

# Managing Organic Matter in Farm and Garden Soils

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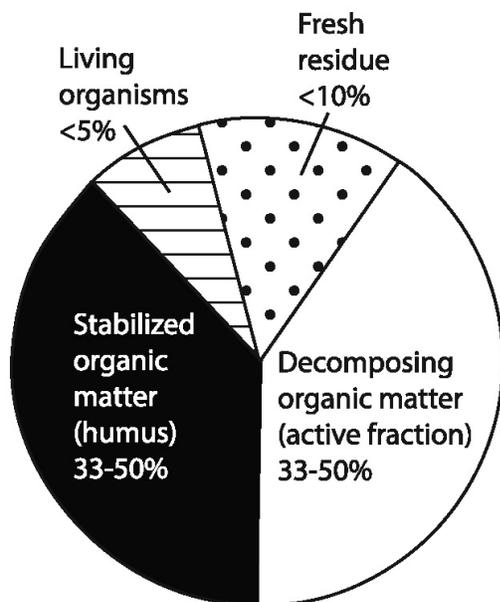
## Introduction

Organic matter is an important component of the soil. Soil organic matter helps improve the soil's water-holding capacity, structure, bulk density (aeration), cation exchange capacity, microbial activity and diversity, and nutrient reserves. Many soils in New Mexico are low in organic matter and can benefit from managing soil organic matter to improve the overall productivity of the soil. Organic matter can be added in the form of composts, manures, and plant material, or can be grown in place as plants (cover crops and green manures) and incorporated back into the soil. But before adding anything to the soil, you should understand some basic principles of soil organic matter.

Before adding organic matter to your garden soil, it is best to pull a soil sample from the top four to eight inches of soil and send it to a soil testing laboratory to determine the soil's current organic matter content. NMSU Extension Guides A-114, *Test Your Garden Soil* ([http://aces.nmsu.edu/pubs/\\_a/A114.pdf](http://aces.nmsu.edu/pubs/_a/A114.pdf)), and A-146, *Appropriate Analyses for New Mexico Soils* ([http://aces.nmsu.edu/pubs/\\_a/A146.pdf](http://aces.nmsu.edu/pubs/_a/A146.pdf)), contain information on how to sample and where to send a soil sample for analysis.

New Mexico soils with 3–5% organic matter are considered adequate and may need some alternative management strategies to continue to maintain and improve the soil. Too often, the over-application of organic material leads to environmental consequences, including leaching of nitrate-N into the groundwater or an excess amount of total salts introduced with the

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**Figure 1.** Organic matter is the main energy source for most soil organisms. The stable organic matter (humus) is relatively unavailable; the other pools of organic matter are in various stages of being decomposed. (Source: Soil Science Society of America)

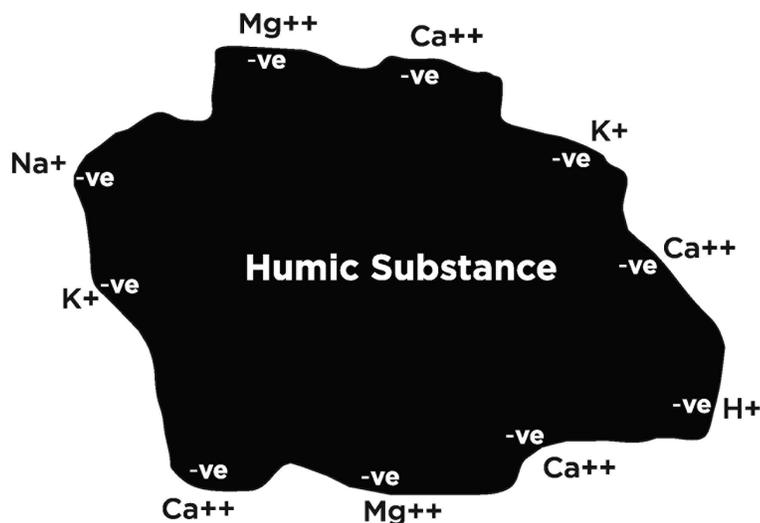
organic material. A soil test will report soil organic matter content as a percentage. Many native soils of New Mexico where rainfall is low will have less than 1% soil organic matter. Improving soil organic matter content in these soils can help improve their productivity, but this should be approached in a way that feeds the soil's microbial population and avoids increased salinity.

Like clay, organic material has a strong affinity for water. Not all of that water is available to plants. Soils with too much fresh organic material, just like clay soils, have less water that is readily available to plants. As that fresh organic material is converted to humus, there is positive improvement in the water-holding capacity of the soil.

### What Is Soil Organic Matter?

Soil organic matter contains a mix of decomposing organic matter, stabilized organic matter, living organisms, and fresh materials like manures and compost (Figure 1). Soil organic matter can be divided into active and passive fractions. The active fraction contains living organisms, organisms that have died, and fresh material that can serve as food for living organisms (recent manures, plant material, compost, dead organisms). Soil organisms play a key role in recycling nutrients into forms that plants can use.

The passive fraction is composed of carbon compounds that are recalcitrant (hard to decompose). These include humic substances and fulvic acids, glomalin, and other organic compounds. These substances help improve the qualities of soil that we equate with a good



**Figure 2.** Soil humic substances have a net negative charge (-ve = variable exchange) that can help keep nutrients for plant growth available to plants. A single particle of humic substance can hold many plant nutrients and adds to what the soil clays can hold for exchange with plant roots.

soil for a farm or garden; collectively, they can be referred to as humus (stabilized soil organic matter). It is humus that has the longer-lasting effects on the quality of garden and farm soils. However, bags of "humus" found in garden centers are really more like compost or peat, and don't meet our definition of soil humus. Adding bottled humic or fulvic acids to your soil is usually too expensive at the amounts that it might take to produce a change in the soil. Most of these types of products have not been adequately tested to determine their effectiveness. Furthermore, humic and fulvic acids will be an end result of the decomposition of the added organic material that becomes humus.

The humus fraction (humic substances) of the soil organic matter gives the soil many important characteristics. This fraction is colloidal in nature (very small particles that will stay suspended when dispersed in water) and is capable of absorbing a tremendous amount of water. In fact, a unit weight of humus fraction can hold up to 20 times its weight in water (Stevenson, 1982). That is why improving the organic matter of the soil makes it more resilient to drought conditions.

The humus fraction is also negatively charged, just like clay particles. This is important because the humus fraction can hold on to positively charged ions in the soil. Nutrients such as potassium (K<sup>+</sup>), magnesium (Mg<sup>++</sup>), and calcium (Ca<sup>++</sup>) can be held by the humic substances, which prevents them from being lost through leaching that takes place when water flows through the soil (Figure 2). That is why the organic matter increases the cation exchange capacity of the soil.

Generally, organic materials used to amend soil contain several other nutrients in the organic form (for example, nitrogen, phosphorus, and sulfur), which are slowly released for plant use as the organic materials decompose. Humus also contributes to improving micronutrient availability to plants. Therefore, improving your soil organic matter is very beneficial not only for providing good nutrition for the soil organisms but also for the nutrition of the crops.

Soil organic matter can produce significant improvement in physical soil conditions. Increased soil organic matter will improve water retention, create more water-stable aggregates, improve air space (pore spaces), and improve water infiltration. A soil with adequate organic matter can be worked more easily with cultivating or tillage tools and will also resist compaction more than a soil with low organic matter (Ruehlmann and Körschens, 2009).

Soil productivity depends on maintaining and improving soil organic matter through careful management. Soil organic matter can be depleted through repeated tillage or less organic material being returned to the soil. Rototilling for example, will intensively break up the soil into fine particles and expose tremendous amounts of soil organic matter to oxidation, thereby causing the soil to lose its precious organic carbon to the air as carbon dioxide. Additionally, intensive tillage practices like rototilling and plowing will also alter the microbial dynamics of the soil by physically displacing soil organisms from their preferred locations. This often causes soil organisms to die due to disruption and relocation by such tillage practices because it becomes difficult for organisms to adapt to their new environment. For more information on reduced tillage practices, see NMSU Extension Guide A-152, *Reducing Tillage in Arid and Semi-arid Cropping Systems: An Overview* ([http://aces.nmsu.edu/pubs/\\_a/A152.pdf](http://aces.nmsu.edu/pubs/_a/A152.pdf)).

### **“Feeding” Soil Organisms (Adding Organic Material)**

In order to manage your soil organic matter, start by selecting organic matter—such as composts or plant residues—that serve as food sources for soil organisms. Try to add a diversity of organic materials to the soil. These can either be incorporated as a soil amendment or left on the soil surface as a mulch. When left on the soil surface, larger organisms such as earthworms will begin incorporating the material into the soil. Incorporating organic material into trenches that don’t disrupt a large volume of soil is an alternative to rototilling. Remember that plant roots from the garden can provide a large pool of organic material for microbial activity if left in the soil, which can, in most cases, make it unnecessary to incorporate surface material.

When adding organic matter to the soil, you need to ensure that the soil environment is warm and moist in order to promote good decomposition. Most organisms require damp—not soggy—conditions at temperatures between 50°F and 90°F. Dry or cold conditions will slow microbial activity and the decomposition rate. Soils that are too wet (over-watered) will cause problems for many soil organisms and slow their ability to improve the soil. It is important to realize that the benefit of soil amendments as nutrient sources relies on having good conditions for decomposition. If the environment for decomposition is not available, the organic material you add will provide very little benefit with regard to providing soil nutrition for crops.

Pesticides are another input that should be carefully used in gardens. Only use pesticides (fungicides, etc.) when absolutely necessary since they may be harmful to soil organisms. Applying grass clippings after they have been treated with herbicides or pesticides may have negative impacts on soil organisms responsible for building soil organic matter. Some pesticides can also kill many of the beneficial insects in the yard, making it easy for insect pests to thrive and attack the growing crops. Generally, the impact of pesticides on soil organisms is related to the active ingredient in the pesticide. Some active ingredients in the pesticide can be very toxic to soil organisms while some may not be toxic. Always read and understand the pesticide label before applying. (See NMSU Extension Guides A-610 through A-614 [[http://aces.nmsu.edu/pubs/\\_a/#pest](http://aces.nmsu.edu/pubs/_a/#pest)] for more information regarding pesticide labels and use.)

### **Types of Mulches**

In the quest to conserve water, plastic sheeting is often used to trap escaping soil moisture, especially under rock mulches. However, it is important **not** to use plastic sheeting, especially when put under rock mulches, because this greatly reduces water and air movement in and out of the soil and prevents incorporation of organic matter into the soil. Placing mulch on top of plastic does not improve soil organic matter and is not a recommended practice.

### **Using Animal Manures**

Animal manures add more organic matter to the soil than nutrients. However, much of the nutrients in manure are in an organic form and not immediately available for use by plants. Commercial fertilizer rates can be reduced or eliminated when animal manures are applied. Fertilizer value should be credited to manures. Composted manures, however, will have fewer nutrients that are readily available to plants.

Animal manures should be dried, aged, or composted before being used in gardens or in flower beds, especially

<b>Mulches (weed-free; applied to soil surface)</b>	<b>Soil amendments (incorporated into soil)</b>
Straw	Animal manures <sup>4</sup> (from non-carnivorous animals)
Hay	Composted manure
Shredded leaves	Composted plant material
Pine needles, broken	Ground plant material (plant meal)
Pecan hulls, broken	Seed meal
Grass clippings (thin layer)	Bone meal
Crimped or terminated cover crops	Blood meal
Shredded wood or bark	Incorporated cover crops (all those listed in the mulch column <sup>5</sup> )
Bark pieces, wood chips, sawdust <sup>1</sup>	Peat moss <sup>6</sup>
Newspaper (two sheets thick, covered with wood, bark, grass, or pecan hulls to hold in place)	Biochar <sup>7</sup>
Coconut coir byproduct <sup>2</sup>	
Rock <sup>3</sup>	

<sup>1</sup> Cedar (from real *Cedrus* spp.) mulch can be poisonous to plants (phytotoxic) when used in a sawdust consistency. Most “cedar” or “red cedar” mulches are actually juniper (*Juniperus* spp.) or arborvitae (*Thuja* spp.), and do not have toxic qualities.

<sup>2</sup> This is the husk material of the coconut fruit. Long fibers are typically removed after soaking in water and then ground, leaving pith tissue and short- and medium-length fibers. Coir dust results if the fibers are screened out (Konduru et al., 1999).

<sup>3</sup> Rock is good for where plants are not planted. Never put rock over black plastic in an area to be planted.

<sup>4</sup> Animal manures will contain more readily available plant nutrients than compost. Before adding manures, though, conduct a soil test to avoid the over-accumulation of excess nutrients. See NMSU Extension Guide A-114, *Test Your Garden Soil* ([http://aces.nmsu.edu/pubs/\\_a/A114.pdf](http://aces.nmsu.edu/pubs/_a/A114.pdf)), for more information.

<sup>5</sup> High carbon-to-nitrogen ratio (C:N) materials, like those coming from trees, will make nitrogen unavailable to plants for a period of time after incorporation. See Table 4 for C:N ratios of common organic materials.

<sup>6</sup> Peat moss is not considered a renewable resource since it is mined from peat bogs; it should be avoided.

<sup>7</sup> “Biochar generally improves the soil physical environment, but long-term field studies are lacking to conclusively ascertain the extent of biochar effects.” (Blanco-Canqui, 2017, p. 687)

chicken manure. Chicken manure or chicken litter has uric acid that evaporates into ammonia and can harm plants that are exposed to this gas. Composting takes care of the ammonia in manures by allowing the manure to “age” for a period of time to reduce the ammonia content. Other fresh manures may have some nitrogen volatility to them that could affect the growth of young plants. If composting isn’t an option, then incorporating the organic material and allowing it to decompose in a moist soil environment for at least three weeks is another option. Topdressing a lawn with manure can cause serious problems similar to leaving grass clippings (thatch) on the lawn. If it is thick enough, the organic matter layer can actually prevent air and water from entering the soil. When using manure as an organic amendment, it is best to work it into the soil to a shallow depth in order to aid decomposition. Table 1 provides a list of mulches that can be applied to the soil surface and manures that can be incorporated into the soil as soil amendments.

Manure quality varies depending on moisture content, the animal, the animal’s diet, and the place where the animal is confined. Manures contain micronutrients that are needed by plants, along with the major nutrients—nitrogen, phosphorus, and potassium, as well as calcium, magnesium, and sulfur—but nutrient concentrations within the manure depend on the source of the animal’s feed. In order to know the amount of nutrients contained in a manure or compost, it is best to send a sample to a manure testing laboratory. Most of the laboratories that do soil analysis will also accept manure or compost samples. Analysis results from the lab will detail the elements contained in the manure/compost and how much of these elements may be made available in the first year. Remember, not all the nutrients in the organic amendment will be available immediately. Since they are slowly released, many of these nutrients will be made available over many years. That is why it is critical to do regular soil testing if you are using organic amendments as your nutrient source.

Animal	Water (%)	Nitrogen	Phosphorus (P <sub>2</sub> O <sub>5</sub> )	Potassium (K <sub>2</sub> O)
		lb of nutrient/100 lb of manure (moist)		
Dairy cows	30	1.25	1.20	2.05
Fattening cattle	32	1.15	1.20	2.05
Sheep	31	1.45	1.30	1.90
Horses	31	1.45	1.30	1.90
Swine	82	0.50	0.45	0.40
Hens without litter	55	1.65	2.25	1.70
Hens with dry litter	25	2.8	2.25	1.70

Unfortunately, manure may contain numerous weed seeds depending on where it was stored and how much weed seed was ingested by the animals. Before you decide to use animal manure in a garden or flower bed, be aware that weed seeds can germinate after the manure has been applied to the soil and can become problematic weeds over several years. Knowing the source of the manure or compost, if possible, can help avoid bringing weed seeds to your location. Heat-treated composts or manures may have less weed germination potential. Storing composts and manures in areas that favor the growth of weeds will also introduce seeds that are unwanted in the garden. Treated manures and composts usually reduce the amount of viable weed seeds, but the treatment adds to the product's retail price. Well-composted manure can have greatly reduced weed seed due to the high temperatures (130–150°F) achieved during composting.

Table 2 shows the average plant nutrient composition of some livestock manures. Price per ton of manure should depend on the moisture content. As an example, stockpiled dairy cow manure has approximately 30% moisture. This means that a ton of this material contains about 600 pounds of moisture and the remaining 1,400 pounds are solids. There is usually some amount of sand, grit, or soil within manure as well.

Moisture contents of most manures can be estimated by using Table 3. All other factors being equal, drier manure is worth more per ton than moist manure.

### **Carbon-to-nitrogen (C:N) Ratio**

Organic materials used to amend soils are not created equal. Some materials decompose faster than others. For example, legumes (bean family) used as green manure decompose faster than grasses. The speed with which soil

Moisture content	Description
≤30%	Dusty to slightly dusty
30–50%	No dust, but crumbly
50–70%	Crumbly to sticky
≥70%	Wet, sticky, and possibly caked

organisms break down organic materials depends on what is called the carbon-to-nitrogen ratio (C:N) of the organic material. When C:N is high (more carbon and less nitrogen), there will not be enough nitrogen in the organic material to satisfy the microorganisms that are decomposing the material; the microorganisms will look for nitrogen elsewhere, and in most cases will use the nitrogen that is already in the soil to break down the material. This situation is called immobilization since the nitrogen that the crops can potentially use for their growth has been used up by the soil microorganisms. This can cause nitrogen deficiency in crops if the period of immobilization coincides with the peak period of nitrogen use by the crops.

This is why materials very high in C:N, such as bark and sawdust, are better used as mulch rather than mixed into the soil. Such materials will decompose slowly on the soil surface and will not interfere with nutrient dynamics of the soil in a negative way. On the other hand, materials with low C:N will decompose faster and supply nitrogen to the soil since there is more than enough nitrogen in the material for soil microbes to break it down. This condition under which nitrogen is released from organic sources and into the soil is called *nitrogen mineralization*. At C:N of 24:1, there is just enough nitrogen in the source materials to be broken down by microbes such that they do not cause either net nitrogen immobilization or mineralization. Any material with C:N of less than 24:1 will lead to mineralization; that is, nitrogen will be produced in the soil. Any material with C:N more than 24:1 will cause immobilization; that is, nitrogen will become temporarily deficient in the soil. C:N ratios of common organic materials used in amending soils are presented in Table 4. High-carbon materials like pine needles, barks, and sawdust will decompose more quickly when incorporated into the soil with an added nitrogen source like ammonium sulfate (21-0-0) or urea (42-0-0).

Decomposition of high-carbon materials is a slow process and can cause nitrogen deficiencies in existing plants if additional nitrogen is not added to the soil. Delay planting by at least four weeks after incorporating a high C:N amendment (e.g., newspaper, dried leaves,

Organic Material		C:N Ratio
Sawdust		375:1
Newspaper		300:1
Wheat straw		125:1
Oat straw		75:1
Leaves		50:1
Corn silage		40:1
Rye cover crop (flowering)		37:1
Pea straw		29:1
Rye cover crop (vegetative)		26:1
Alfalfa hay		25:1
<b>Ideal microbial diet</b>		
Horse manure		22:1
Compost		18:1
Grass clippings		17:1
Legume hay		17:1
Cow manure		15:1
Food waste		15:1
Hairy vetch cover crop		11:1
Poultry manure		10:1
Cottonseed meal		7:1
Blood meal		3:1

A more complete listing of C:N ratios can be found in the *On Farm Composting Handbook* (Rynk, 1992).

sawdust, pine needles, etc.), and add sufficient nitrogen fertilizer or low C:N material to aid decomposition.

### Summary

Adding organic materials to soil is a good practice. Think of it as feeding the soil organisms that help plants grow.

The over-application of some manures and composts can result in excessive nutrients or salinity in the soil. When in doubt about the amendment's salt content, please have it tested for total salt content and sodium concentration. As a general rule of thumb, do not apply more than 10 pounds of sodium or 45 pounds of total salts per 1,000 square feet of garden.

Growing your organic matter in the form of cover crops like wheat could return 200 or more dry pounds (per 1,000 square feet) of aboveground organic matter back to the soil to help feed soil organisms. Diversify

the plants you use to feed soil organisms by including legumes and other crops.

Know the approximate C:N ratio of the organic matter you are adding to the soil. Some growers will benefit from adding organic materials while practicing intensive tillage and be able to maintain an acceptable level of soil organic matter. However, a reduction in organic matter may mean too much tillage with insufficient replacement of soil carbon.

Soil testing is key to making management decisions such as how much and what kind of carbon to add to the soil or to grow in place.

### List of Terms

**Biochar:** A form of charcoal that is produced by exposing organic waste matter to heat in a low-oxygen environment and that is used especially as a soil amendment (Merriam-Webster, 2017).

**Fulvic acid:** The pigmented organic material that remains in solution after removal of humic acid by acidification. It is separated from the fulvic acid fraction by adsorption on a hydrophobic resin at low pH values.

**Glomalin:** A sugar-protein complex secreted by certain fungi, primarily in the plant root zone, that is thought to contribute to soil aggregation.

**Humic acid:** The dark-colored organic material that can be extracted from soil with dilute alkali and other reagents and that is precipitated by acidification to pH 1 to 2.

**Humic substances:** A series of relatively high-molecular-weight, yellow- to black-colored organic substances formed by secondary synthesis reactions in soils. The term is used in a generic sense to describe the colored material or its fractions obtained on the basis of solubility characteristics. These materials are distinctive to soil environments in that they are dissimilar to the biopolymers of microorganisms and higher plants (including lignin).

**Humification:** The process whereby the carbon of organic residues is transformed and converted to humic substances through biochemical and abiotic processes.

**Humus:** The well decomposed, more or less stable part of the organic matter in mineral soils. Humus is an organic soil material that is also one of the USDA textures of muck (sapric soil material), mucky peat (hemic soil material), or peat (fibric soil material). Most likely it is muck.

**Immobilization:** The conversion of an element from the inorganic to the organic form in microbial or plant tissues.

**Micronutrients:** A plant nutrient found in relatively small amounts (<100 mg kg<sup>-1</sup>) in plants. These are usually B, Cl, Co, Cu, Fe, Mn, Mo, Ni, and Zn.

**Mineralization:** The conversion of an element from an organic form to an inorganic state as a result of microbial activity.

**Sapric:** Organic soil material that contains less than 1/6 recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low, and water-holding capacity very high.

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