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SOIL QUALITY AND SOIL ORGANIC MATTER

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SOIL QUALITY

Recent interest in sustainable agricultural has brought renewed attention to soil quality, a critically important aspect of any agricultural system. Soil quality is a complex concept incorporating physical, chemical, and biological processes. Its complicated nature makes it hard to define and difficult to measure. Soil organic matter (SOM) is essential to soil quality. Soils with high SOM content are generally considered high quality soils; those with low SOM are regarded as low quality soils. A variety of methods to assess the SOM have been developed; however, they are subject to high variability and can be easily misinterpreted. To understand the exact role of SOM in maintaining high soil quality, more information is needed on how SOM responds to tillage practices, crop rotations, residue, fertilization, and other management practices.

SOIL ORGANIC MATTER

Not all carbon-containing material in the soil is organic matter. Carbonate minerals contain inorganic carbon. Together, the carbonate minerals and SOM constitute the bulk of soil carbon. While carbonate minerals are usually present only in arid soils, organic carbon occurs in all soils.

The SOM content in surface soils can be as low as half a percent in desert soils, and over 5 percent in the surface layer of temperate grassland soils. The annual production of foliage and roots by plants in humid temperate regions is about 9 tons per acre. Semiarid regions typically produce only 2 to 4 tons per acre. In general, the amount of SOM decreases with soil depth (Bohn et al., 1979).

Soil organic matter is composed of living and dead fractions. The living component includes plant roots, soil animals such as worms, and microorganisms such as bacteria, algae, and fungi. The dead fraction includes the remains of plants and animals, organic material in all stages of decomposition, and humus--the end product of decomposition.

In most soils, humus is the largest fraction of SOM. Humus is brown or black in color and composed of a varied group of substances of unknown origin. Soil scientists have investigated humus composition for a long time, but its exact chemical structure is still unknown. It is a product of microbial metabolism, that is continually being reformed by soil microorganisms from organic material. Only a small portion of humus is soluble in water. Although very resistant to further decomposition, humus is an important food source for soil microorganisms.

The largest source of organic material entering the soil comes from plant residues. Within the residues, the various chemical components have different susceptibilities of decay (Table 1).

Table 1. Amount and Type of Material Contributed to the Soil by Plant Residues

Residue Fraction	Percent by weight	Average Life Span
Cellulose	15 - 60	1-3 Yr
Hemicellulose	10 - 30	3-60 Yr
Lignin	5 - 30	60-1000 Yr
Protein	2 - 15	10-40 Da
Soluble material†	10	10 Da

†Sugars, amino sugars, organic acids and amino acids. Yr = years, Da = days. Adapted from Jenkinson and Ayanaba, 1977, and Paul and Clark, 1989.

Soil microorganisms quickly utilize the soluble carbohydrates and proteins that are leached from the residues. These compounds are used for energy and production of new microbial tissue. Ammonia, sulfate, and carbon dioxide are liberated during the decomposition process. Soil microorganisms do not attack cellulose or hemicellulose as rapidly as the soluble materials. Lignin is even more difficult to decompose. Lignin is retained for the longest time and contributes greatly to the humus content of soils.

It is generally assumed that the SOM content in undisturbed soils slowly increases or remains relatively constant. The organic matter in untilled soils has built up over thousands of years. The long-term addition of organic residue to the soil has been greater than decay and any loss to erosion. Temperature, water content, and oxygen concentration all impact SOM by changing the balance between organic residue addition and loss of older SOM. Soil organic matter content tends to increase as average soil temperature decreases. Cool temperatures reduce the activity of the soil microorganisms and thus SOM decomposition. Soil organic matter tends to increase with increasing precipitation, primarily due to greater biomass production in the wetter environment. Likewise, the use of irrigation can increase SOM content. This increase can be negated, however, if a substantial amount of the harvested crop is removed from the field.

The main factor controlling the decay of SOM is access to oxygen in the presence of adequate water. Poorly drained soils (wetlands and bogs) in cool climates can accumulate SOM. The amount of vegetation produced exceeds the amount decayed because of cool temperatures and low oxygen concentrations. In well-drained soils, the potential decay rate is usually comparable to the natural production of vegetation. When a soil is cultivated or drained, the internal oxygen level rises. Efficient aerobic microorganisms multiply rapidly and decompose the accumulated SOM more rapidly.

LOSS OF SOIL ORGANIC MATTER

Soil organic matter is lost either by decomposition (biological oxidation) or erosion (Bohn et al., 1979). Cultivation of grassland soils commonly causes the loss of one-third to one-half of the native SOM in the first 40-60 years (Rasmussen and Collins, 1991). Agricultural practices that remove plant material, such as burning, grazing or harvesting part of the cultivated crop for human or animal feed, decrease SOM levels. Practices that increase plant growth, such as fertilization or irrigation, will increase SOM levels. Green manuring or the addition of manure will slow the rate of SOM loss. In long-term plots at the Columbia Basin Agricultural Experiment Station, annual addition of manure to a wheat-fallow rotation has maintained a SOM content roughly equal to that of annually cropped soil receiving moderate inorganic fertilizer application. Erosion is very incompatible with maintaining SOM, especially on sloping landscapes. Any management practice that retards erosion will decrease the loss of SOM. Retaining residue on the ground is beneficial in both reducing erosion and maintaining SOM content.

ESTIMATION OF SOIL ORGANIC MATTER

Soil organic matter is difficult to accurately measure. It is generally estimated indirectly by laboratory analysis of carbon liberated during wet or dry combustion and applying a conversion factor,

ranging from 1.7 to 2.2 (Nelson and Sommers, 1982). Dry combustion is performed by heating the soil with a catalyst to about 1,850° F under oxygen or carbon dioxide free air. Wet combustion in generally carried out by refluxing a soil sample with a mixture of potassium dichromate and strong acid (normally sulfuric and phosphoric acids). The carbon dioxide liberated by either method is trapped in a suitable reagent and determined by weight or volume. The estimation of SOM by combustion is not highly accurate because the ratio of SOM to carbon dioxide liberated varies widely from soil to soil and within the soil profile.

Soil organic matter may be estimated by direct determination. In this technique, SOM must be removed from the rest of the soil. In the most common procedure, the soil is weighed before and after the SOM is destroyed by oxidation (Nelson and Sommers, 1982). It is assumed the loss in weight of the soil reflects only vaporized organic material. Any method used to oxidize SOM must remove it entirely, but cannot destroy or alter any inorganic fraction that changes its weight. The two most common methods of SOM analysis are oxidation with hydrogen peroxide (Walkley-Black procedure) and burning at about 1,750° F (Loss-on-Ignition procedure). Oxidation with hydrogen peroxide is usually incomplete and accuracy varies with soil type. The loss-on-ignition method gives quantitative oxidation, but at 950° F carbonate minerals are decomposed and some soil fractions will lose structural water. This results in weight losses considerably in excess of the actual SOM. Carbonates and waters of hydration can be removed by pretreatment with hydrochloric and hydrofluoric acid, to improve accuracy, but the procedure is elaborate and time-consuming. The oxi-dation of SOM by heating at a lower temperature, 665 to 825° F, will reduce carbonate decomposition and retain structural water, but may not completely destroy SOM. Some soils lose structural water at temperatures as low as 570° F.

These relatively harsh treatments measure soil carbon quantity--not organic matter quality. Nearly elemental and essentially inert forms of carbon that are not SOM, such as charcoal or ash, will be reported as SOM. It is improbable that these inert forms of carbon, including the charred material from residue burning, can support the activity of microorganisms or will ever be incorporated into SOM (Albrecht, et al., 1994).

SUMMARY

Soil organic matter is a significant part of soil quality. The humus fraction is especially important as it provides soil structure, pH-buffering and water and mineral-holding capacities. Agricultural practices that increase SOM will enhance soil quality. To maintain SOM, crop residue must be added to the soil. Current methodologies do not accurately measure SOM, and are of limited value. A greater understanding of how management practices affect SOM will contribute significantly to sustainable agriculture and increase soil health, yields, and profits.

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