MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #241

Soil Amendments

Outline:

Terms

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

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

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

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

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

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

reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances. Many of the organic fertilizers listed here will meet NOP standards based on the National List. Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

Managing Soil Texture and Structure

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

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

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

Table 1. Routine Application Rate for Compost

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

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

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

Selecting Soil Amendments

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

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

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

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

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

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

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

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

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

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

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

Over Amending

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

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

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

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

Evaluating the Quality of Organic Amendments

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

Visual Evaluation

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

Laboratory Testing

C:N Ratio – Ratio of carbon to nitrogen.

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

Organic Matter

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

pH

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

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

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

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

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

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

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

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

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

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

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

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

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

Nutrient Content – This varies greatly from product to product.

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

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

Examples of Soil Amendments

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

Sphagnum Moss and Peat Moss

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

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

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

Coconut Coir

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

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

Biosolids

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

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

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

Worm Castings

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

Castings can be used in potted plants, soil mixes, and in garden beds. Castings can be harvested every three to four months from a vermicompost bin, and then applied as a top dressing (1/2 to 1 inch deep) to potted plants or incorporated into a soil mix (casting should make up no more than 25% of the mix by volume). Avoid direct contact between the castings and plants, as castings may

have a higher soluble salt content. Some batches made from livestock manure may have high salts depending on whether the animals producing the manure had access to a salt lick and if the vermicompost maker leached them out or not.

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

Perlite and Vermiculite

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

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

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

Summary: Considerations in Selecting Soil Amendments

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

Goals:

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

Cost/Availability:

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

Need for Fertilizer After Amending:

- Soil organic matter content.
- Nitrogen content of soil.

Precautions With Specific Products:

- Salts (manure and biosolids).
- Weed seeds (manure and compost).
- Plant pathogens (compost).
- Human pathogens (manure).

Alternatives to Amending:

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

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

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

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

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

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

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

Revised September 2023