Soil Organic Matter Level and Interpretation

Fact Sheet FS1136

Cooperative Extension

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What is Organic Matter?

Organic matter refers to carbon-based compounds and structures that are derived from living organisms[1]. Organic matter contains carbon in a reduced form as well as other elements that serve as plant nutrients. It includes living organisms, although in soil the term is generally used to mean the breakdown products of organisms and their wastes. The non-living organic matter may be in various stages of decomposition, on a continuum from fresh residue to humus. "Humus" is organic matter in its most decomposed state, retaining only the most basic biochemical structures from the original material and its metabolic byproducts. Most organic matter in native soil is not visible, occurring primarily as humus coatings on mineral particles, except that any given soil tends to appear darker as organic matter content increases. However, soil organic matter content can be quantified in the laboratory.

How is the Organic Matter Content of Soils Determined?

The first step in nearly all laboratory soil testing is to dry and sift the sample to remove any particles greater than 2 mm (0.08") in diameter. This is the upper particle size limit for soil; any mineral fragment larger than this is a "coarse fragment": gravel, stone, etc. The same sifting process will also remove earthworms and beetles and twigs and similar material. Thus, while these are technically part of soil organic matter, the contribution made by these larger undecomposed residues, living or otherwise, will not be included in a laboratory analysis.

The most common tests to determine the amount of organic matter in a soil are the loss-on-ignition (LOI) method and a chemical oxidation method. Both involve oxidizing the chemically reduced carbon of organic matter.

Soil laboratory analytical methods must sometimes be geographically specific because of the soil properties commonly encountered in a specific part of the world. The eastern United States is characterized by a humid climate where the soils tend to be acidic. Since acidic soils are leached of carbonate minerals, the carbon measured by these analyses can be assumed to originate in the soil organic matter. Analysis of soils from more arid regions (thus alkaline soil) would require additional steps to distinguish between the carbon coming from organic matter versus from carbonates in the soil.

Loss-on-ignition (LOI): In this method a soil sample is dried in an oven, weighed, "ignited" at temperatures ranging from
360° to 440°C (680° to 824°F) to destroy the organic matter, and then re-weighed. Organic matter's major components: carbon, hydrogen, and oxygen, escape as gases during combustion, leaving behind ash. The resulting loss in mass allows the percentage of organic matter to be calculated. This method is best used in soils containing high levels of organic matter: 10 percent or more. Highly organic soils, especially those with particulate organic matter, tend to be more variable than low organic matter soil, which complicates obtaining a representative sample in the laboratory. The LOI method accommodates much larger samples, which will be more representative of the whole soil, compared to the small sample size used in the chemical oxidation method. Its measured value will

1 Exceptions: biologically derived carbon-containing compounds which are inorganic include carbonate structures (shell) and carbon dioxide.

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include particulate organic matter — recognizable plant tissue — in the size range of soil (less than 2mm) as well as the active and humified organic matter. In soils amended with organic matter, the LOI method generally estimates greater organic matter content compared to the chemical oxidation procedure because it includes the particulate organic matter. Some laboratories use a calibration factor to adjust LOI values to percentages equivalent to chemical oxidation results. The LOI method is often specified for soil blend quality control to achieve rapid turnaround, and consistency in methodology is required for comparing results of different soil blends and between different laboratories. When using the LOI method, the data user should be aware that the particulate fraction of the organic matter will continue to break down and decompose in a relatively short time frame, which may result in significantly less organic matter in the field after one growing season.

Chemical oxidation: In this method, a soil sample is chemically digested with potassium dichromate and sulfuric acid at a temperature of 176°C (349°F), and the amount of carbon oxidized is quantified by titration with a reducing agent. Soil organic matter does not have an exact chemical structure; however, its proportion of carbon is quite consistent. This permits the use of the carbon weight, determined by titration, to calculate an organic matter percentage (by weight) using a conversion factor. This method is recommended for soils containing less than 10% organic matter. The small sample size (e.g. 0.3 g) used for this analysis may be one disadvantage of this method, depending on how homogenous or heterogeneous the sample is. Also, particulate organic matter (visible fragments of organic residue) may not be fully digested with this procedure, which is another source of discrepancy from LOI values.

How Is Organic Matter Level Interpreted?

The organic matter content of New Jersey soils varies widely depending on drainage conditions, soil texture, planting history, cultivation and other management practices, degree of water and wind erosion, and other factors. Generally, fine-textured soils with greater clay content can hold more organic matter than coarser, sandier soil. The following table may be used to assess mineral soils in New Jersey on the basis of relative organic matter content.

Table 1. Interpretation of Organic Matter Levels in NJ Soils

Organic Matter Range (% by weight)	Soil Textural Class			
	Loamy Sand	Sandy Loam	Loam	Silt Loam
0-0.5	Very low	Very low	Very low	Very low
0.5-1.0	Low	Very low	Very low	Very low
1.0-1.5	Medium	Low	Very low	Very low
1.5-2.0	High	Medium	Low	Very Low
2.0-2.5	Very high	High	Medium	Low
2.5-3.0	Very high	Very high	Medium	Medium
3.0-4.0	Very high	Very high	High	Medium
4.0-5.0	Very high	Very high	Very high	High
Above 5.0	Very high	Very high	Very high	Very high

Further Evaluation of Soil Organic Matter

Quantity and quality of soil organic matter can also be assessed by a soil respiration test. This entails placing a standardized amount of dry soil into a closed container, wetting the soil to field capacity, and determining the amount of carbon dioxide (CO_2) produced/respired in a known time period, typically 24 hours. CO_2 is a product of the biological oxidation process in which the soil microbial community consumes organic matter, and it takes place at ambient temperature. This test permits an assessment of the amount of soil organic matter capable of being a food source for the soil microbial community and is also a measure of the active microbial biomass (typically the organic matter in soil is fully colonized by soil bacteria). From the quantity of CO_2 produced, estimates may be made of certain plant nutrients (especially N and P previously part of the structure of the soil organic matter) made available for plant use by the biological oxidation of soil organic matter by the soil microbial community. These estimates may be used as credits against the fertilizer recommendations made for a given plant.

Since the amount of fertilizer applied would be reduced by this credit, the soil respiration test makes an important contribution to Comprehensive Nutrient Management Plans and has the potential both to save money (for fertilizer) and protect the environment, especially aquatic ecosystems, from excessive fertilizer runoff.

Can Soils Have Too Much Organic Matter?

Yes, soils can have "too much" organic matter, meaning a level at which the disadvantages begin to outweigh the advantages, or that it constitutes a wasteful use of a valuable resource. While organic matter is a very valuable component of good-quality soil, too much organic matter can become problematic. Excessive organic matter might cause too much water retention, leading to aeration problems in certain sites for unadapted plants. Soil that is continually wet will also promote root disease in susceptible plants. On the other side of the spectrum, organic matter can also cause problems in hot, dry sites. Dry organic matter becomes hydrophobic and will actually repel water rather than absorb it.

While naturally organic soils ("Histosols", >20% organic matter) are prized for growing vegetable crops, there are disadvantages that can be afforded in high–value crops. Certain nutrient deficiencies are associated with organic soils which must be controlled with careful fertilizer management.

Furthermore, organic soils typically form in poorly drained sites, which are often then subjected to artificial drainage systems to allow crop production. Lowering the water table allows greater rates of oxidation (decomposition) of the accumulated organic matter, causing the land surface to "subside", losing inches of depth over a decade. Similarly, soils having higher organic matter content than either texture or management can sustain will decrease in volume over time, requiring continual replenishment to avoid negative consequences to perennial landscaping or crops.

For these reasons, very high soil organic matter content is not encouraged; 10% organic matter content of soil is suggested as a maximum for general agronomic/horticultural use.

That being said, "soilless" mixes which are predominantly organic-matter based with little if any mineral soil, have much utility for container-gardening and greenhouse use.

Acknowledgement

Modified & updated from an unofficial fact sheet (#4S) by Dr. Roy Flannery, former extension specialist/professor, Rutgers University.

Additional Resources

Rutgers Cooperative Extension Fact Sheet FS1135 Soil Organic Matter.

Rutgers Cooperative Extension Fact Sheet FS1137 Improving Soil Quality by Increasing Organic Matter Content.

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