly, will perform best in a shaded north or east exposure.

## Salt Accumulation

Soil modification or amendment is a problem in our semiarid, highly alkaline soils. Organic matter, if added in large amounts all at once, can provide for a more porous soil. However, this practice can lead to the accumulation of soluble salts. Unless



## Quick Facts

- Low humidity, fluctuating temperatures, alkaline clay soils and drying winds often restrict plant growth more than low temperatures.
- Selecting plants that tolerate our soil and climatic conditions is key to Colorado gardening.
- Colorado grows excellent flowers, vegetables and lawns.
- Gardeners who are patient, know how to select plants that will do well, and manipulate the soil and microclimate will be amply rewarded.

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the soil is porous so that salts can be leached away with water, the salts tend to accumulate in the amended soil layer. The soluble salts may remain in the organic matter much like water remains in a sponge. Rapid evaporation may concentrate the salts in the root zone, where they can injure plant roots.

A solution to this problem is to slowly, over a period of years, improve the soil tilth. Tilth refers to the physical properties of soil which make it able to support plant growth. An alternative to leaching salts and improving soil tilth is to choose plants that are more tolerant of saline soil conditions. For instance, instead of planting a pine knowing that it would do poorly under saline conditions, one may have to settle for a juniper. Look to Colorado native plants native to your life zone and soil conditions for more options.

## Iron Problems

The name Colorado comes from the Spanish words “color rojo,” meaning color red, referring to the dominant red soils. The red color is due to high amounts of iron in the soil. Yet, a yellowing condition in certain plants, known as iron chlorosis, is brought about by an iron deficiency in the plant. Colorado’s highly calcareous soils tie up the iron in a form unavailable to the plant.

Trees with high iron requirements such as pin oak, silver maple and red maple

perform poorly in Colorado’s alkaline, calcareous soils.

Making iron more available is not easy and usually not economical. Adding available forms of iron such as iron sulfate to the soil is, at best, a temporary measure. Normal chemical reactions in the soil will quickly cause much of the added iron to become unavailable. The best alternative is to select plants tolerant of Colorado’s alkaline soil. Instead of pin oak, choose bur oak or Norway maple instead of silver maple, etc.

## Untimely Snows

In Colorado, heavy, wet snows in the late spring or early autumn are common. Trees, shrubs and perennials are caught in full leaf or just at the peak of bloom. These “limb-breaker” storms cause severe damage that leaves permanent scars and tends to keep trees to smaller-than-normal size.

Following such a storm, tree diseases tend to increase. Broken limbs and central leaders can cause problems for trees for many years. To minimize damage, choose less brittle trees such as lindens, oaks and conifers instead of silver maple, Siberian elm and willow. This, however, brings about another dilemma. The less brittle ones are also the slower-growing ones.

## What About Freezes?

Occasionally, Colorado will experience frosts when plants aren’t ready to cope with them. It is not uncommon for mountain communities to have an already short growing season interrupted by a killing frost.

In Leadville with an elevation of 10,177 feet and an average growing season of about 25 days (compared with over 150 in many areas on the plains), a frost may occur in July. Yet, with careful selection of plants, even Leadville can flaunt colorful garden flowers, vegetables and hardy trees and shrubs.

Table 1 lists average frost-free periods for selected cities at several elevations in Colorado. While growing seasons tend to be shorter at higher elevations, use caution when interpreting this table. Note that some higher elevations have a longer season than lower elevations. Compare, for instance, the average growing seasons of Dillon, elevation 9,800 feet with that of Fraser, elevation 8,560 feet. Fraser is lower than

**Table 1: Elevation and average growing season for selected Colorado cities.**

| Location          | Elevation | Average Frost-Free Days |
|-------------------|-----------|-------------------------|
| Alamosa           | 7,536     | 95                      |
| Aspen             | 7,913     | 88                      |
| Bailey            | 7,733     | 82                      |
| Boulder           | 5,444     | 156                     |
| Burlington        | 4,167     | 153                     |
| Center            | 7,668     | 96                      |
| Colorado Springs  | 6,090     | 152                     |
| Craig             | 6,247     | 98                      |
| Crested Butte     | 8,855     | 37                      |
| Denver            | 5,280     | 155                     |
| Dillon            | 9,800     | 25                      |
| Durango           | 6,554     | 110                     |
| Eagle             | 6,497     | 86                      |
| Fort Collins      | 5,004     | 142                     |
| Fraser            | 8,560     | 9                       |
| Grand Junction    | 4,597     | 183                     |
| Gunnison          | 7,694     | 62                      |
| Idaho Springs     | 7,569     | 93                      |
| Leadville         | 10,177    | 26                      |
| Meeker            | 6,242     | 91                      |
| Mesa Verde        | 7,070     | 148                     |
| Monte Vista       | 7,665     | 97                      |
| Monument          | 7,400     | 150                     |
| Norwood           | 7,017     | 108                     |
| Pueblo            | 4,639     | 158                     |
| Salida            | 7,060     | 109                     |
| Steamboat Springs | 6,770     | 46                      |
| Trinidad          | 6,030     | 152                     |
| Walsenburg        | 6,221     | 148                     |

From: The Western Regional Climate Center  
[www.wrcc.dri.edu/summary/climsmco.html](http://www.wrcc.dri.edu/summary/climsmco.html)  
 accessed 11-17-2006.

Dillon, but has a shorter average growing season. A primary reason is air drainage; Fraser has shorter seasons because of cold air drainage from surrounding mountains.

The same air drainage phenomenon can make a difference in the location of a garden. Gardens in areas where cold air is trapped may have earlier frost kill than gardens even a short distance away. Cold air may be trapped by any obstruction on the down-slope side of a garden, such as a hedge, wall or solid fence. To avoid early

## Obtaining Help

Colorado State University Extension has county offices ([www.ext.colostate.edu/cedirectory/allcounties2.cfm](http://www.ext.colostate.edu/cedirectory/allcounties2.cfm)) prepared to help with individual Gardening needs. They have a supply of fact sheets similar to this one that can provide detailed information on the selection and care of trees, shrubs, perennials, vegetables and lawns. Go to [www.ext.colostate.edu](http://www.ext.colostate.edu) to view these fact sheets on the web.

To find your local Colorado State University Extension office in the white pages of the telephone book, look under the heading “Colorado State University” or under the county government listings.

cold injury to gardens, do not put hedges, fences and other landscape features where they may obstruct the flow of air.

The real killers, however, are the infrequent but rapid changes from warm, balmy weather to cold, subzero temperatures. In 1949, a 90 degree F change was recorded near Fort Collins in less than 24 hours. The change from 50 degrees F to -40 degrees F resulted in the ear-popping fracture of entire trees and virtually wiped out the local sour cherry industry. On October 19, 1969, Denver experienced a temperature drop to -3 degrees F, that was preceded by balmy 85 degree weather. Similar rapid temperature changes occurred on September 17, 1971, and October 28, 1991.

Such freeze injury leaves crippling marks on trees and shrubs for years and serves to eliminate many plants with borderline hardiness. Most severely injured in such freezes are the lush, rapid-growing trees, because they have a higher internal moisture content than the slower-growing, more solid wood species. To help reduce injuries from such sudden temperature changes, gradually reduce water in late summer and avoid late applications of fertilizers high in nitrogen.

## The Brighter Side

Up to this point, gardeners might want to throw up their hands and say, "What's the use?" But there is a brighter side. Colorado's many days of sunshine, while leading to some problems already mentioned, enables gardeners to grow some of the best flowers in the nation. The high light intensity produces strong-stemmed plants and flowers with extra brilliance.

Winter sunlight melts snows at lower elevations, reducing snow mold diseases in lawns. The cool, crisp nights and warm days of summer produce healthy lawns. These same climatic conditions enable the home gardener to produce excellent potatoes, cabbage, lettuce, broccoli, cauliflower and other cool-season vegetables.

The lower humidity not only helps to make the cold days seem less cold and hot days less hot, but discourages many plant diseases that are common in more humid

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areas. Perhaps the brightest side lies in the challenges of problems growing plants in Colorado. Gardeners who are patient, know how to select plants that will do well, and manipulate the soil and microclimate will be amply rewarded.

*For more information on native plants see fact sheets*

- 7.421, Native Trees for Colorado Landscapes
- 7.442, Native Shrubs for Colorado Landscapes
- 7.423, Trees and Shrubs for Mountain Areas

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CMG GardenNotes #241

## Soil Amendments

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Outline:

- Terms, page 1
- Managing soil texture and structure, page 2
- Selecting soil amendments, page 2
  - Over amending, page 4
- Evaluating the quality of soil amendments, page 4
- Examples of soil amendments, page 5
  - Peat, page 5
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  - Compost, cover crops and green manure crops, and manure, page 6
  - Worm castings, page 6
  - Perlite and vermiculite, page 6
- Summary: Considerations in selecting soil amendments, page 7

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### 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](http://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 ( $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{HPO}_4^{2-}$ ,  $\text{H}_2\text{PO}_4^-$ ,  $\text{K}^+$ ) 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. Products 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.

| <b>Table 1. Routine Application Rate for Soil Amendments</b>  |  |   |  |
|---|--|---|--|
| <b>Site</b>   | <b>Incorporation Depth<sup>2</sup></b> | <b>Depth of Compost Before Incorporation<sup>1</sup></b>                          |  |
|   |  | <b>Plant-Based Compost and other compost known to be low in salts<sup>3</sup></b> | <b>Compost Made with Manure or Biosolids for which the salt content is unknown<sup>4</sup></b> |
| <b>One-time application—</b><br>such as lawn area   | 6-8 inches                             | 2-3 inches  | 1 inch   |
| <b>Annual application to</b><br>vegetable and flower<br>gardens – <b>first three</b><br><b>years</b>      | 6-8 inches                             | 2-3 inches  | 1 inch   |
| <b>Annual application to</b><br>vegetable and flower<br>gardens – <b>fourth year</b><br><b>and beyond</b> | 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 waste 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**

| <b>Soil Organic Content</b> | <b>Routine Application Rate For Gardens</b> |
|-----------------------------|---|
| 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:

- Excessive nitrogen, phosphorus, and potassium
  - High salts
  - 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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## **I. Objectives**

This chapter teaches people to:

1. Identify the physical properties of soil and describe how they impact the suitability of soil for growing plants.
2. Describe organic matter and how it can be used to improve the soil.
3. Explain how to collect a soil sample and how to use a soil test report.
4. For each of the six macronutrients, describe symptoms of deficiency and of excess.
5. Identify strategies to reduce the impact of fertilizer on water quality.
6. Identify the variety of soil-dwellers, their benefits, and strategies for promoting their health.

## **II. Introduction: What Is Soil?**

Soil is a living, breathing, natural entity composed of solids, liquids, and gases. Soil has five major functions:

1. Provides a habitat for organisms
2. Recycles waste products
3. Filters water
4. Serves as an engineering material
5. Provides a medium for plant growth<sup>1</sup>

Our focus will be on the fifth function. In this role, soil provides structural stability for plants and retains and relinquishes water and the nutrients necessary for plant growth.

An ideal soil for plant growth contains 50% porespace and 50% solids, with the porespace filled with equal parts air and water. This distribution rarely occurs because porespace varies with soil texture and soil management. For example, tilling increases porespace, while poor drainage and compaction reduce it.

Soil solids are a blend of mineral materials and organic matter. The mineral materials are typically weathered rock of varying sizes called sand, silt, and clay. The organic matter consists of decaying plant and microbial residues. The relative amounts of porespace and mineral and organic matter vary greatly among different soil types. But for plant growth, most soil scientists agree that 50% porespace, 45% mineral matter, and 5% organic matter make up an ideal ratio.

## **III. The Soil Profile**

Most naturally occurring, undisturbed soils have three distinct layers of variable thicknesses. The layers are the topsoil, subsoil, and parent material. Each layer can have two or more sublayers called horizons. Collectively, the horizons make up the soil profile. Soil properties often limit the depth to which plant roots can penetrate. For example, roots will not grow through an impenetrable layer. That layer may be bedrock, compacted soil, or a chemical barrier, such as an acidic (very low) pH. A high water table can also restrict root growth due to poor soil aeration. Few big trees grow in shallow soils because big trees are unable to develop a root system strong enough to prevent them from toppling over. Shallow soils also tend to be more drought-prone because they hold less water and thus dry out faster than deeper soils. Water lost to runoff on shallow soils would instead be

absorbed by a deeper soil. In addition, deep soils allow the roots to explore a greater volume, which means the roots can retain more water and plant nutrients.

Soils change in three dimensions. The first dimension is from the top to the bottom of the soil profile. The other two dimensions are north to south and east to west. The practical meaning of this three-dimensional variability is that as you move across a state, a county, or even a field, the soils change. Five factors of soil formation account for this variation:

1. Parent material
2. Biological activity
3. Climate
4. Topography
5. Time

Differences in even one of these factors will result in a different soil type. Soils forming from different parent materials differ. Soils forming from the same parent material in varying climates differ. Soils at the top of a hill differ from soils at the bottom. The top of the hill loses material due to natural erosion; the bottom gains the material from above.

#### **IV. Physical Properties of Soil**

The physical properties of soil are characteristics that can be seen, felt, or measured. These include color, texture, structure, and water-holding capacity. Such properties usually determine the suitability of soil as a growth medium. Some physical properties, such as texture, are not economically feasible to change on a large scale.

##### **Color**

Organic matter, the soil minerals present, and the drainage conditions all influence soil color. Color alone is not an indicator of soil quality, but color does provide clues about certain conditions. For example, light or pale colors in grainy topsoil are frequently associated with low organic matter content, high sand content, and excessive leaching. Dark soil colors may result from poor drainage or high organic matter content. Shades of red indicate a clay soil is well-aerated, while shades of gray indicate inadequate drainage.

##### **Texture**

Soil texture, which refers to the proportions of sand, silt, and clay, influences nearly every aspect of soil use and management. Sand is the largest particle (at 2.0 to 0.05 mm), silt is much smaller (0.05 to 0.002 mm), and clay is the smallest (less than 0.002 mm). To compare particle sizes, imagine that a sand particle is the size of a basketball. On that scale, a silt particle would be the size of a marble, and a particle of clay would be a pinpoint. How fine (clayey) or coarse (sandy) a soil is will determine many of the soil's physical and chemical properties.

##### **Rocks and Gravel**

Rocks and gravel, which are large, coarse materials, can be found in many soils, but they are not considered when determining soil texture. Although some rocks and gravel in the soil will not affect plant nutrient uptake, they can make the soil difficult to dig. If the garden is mostly rocks or gravel, the soil will have a reduced water- and nutrient-holding capacity, and will be unfit for growing plants. In such a situation, it may be easiest to install raised beds and import soil.

Adding organic matter is a more economically feasible alternative for improving soil. Adding organic matter does not change a soil's texture—the percentage of sand, silt, and clay in the soil—but adding organic matter will alter soil structure by increasing the porespace and improving drainage. Gardeners can be successful with any soil texture, as long as they know the attributes and limitations of that soil. The relative proportions of sand, silt, and clay determine a soil's textural class. For example, a soil that is 12% sand, 55% clay, and 33% silt is in the clay textural class. Soil texture is a permanent feature, not easily changed by human activity. Consider a typical mineral soil that is 6 inches deep on 1 acre. That soil weighs about 2 million pounds. To change the sand content just 1% would require adding 20,000 pounds (or 10 tons) of sand. A 1% change in sand content would have minimal effect. A significant effect might require a 10% change, which would mean adding 100 tons of sand.

Typically, laboratory procedures are used to determine the soil texture. It is possible, however, to use the procedure outlined in to determine the textural class by the “*feel*” method. It takes practice and calibration, but it can provide a reasonable estimate of the soil texture.

### **Sandy or Coarsely Textured Soils**

- Low in organic matter content and native fertility.
- Rapidly permeable and do not hold soil moisture.
- Nutrient leaching is a concern, so proper fertilization is a must. Apply smaller amounts of nutrients, and apply them more frequently.
- Low in cation exchange and buffer capacities.
- Well-suited for road foundations and building sites.
- Feel gritty.

### **Loamy or Medium-Textured Soils**

- Contains more organic matter.
- Permit slower movement of water and are better able to retain moisture and nutrients.
- Are generally more fertile.
- Have higher cation exchange and buffer capacities.
- Feel crumbly.

### **Clayey or Finely Textured Soils**

- Higher nutrient-holding capacity.
- Higher available water-holding capacity.
- Finely textured soils exhibit properties that are somewhat difficult to manage or overcome.
- Often too sticky when wet and too hard when dry to cultivate.
- May have shrink-and-swell characteristics that affect construction uses.
- Feel slippery.

### **How Do Soil Types Affect Gardeners?**

**Compaction.** Compaction occurs when pressure is applied to soil particles and the air and water are pushed out of the porespaces. Large, cubic sand particles are not easily compacted. Clay particles, small and platelike, are easily aligned and can compact, especially when wet. Compaction inhibits the movement of water, gases (air), and roots.

Compacted soils have less infiltration, greater runoff, a higher risk of erosion, and more restricted root growth than soils without compaction. Water drains slowly, which may increase the likelihood of plant root diseases.

**Erosion.** Sand particles are heavy, so they are not easily picked up and moved by water or wind. Clay particles are sticky, so they are not easily moved. Silty loam particles are light and not sticky, so erosive forces easily move them. Eroded soils are usually harder to till and have lower productivity than soils without erosion. The main causes of soil erosion in North Carolina are insufficient vegetative or mulch cover, and improper equipment and methods used to prepare and till the soil ([Figure 1–12](#)).

Soil erosion can be minimized by following a few preventive measures:

- Choose plants suited to the soil so they establish well.
- Mulch the surface each year with organic materials 1 inch to 3 inches deep.
- Adequately fertilize to promote vigorous, but not excessive, plant growth.
- Create a water diversion, such as a grass waterway, to capture and slow water movement.
- Align rows to follow the land's contour so that water flowing downhill is slowed.
- Use proper tillage methods, such as not tilling when the soil is overly wet and not overtilling.
- Plant a winter cover crop.
- Consider installing rain gardens to capture sediment and runoff.

### **Structure**

Soil structure refers to the grouping of individual soil particles into larger pieces called peds or aggregates. The structure of topsoil is usually granular and resembles chocolate cookie crumbs. Good granular structure allows rapid movement of air and water within the soil. Poor granular structure decreases movement of air and water. Good soil structure allows for extensive root development; poor structure can limit root growth. Supplying an adequate amount of organic matter and working the soil only when it is not excessively wet promotes good topsoil structure.

### **Water-Holding Capacity**

Water enters the soil from precipitation or irrigation. It exits by draining from the soil, evaporating from the surface, and through transpiration from plant leaves. Water-holding capacity—the retention of water moving through soil—depends on differences in soil porespace. Ideal soils are half porespace with equal amounts of air and water filling the pores. Too much air means plants will wilt. Too much water means reduced plant vigor and susceptibility to root rot, which occurs due to anaerobic conditions.

Soils differ in the number of large (macro), medium (meso), and small (micro) pores. Macropores, which are more common in sandy soils, take up water more quickly and drain faster than meso- and micropores. This rapid draining from macropores is called “gravitational water” because the weaker forces of adhesion and cohesion in macropores cannot overcome gravity's pull. Within 24 hours after a saturating rain, gravitational water reaches the lower soil horizons, and the soil is at field capacity: the meso- and micropores are still full of water because their adhesive and cohesive forces are stronger than gravity. Water in the mesopores is available to plants. But when the mesopores lose water as the soil dries through plant uptake and transpiration, soil moisture reaches the permanent

wilting point. At the permanent wilting point, micropores are still full of water, but this water is so tightly held that it is not plant-available. Note that plants may wilt before the permanent wilting point if the plant transpires water through the leaves faster than it can take water up from the soil through its roots. This is why plants may wilt on hot days and then recover once the sun goes down and why plants can balance uptake with transpiration.

### **How to Remediate Compaction**

Compaction is a likely problem if there has been recent construction or other traffic over the area. Deep cultivation, which is mixing the top 6 inches to 2 feet of soil with a tiller, disk, or hand tools, may be needed to loosen the soil. Incorporation of organic matter during deep cultivation can help to rehabilitate soil structure by creating aggregates and both macropores (for drainage) and mesopores (for plant-available water). Digging or cultivating soil when it is wet or excessively dry can destroy structure.

Be wary of quick fixes, such as starting over with a truckload of topsoil. Unfortunately, there are no standards on material sold as “topsoil.” New problems may be brought on site, such as weed seeds and disease organisms. Adding new topsoil to existing soil may also create drainage problems when water moves through the purchased topsoil and reaches the compacted layer. The water can pool and create unfavorable conditions for root growth. Clay soils, which tend to hold excessive amounts of water and become compacted easily, present some tricky problems. Common mistakes are adding sand or peat moss to improve drainage. Adding sand to clay will reduce soil structure, lowering pore space. Adding peat moss will increase the clay soil's high moisture-holding capacity. The best advice is to add smaller amounts of organic matter consistently every year, minimize compaction, and let soil biology naturally improve the structure over time.

## **V. Organic Matter**

Organic matter consists of the remains of plants and animals and gives soil a gray to very-dark-brown color. Organic matter is home to many soil organisms.

Earthworms, insects, bacteria, fungi, and animals use organic matter as food, breaking it down to obtain energy and essential nutrients. Humus is the portion of organic matter that remains after most decomposition has taken place.

When organic matter decomposes in the soil, carbon dioxide is released and replaces some of the oxygen in soil pores. Carbon dioxide is dissolved by water in soil to form a weak acid. This solution reacts with soil minerals to release nutrients that can be taken up by plants. The digested and decomposing organic matter also helps develop good air-water relationships. In sandy soil, organic material occupies some of the space between the sand grains. This binds them together and increases water-holding capacity. In a finely textured or clay soil, organic material creates aggregates of soil particles. This allows water to move more rapidly around soil particles.

The amount of organic matter in the soil depends primarily on rainfall, air temperature, the kinds of plants that have been growing in a soil, management practices, soil temperature, and drainage. Soils that are tilled frequently are usually low in organic matter because tilling decreases residue particle size and increases the amount of air in the soil, increasing the rate of organic matter decomposition. Poorly drained soils tend to have a high

percentage of organic matter because low oxygen levels limit decomposition organisms. To build organic matter in garden soil, till in compost when the garden is first created, but do not till in subsequent years. Instead, apply thin layers (1 inch to 3 inches), of organic mulch or compost to the soil surface each year. This material will break down, and the organic matter levels in the soil will gradually increase.

### **Improving the Soil**

Good aeration and drainage, as well as the ability to hold adequate moisture and nutrients, are key components of an ideal soil environment. Although there is no cookbook recipe for creating this ideal environment, these are some of the most important strategies for improving soil quality:

- Minimize soil compaction (do not walk on garden beds or work wet soil)
- Reduce drainage problems.
- Decrease erosion.
- Plant a cover crop
- Incorporate organic matter.
- Provide a 1- to 3-inch layer of organic mulch on the soil's surface.

### **Incorporating Soil Amendments**

Conditioning soil requires increasing organic matter content to 25% by volume. Incorporating a minimum of 2 inches of material into the top 6 inches of soil will create approximately 8 inches of amended soil. These additions raise the planting bed, improving drainage and making plants more visible. Incorporating more than 50% organic matter may negatively affect plant growth. Be careful when using organic material, making certain that it is fully composted and not merely aged. Microbes attracted to partially decomposed materials will compete with plants for nutrients, especially nitrogen and sulfur, resulting in nutrient deficiencies and poor plant growth.

The best organic matter amendments for clay soils are pine bark (less than ½ inch in diameter) and composted leaf mold. The following amendments are not recommended because they do not adequately improve the physical properties of clay soil: peat moss, sand, hardwood bark, wood chips, and pine straw.

For sandy soils, organic matter amendments, such as pine bark or compost, will improve water retention.

## **VI. Chemical Properties of Soil**

There are strong relationships between soil physical properties and soil chemical properties. For example, surface area is directly related to chemical reactivity.

### **Cation Exchange Capacity (CEC)**

The negative ends of two magnets repel each other. The negative end of one magnet attracts the positive end of another magnet. This same principle affects the retention of plant nutrients in soil. Some plant nutrients are cations, which have a positive charge, and some are anions, which have a negative charge. Just like the opposite poles on magnets, cations will be attracted to anions.

Soil particles are similar to a magnet, attracting and retaining oppositely charged ions and holding them against the downward movement of water through the soil profile. The nutrients held by the soil in this manner are called “exchangeable cations” and can be

displaced or exchanged only by other cations that take their place. Thus, the negative charge on a soil is called the cation exchange capacity (CEC). Soils with high CEC not only hold more nutrients, they are better able to buffer or avoid rapid changes in the soil solution levels of these nutrients. A soil test will tell you the CEC number of your soil. Soils high in clay, silt, or organic matter will have a CEC number of 10 or greater, and no remediation is needed. Sandy soils will have a CEC number between 1 and 5. Adding organic matter to these soils will help increase the CEC.

### **Too Much of a Good Thing: Nitrogen Leaching**

Just like magnets, negative charges repel negative charges. Soils with high CEC tend not to hold anions. As a result, water moving through the soil profile will leach negatively charged nutrients, such as chloride, nitrate, and sulfate out of the root zone. This leaching can result in contamination of groundwater, streams, and lakes or have other environmental implications ([Figure 1–20](#)). Excess fertilizer becomes a contaminant and can have adverse effects on human health. The U.S. Environmental Protection Agency has set standards for nutrients in groundwater used for drinking water. This is one of many reasons that appropriate levels of fertilization are essential.

## **VII. Soil Testing**

Soil testing provides valuable information on pH and plant-available nutrients. Test your soil before planting and every two to three years thereafter.

## **VIII. Plant Nutrition and Fertilization**

Many people confuse plant nutrition with fertilization. Plant nutrition refers to the needs of the plant and how a plant uses the basic chemical elements. Fertilization is the term used when these elements are supplied to the soil as amendments. Adding fertilizer during unfavorable growing conditions will not enhance plant growth and may actually harm or kill plants.

### **Soil Nutrients**

For a plant to absorb an element, it must be in a chemical form used by the plant and dissolved in the soil water. In addition to those nutrients already dissolved in soil water, nutrients can be present in the soil in these forms:

- Undissolved or granular form, as from newly applied fertilizer
- Chemicals bound to soil particles
- The chemical structure of soil organic matter released by microbial decomposition

Undissolved or granular nutrients, and those that are chemically bound to soil particles, are not immediately useful, although they have the potential to benefit the plant. For many plant nutrients, the soil acts as a bank. Withdrawals are made from the soil solution, much as you would withdraw money from a checking account. The undissolved pool of soil nutrients is like a savings account. When checking funds are low, transfers are made from the savings account to the checking account. When a checking account is flush with money, some can be moved to savings for long-term retention. In the same way, for many plant nutrients, when the soil solution has excess nutrients, some bind to the soil to become temporarily unavailable, and some react with other chemical elements to form insoluble minerals, which can dissolve again later.

Several factors improve a plant's ability to use nutrients:

- **Type of soil:** The more clay and organic matter a soil has, the higher its CEC will be, and the more cationic (positively charged) nutrients it will retain.
- **Soil pH:** The pH affects how tightly nutrients are bound to soil particles. If the soil pH is extremely high (basic) or very low (acidic), many nutrients become inaccessible to the plant because they are no longer dissolved in the soil water.
- **Types of nutrients in the soil:** Some nutrients affect the availability of other nutrients. In fact, an apparent deficiency of one nutrient may actually be caused by a large amount of another.
- **Amount of soil water:** Too much rain leaches nutrients from the soil. If there is too little water, the nutrients cannot dissolve and move into the plant.
- **Anything that affects the plant's growth:** If growing conditions are good, a plant will absorb nutrients from the soil. If the plant experiences extremes in temperature, incorrect light levels, or waterlogged or compacted soil, it will have a limited ability to absorb nutrients. Also, plants in dormant stages absorb few nutrients.

## Fertilizers

Fertilizers provide some elements that might be lacking in the soil and stimulate healthy, vigorous growth. How much and when to apply fertilizers should be based on observing plant performance, a reliable soil test, and an understanding of the factors that affect growth: light, water, temperature, pests, and nutrition. Simply applying fertilizer because a plant is not growing adequately will not solve many plant problems (insects, disease, or poor drainage, for example), and, in fact, excess nitrogen can often increase insect and disease infestation.

All fertilizers are labeled with three numbers, giving the percentage (by weight) of nitrogen (N), phosphorus (P), and potassium (K). This is referred to as the fertilizer grade. A 100-pound bag of fertilizer labeled 0-20-10 has 0 pounds of N, 20 pounds of P (reported as  $P_2O_5$ ), 10 pounds of K (reported as  $K_2O$ ), and 70 pounds of filler. Filler is added to make the fertilizer easier to spread and to reduce the likelihood of burning plants with too much fertilizer (the fertilizer salts can pull water out of the plant). A fertilizer may also contain secondary macronutrients or micronutrients not listed on the label because the manufacturer does not want to guarantee their exact amounts.

Fertilizers can be divided into two broad categories: natural and synthetic.

**Natural fertilizers** are commonly misnamed “organic.” “Natural fertilizers” is a more accurate description because these materials can be both complex chemical substances containing carbon (organic materials) or inorganic ores, such as rock phosphate, which are mined. Natural fertilizers containing organic materials include manures and composts, animal byproducts (such as bone meal, blood meal, feather meal), and seed meals. Natural fertilizers that are inorganic ores include potassium and lime.

Natural fertilizers typically release nutrients at a slower rate and over a longer period than synthetic fertilizers because microorganisms are involved in a breakdown and release cycle called mineralization. Moisture, temperature, and the microbial species and populations in the soil affect mineralization. Some water-soluble natural fertilizers, such as fish emulsion, are available when rapid nutrient delivery is desired.

When using natural fertilizers, it is helpful to incorporate them and provide adequate moisture for active microbial populations. When packaged as fertilizers, natural fertilizers will have the nutrient analysis stated on the labels. How much to use varies with the nutrient content of the material. The age of the material is also a factor. Producers are not required by law to state the nutrient content on bulk organic materials, such as compost, manure, and sludges.

The age of the natural fertilizers is another important factor. When natural material decays and is rained on, it loses nutrients, especially potassium and, to some extent, nitrogen. Even natural sources of nutrients can be overapplied and damage plants. Fresh manures, for example, may injure plants by adding excessive nitrogen or potassium, especially when applied in large quantities.

Natural fertilizers can be expensive if applied in amounts adequate to supply nutrients for good plant growth, but have the added benefit of improving soil structure and plant vigor. When applying natural fertilizers, calculate as closely as possible the amounts of nutrients being supplied. Always err on the low side of application rates, then test the soil and augment as recommended on the soil test report. The nutrient content may need to be supplemented with other natural or synthetic materials to achieve a balanced ratio of nutrients.

**Synthetic fertilizers** are made through industrial processes or mined from deposits in the earth. They are purified, mixed, blended, and altered for easy handling and application. Most are noncarbonaceous chemicals from nonliving sources and are usually cheaper than natural fertilizers. In general, nutrients are more rapidly available to plants because they are more water-soluble or in a form plants can use. The disadvantage is that it may be easier to overapply a synthetic fertilizer than a natural one, which may result in fertilizer burn. In addition, synthetic fertilizers may not support beneficial microbial populations to the same extent as natural fertilizers.

## **IX. The Biology of Soil**

There is more life below the soil surface than there is above. Soil life consists of burrowing animals, such as moles and earthworms, insects, and other soil creatures that are difficult or impossible to see without a microscope, such as mites, springtails, nematodes, viruses, algae, bacteria, yeast, actinomycetes, fungi, and protozoa. There are about 50 billion microbes in 1 tablespoon of soil. In a typical soil, each gram (what a standard paperclip weighs) likely contains these organisms, listed from largest to smallest:

Nematodes—10 to 5,000

- Algae—1,000 to 500,000
- Protozoa—1,000 to 500,000
- Fungi—5,000 to 1,000,000
- Actinomycetes—1,000,000 to 20,000,000
- Bacteria—3,000,000 to 500,000,000

Soil-dwellers move through the soil, creating channels that improve aeration and drainage. Nematodes and protozoa swim in the film of water around soil particles and feed on bacteria. Mites eat fungi, and fungi decompose soil organic matter. The microorganisms' primary role is to break down organic matter to obtain energy. Microorganisms help

release essential nutrients and carbon dioxide and perform key roles in nitrogen fixation, the nitrogen and phosphorus cycles, denitrification, immobilization, and mineralization. Microbes must have a constant supply of organic matter, or their numbers will decline. Conditions that favor soil life also promote plant growth.