Why Soil Organic Matter Is So Important

A fertile and healthy soil is the basis for healthy plants, animals, and humans. And soil organic matter is the very foundation for healthy and productive soils. Understanding the role of organic matter in maintaining a healthy soil is essential for developing ecologically sound agricultural practices. But how can organic matter, which only makes up a small percentage of most soils, be so important that we devote the three chapters in this section to discuss it? The reason is that organic matter positively influences, or modifies the effect of, essentially all soil properties. That is the reason it's so important to our understanding of soil health and how to manage soils better. Organic matter is essentially the heart of the story, but certainly not the only part. In addition to functioning in a large number of key roles that promote soil processes and crop growth, soil organic matter is a critical part of a number of global and regional cycles.

It's true that you can grow plants on soils with little organic matter. In fact, you don't have to have any soil at all. (Although gravel and sand hydroponic systems without soil can grow excellent crops, large-scale systems of this type are usually neither economically nor ecologically sound.) It's also true that there are other important issues aside from organic matter when considering the quality of a soil. However, as soil organic matter decreases, it becomes increasingly difficult to grow plants, because problems with fertility, water availability, compaction, erosion, parasites, diseases, and insects become more common. Ever higher levels of inputs—fertilizers, irrigation water, pesticides, and machinery—are required to maintain yields in the face of organic matter depletion. But if attention is paid to proper organic matter management, the soil can support a good crop without the need for expensive fixes.

WHAT MAKES TOPSOIL?

Having a good amount of topsoil is important. But what gives topsoil its beneficial characteristics? Is it because it's on TOP? If we bring in a bulldozer and scrape off one foot of soil, will the exposed subsoil now be topsoil because it's on the surface? Of course, everyone knows that there's more to topsoil than its location on the soil surface. Most of the properties we associate with topsoil—good nutrient supply, tilth, drainage, aeration, water storage, etc.—are there

because topsoil is rich in organic matter and contains a huge diversity of life.

The organic matter content of agricultural topsoil is usually in the range of 1–6%. A study of soils in Michigan demonstrated potential crop-yield increases of about 12% for every 1% organic matter. In a Maryland experiment, researchers saw an increase of approximately 80 bushels of corn per acre when organic matter increased from 0.8% to 2%. The enormous influence of organic matter on so many of the soil's properties— biological, chemical, and physical—makes it of critical importance to healthy soils (figure 2.3). Part of the explanation for this influence is the small particle size of the well-decomposed portion of organic matter—the humus. Its large surface area–to–volume ratio means that humus is in contact with a considerable portion of the soil. The intimate contact of humus with the rest of the soil allows many reactions, such as the release of available nutrients into the soil water, to occur rapidly. However, the many roles of living organisms make soil life an essential part of the organic matter story.

Plant Nutrition

Plants need eighteen chemical elements for their growth—carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S),

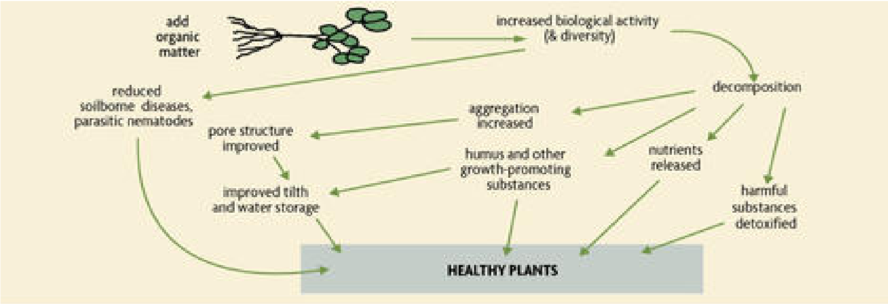

Figure 2.3. Adding organic matter results in many changes. Modified from Oshins and Drinkwater (1999).

calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), boron (B), zinc (Zn), molybdenum (Mo), nickel (Ni), copper (Cu), cobalt (Co), and chlorine (Cl). Plants obtain carbon as carbon dioxide (CO_2) and oxygen partially as oxygen gas (O_2) from the air. The remaining essential elements are obtained mainly from the soil. The availability of these nutrients is influenced either directly or indirectly by the presence of organic matter. The elements needed in large amounts—carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur—are called macronutrients. The other elements, called micronutrients, are essential elements needed in small amounts. (Sodium [Na] helps many plants grow better, but it is not considered essential to plant growth and reproduction.)

Nutrients from decomposing organic matter.

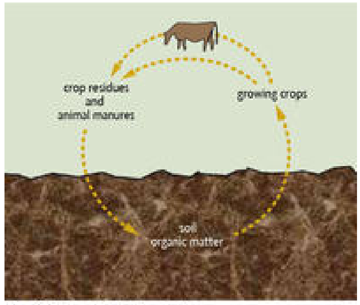

Figure 2.4. The cycle of plant nutrients.

Most of the nutrients in soil organic matter can't be used by plants as long as those nutrients exist as part of large organic molecules. As soil organisms decompose organic or mineral forms that plants can easily use. This process, called mineralization, provides much of the nitrogen that plants need by converting it from organic forms. For example, proteins are converted to ammonium (NH_4^+) and then to nitrate (NO_3^-). Most plants will take up the majority of their nitrogen from soils in the form of nitrate. The mineralization of organic matter is also an important mechanism for supplying plants with such nutrients as phosphorus and sulfur and most of the micronutrients. This release of nutrients from organic matter by mineralization is part of a larger agricultural nutrient cycle (see figure 2.4). For a more detailed discussion of nutrient cycles and how they function in various cropping systems, see chapter 7.

Addition of nitrogen.

Bacteria living in nodules on legume roots convert nitrogen from atmospheric gas (N_2) to forms that the plant can use directly. A number of free-living bacteria also fix nitrogen.

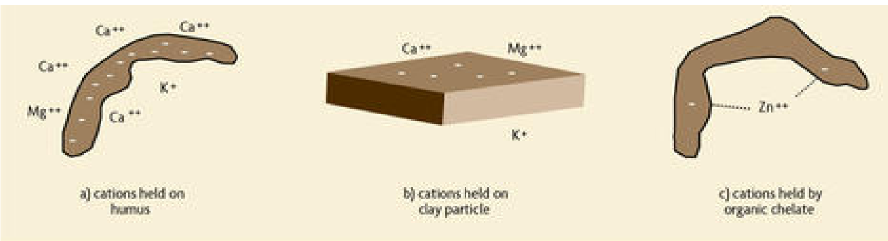

Figure 2.5. Cations held on negatively charged organic matter and clay.

Storage of nutrients on soil organic matter.

Decomposing organic matter can feed plants directly, but it also can indirectly benefit the nutrition of the plant. A number of essential nutrients occur in soils as positively charged molecules called cations (pronounced cat-eye-ons). The ability of organic matter to hold on to cations in a way that keeps them available to plants is known as cation exchange capacity (CEC). Humus has many negative charges. Because opposite charges attract, humus is able to hold on to positively charged nutrients, such as calcium (Ca^{++}), potassium (K^+), and magnesium (Mg^{++}) (see figure 2.5a). This keeps them from leaching

ORGANIC MATTER INCREASES THE AVAILABILITY OF NUTRIENTS . . .

Directly

- As organic matter is decomposed, nutrients are deep into the subsoil when water moves through the topsoil. Nutrients held in this way can be gradually released into the soil solution and made available to plants throughout the growing season. However, keep in mind that not all plant nutrients occur as cations. For example, the nitrate form of nitrogen is negatively charged (NO_3^-) and is actually repelled by the negatively charged CEC. Therefore, nitrate leaches easily as water moves down through the soil and beyond the root zone.

Clay particles also have negative charges on their surfaces (figure 2.5b), but organic matter may be the major source of negative charges for coarse and medium-textured soils. Some types of clays, such as those found in the southeastern United States and in the tropics, tend to have low amounts of negative charge. When those clays are present, organic matter may be the major source of negative charges that bind nutrients, even for fine-textured (high-clay-content) soils.

Protection of nutrients by chelation.

Organic molecules in the soil may also hold on to and protect certain nutrients. These particles, called "chelates" (pronounced key-lates) are by-products of the active decomposition of organic materials and are smaller than the particles that make up humus. In general, elements are held more strongly by chelates than by binding of positive and negative charges. Chelates work well because they bind the nutrient at more than one location on the organic molecule (figure 2.5c). In some soils, trace elements, such as iron, zinc, and manganese, would be converted to unavailable forms if they were not bound by chelates. It is not uncommon to find low-organic-matter soils or exposed subsoils deficient in these micronutrients.

Other ways of maintaining available nutrients.

There is some evidence that organic matter in the soil can inhibit the conversion of available phosphorus to forms that are unavailable to plants. One explanation is that organic matter coats the surfaces of minerals that can bond tightly to phosphorus. Once these surfaces are covered, available forms of phosphorus are less likely to react with them. In addition, humic substances may chelate aluminum and iron, both of which can react with phosphorus in the soil solution. When they are held as chelates, these metals are unable to form an insoluble mineral with phosphorus.

converted into forms that plants can use directly.

- CEC is produced during the decomposition process, increasing the soil's ability to retain calcium, potassium, magnesium, and ammonium.
- Organic molecules are produced that hold and protect a number of micronutrients, such as zinc and iron.

Indirectly

- Substances produced by microorganisms promote better root growth and healthier roots, and with a larger and healthier root system plants are able to take in nutrients more easily.
- Organic matter contributes to greater amounts of water retention following rains because it improves soil structure and thereby improves water-holding capacity. This results in better plant growth and health and allows more movement of mobile nutrients (such as nitrates) to the root.

Beneficial Effects of Soil Organisms

Soil organisms are essential for keeping plants well supplied with nutrients because they break down organic matter. These organisms make nutrients available by freeing them from organic molecules. Some bacteria fix nitrogen gas from the atmosphere, making it available to plants. Other organisms dissolve minerals and make phosphorus more available. If soil organisms aren't present and active, more fertilizers will be needed to supply plant nutrients.

A varied community of organisms is your best protection against major pest outbreaks and soil fertility problems. A soil rich in organic matter and continually supplied with different types of fresh residues is home to a much more diverse group of organisms than soil depleted of organic matter. This greater diversity of organisms helps insure that fewer potentially harmful organisms will be able to develop sufficient populations to reduce crop yields.

Soil Tilth

When soil has a favorable physical condition for growing plants, it is said to have good *tilth*. Such a soil is porous and allows water to enter easily, instead of running off the surface. More water is stored in the soil for plants to use between rains, and less erosion occurs. Good tilth also means that the soil is well aerated. Roots can easily obtain oxygen and get rid of carbon dioxide. A porous soil does not restrict root development and exploration. When a soil has poor tilth, the soil's structure deteriorates and soil aggregates break down, causing increased compaction and decreased aeration and water storage. A soil layer can become so compacted that roots can't grow. A soil with excellent physical properties will have numerous channels and pores of many different sizes.

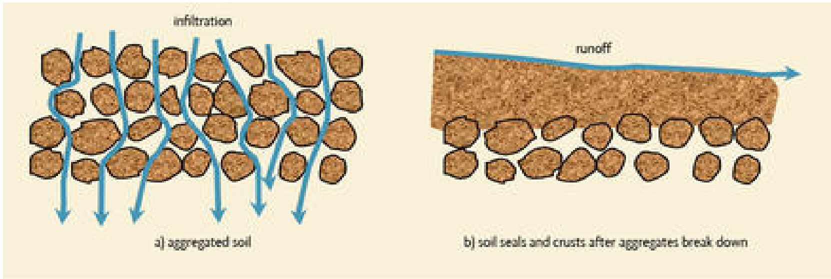

Figure 2.6. Changes in soil surface and water-flow pattern when seals and crusts develop.

Studies on both undisturbed and agricultural soils show that as organic matter increases, soils tend to be less compact and have more space for air passage and water storage. Sticky substances are produced during the decomposition of plant residues. Along with plant roots and fungal hyphae, they bind mineral particles together into clumps, or aggregates. In addition, the sticky secretions of mycorrhizal fungi—beneficial fungi that enter roots and help plants get more water and nutrients—are important binding material in soils. The arrangement and collection of minerals as aggregates and the degree of soil compaction have huge effects on plant growth (see chapters 5 and 6). The development of aggregates is desirable in all types of soils because it promotes better drainage, aeration, and water storage. The one exception is for wetland crops, such as rice, when you want a dense, puddled soil to keep it flooded.

Organic matter, as residue on the soil surface or as a binding agent for aggregates near the surface, plays an important role in decreasing soil erosion. Surface residues intercept raindrops and decrease their potential to detach soil particles. These surface residues also slow water as it flows across the field, giving it a better chance to infiltrate into the soil. Aggregates and large channels greatly enhance the ability of soil to conduct water from the surface into the subsoil.

Most farmers can tell that one soil is better than another by looking at them, seeing how they work up when tilled, or even by sensing how they feel when walked on or touched. What they are seeing or sensing is really good tilth. **For an example, see the photo on the back cover of this book. It shows that soil differences can be created by different management strategies. Farmers and gardeners would certainly rather grow their crops on the more porous soil depicted in the photo on the right.**

Since erosion tends to remove the most fertile part of the soil, it can cause a significant reduction in crop yields. In some soils, the loss of just a few inches of topsoil may result in a yield reduction of 50%. The surface of some soils low in organic matter may seal over, or crust, as rainfall breaks down aggregates and pores near the surface fill with solids. When this happens, water that can't infiltrate into the soil runs off the field, carrying valuable topsoil (figure 2.6).

Large soil pores, or channels, are very important because of their ability to allow a lot of water to flow rapidly into the soil. Larger pores are formed in a number of ways. Old root channels may remain open for some time after the root decomposes. Larger soil organisms, such as insects and earthworms, create channels as they move through the soil. The mucus that earthworms secrete to keep their skin from drying out also helps to keep their channels open for a long time.

Protection of the Soil against Rapid Changes in Acidity

Acids and bases are released as minerals dissolve and organisms go about their normal functions of decomposing organic materials or fixing nitrogen. Acids or bases are excreted by the roots of plants, and acids form in the soil from the use of nitrogen fertilizers. It is best for plants if the soil acidity status, referred to as pH, does not swing too wildly during the season. The pH scale is a way of expressing the amount of free hydrogen (H+) in the soil water. More acidic conditions, with greater amounts of hydrogen, are indicated by lower numbers. A soil at pH 4 is very acid. Its solution is ten times more acid than a soil at pH 5. A soil at pH 7 is neutral—there is just as much base in the water as there is acid. Most crops do best when the soil is slightly acid and the pH is around 6 to 7. Essential nutrients are more available to plants in this pH range than when soils are either more acidic or more basic. Soil organic matter is able to slow down, or buffer, changes in pH by taking free hydrogen out of solution as acids are produced or by giving off hydrogen as bases are produced. (For discussion about management of acidic soils, see chapter 20.)

Stimulation of Root Development

Figure 2.7. Corn grown in nutrient solution with (right) and without (left) humic acids. Photo by R. Bartlett. In this experiment by Rich Bartlett adding humic acids to a nutrient solution increased the growth of tomatoes and corn as well as the amount and branching of roots.

Microorganisms in soils produce numerous substances that stimulate plant growth. Humus itself has a directly beneficial effect on plants (figure 2.7). The reason for this stimulation has been found mainly to be due to making micronutrients more available to plants—causing roots to grow longer and have more branches, resulting in larger and healthier plants. In addition, many soil microorganisms produce a variety of root-stimulating substances that behave as plant hormones.

Darkening of the Soil

Organic matter tends to darken soils. You can easily see this in coarse-textured sandy soils containing light-colored minerals. Under well-drained conditions, a darker soil surface allows a soil to warm up a little faster in the spring. This provides a slight advantage for seed germination and the early stages of seedling development, which is often beneficial in cold regions.

Protection against Harmful Chemicals

Some naturally occurring chemicals in soils can harm plants. For example, aluminum is an important part of many soil minerals and, as such, poses no threat to plants. As soils become more acidic, especially at pH levels below 5.5, aluminum becomes soluble. Some soluble forms of aluminum, if present in the soil solution, are toxic to plant roots. However, in the presence of significant quantities of soil organic matter, the aluminum is bound tightly and will not do as much damage.

Organic matter is the single most important soil property that reduces pesticide leaching. It holds tightly on to a number of pesticides. This prevents or reduces leaching of these chemicals into groundwater and allows time for detoxification by microbes. Microorganisms can change the chemical structure of some pesticides, industrial oils, many petroleum products (gas and oils), and other potentially toxic chemicals, rendering them harmless.

Organic Matter: What It Is And Why it's So Important | Top | Organic Matter and Natural Cycles