8 Nutrient Management Module No. 8

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Soil pH and Organic Matter

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Introduction

This module is the eighth in a series of Extension materials designed to provide Extension agents, Certified Crop Advisers (CCAs), consultants, and producers with pertinent information on nutrient management issues. To make the learning 'active,' and to provide credits to Certified Crop Advisers, a quiz accompanies this module. In addition, realizing that there are many other good information sources, including previously developed Extension materials, books, web sites, and professionals in the field, we have provided a list of additional resources and contacts for those wanting more in-depth information about soil pH and organic matter. This module covers the following Rocky Mountain CCA Nutrient Management Competency Areas with the focus on soil pH and organic matter: soil reactions and soil amendments, and soil test reports and management recommendations.

Objectives

After reading this module, the reader should:

1. Know what soil pH is and how it is calculated
2. Understand how soil pH affects nutrient availability in the soil
3. Learn techniques for managing soil pH
4. Know the processes of soil organic matter cycling
5. Understand the role of soil organic matter in nutrient and organic carbon management

Nutrient Management

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Background

As noted throughout *Nutrient Management Modules 2-7*, soil pH and organic matter strongly affect soil functions and plant nutrient availability. Specifically, pH influences chemical solubility and availability of plant essential nutrients, pesticide performance, and organic matter decomposition. Although soil pH is relatively similar in Montana and Wyoming (pH 7-8), it is known to vary from 4.5 to 8.5, causing considerable fertility and production problems at these extremes. Therefore, to understand plant nutrient availability and optimal growing conditions for specific crops, it is important to understand soil chemistry and interacting factors that affect soil pH.

Soil organic matter (SOM) serves multiple functions in the soil, including nutrient storage and soil aggregation. SOM levels have declined over the last century in some soils as a result of over-grazing grasslands and the conversion of grasslands to tilled farmland. This reduction has lead to decreased soil fertility, increased fertilization needs, and increased soil erosion in some areas. Furthermore, SOM has been recognized for its role in the carbon (C) cycle as a sink for carbon dioxide (CO_2) and other greenhouse gas emissions to the atmosphere and is a key indicator of soil quality.

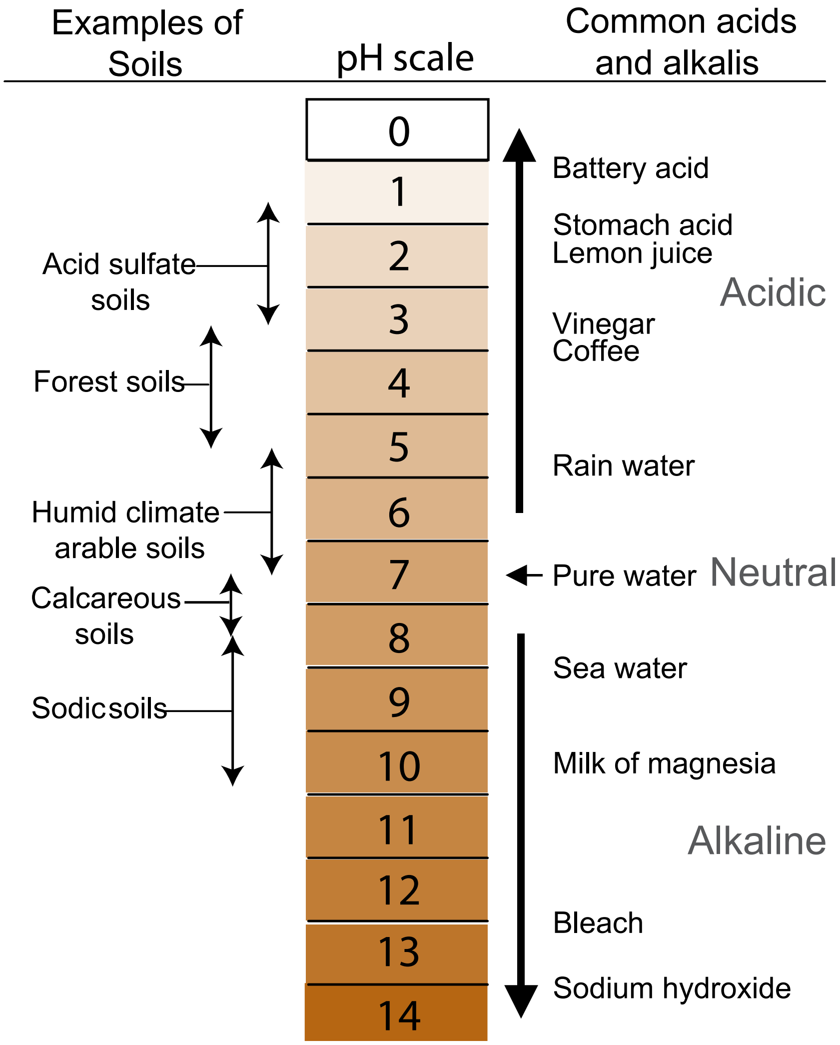

Figure 1. The pH scale (From Nutrient Manager, 1996).

Soil pH

Soil pH is a measure of the soil solution's acidity and alkalinity. By definition, pH is the 'negative logarithm of the hydrogen ion concentration [H^+]', i.e.,pH = -log [H^+]. Soils are referred to as being acidic, neutral, or alkaline (or basic), depending on their pH values on a scale from approximately 0 to 14 (Figure 1). A pH of 7 is neutral (pure water), less than 7 is acidic, and greater than 7 is alkaline. Because pH is a logarithmic function, each unit on the pH scale is ten times less acidic (more alkaline) than the unit below it. For example, a solution with a pH of 6 has a 10 times greater concentration of H^+ ions than a solution with a pH of 7, and a 100 times higher concentration than a pH 8 solution.

Soil pH is influenced by both acid and base-forming ions in the soil. Common acid-forming cations (positively charged dissolved ions) are hydrogen (H^+), aluminum (Al^{3+}), and iron (Fe^{2+} or Fe^{3+}), whereas common base-forming cations include calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+). Most agricultural soils in Montana and Wyoming have basic conditions with average pH values ranging from 7 to 8 (Jacobsen, unpub. data; Belden, unpub. data). This is primarily due to the presence of base cations associated with carbonates and bicarbonates found naturally in soils and irrigation waters. Due to relatively low precipitation amounts, there is little leaching of base cations, resulting in a relatively high degree of base saturation and pH values greater than 7. In contrast, acid conditions occur in soil having parent material high in elements such as silica (rhyolite and granite), high levels of sand with low buffering capacities (ability to resist pH change), and in regions with high amounts of precipitation. An increase in precipitation causes increased leaching of base cations and the soil pH is lowered.

In Montana and Wyoming, acidic soils are most commonly found west of the continental divide or in high elevation areas (increased precipitation), in areas where soils were formed from acid-forming parent material, forest soils, mining sites containing pyritic (iron and elemental sulfur) minerals, and a few other isolated locations. Figure 2 shows average soil pH values for select counties in Montana and Wyoming.

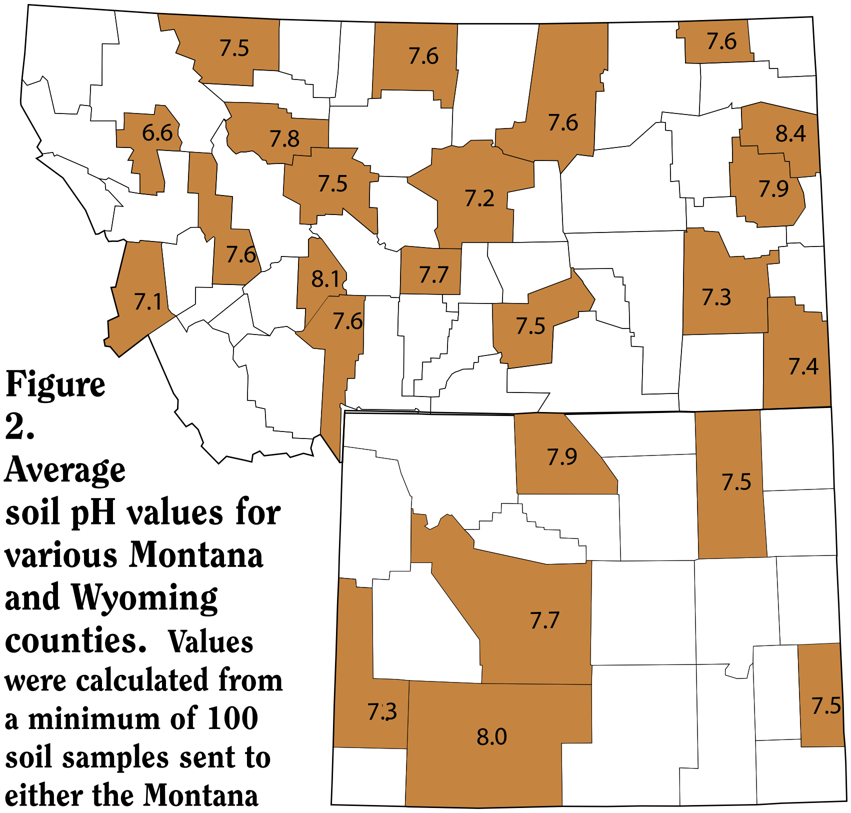

Figure 2. Average soil pH values for various Montana and Wyoming counties. Values were calculated from a minimum of 100 soil samples sent to either the Montana State University Soil Testing Laboratory (currently Soil, Plant, Water Analytical Laboratory) in Bozeman or the University of Wyoming Soil Testing Laboratory in Laramie, respectively. (Jacobsen, unpub. data; Belden, unpub. data).

NUTRIENT AVAILABILITY

Exchange Capacity

Cation and anion exchange capacities are directly affected by soil pH as described in *Nutrient Management Module 2*. Briefly, exchange capacity is the soil's ability to retain and supply nutrients to a crop. Because most soils throughout Montana and Wyoming have a net negative charge, the soil's cation exchange capacity (CEC) is higher than the anion exchange capacity (AEC). Soils with high CECs are able to bind more cations such as Ca^{2+} or K^+ to the exchange sites (locations at which ions bind) of clay and organic matter particle surfaces. A high CEC soil will also have a greater buffering capacity, increasing the soil's ability to resist changes in pH. Soils with high amounts of clay and/or organic matter will typically have higher CEC and buffering capacities than more silty or sandy soils.

Since H^+ is a cation, it will compete with other cations for exchange sites. When the soil pH is high (i.e., more basic, low concentration of H^+), more base cations will be on the particle exchange sites and thus be less susceptible to leaching. However, when the soil pH is lower (i.e., less basic, higher concentration of H^+), more H^+ ions are available to "exchange" base cations, thereby removing them from exchange sites and releasing them to the soil solution (soil water). As a result, exchanged nutrients are either taken up by the plant or lost through leaching or erosion.

Nutrient Availability

As described above, plant nutrient availability is greatly influenced by soil pH. Figure 5 in *Nutrient Management 2* shows optimal availability for many nutrients at corresponding pH levels. With the exception of P, which is most available within a pH range of 6 to 7, macronutrients (N, K, Ca, Mg, and S) are more available within a pH range of 6.5 to 8, while the majority of micronutrients (B, Cu, Fe, Mn, Ni, and Zn) are more available within a pH range of 5 to 7. Outside of these optimal ranges, nutrients are available to plants at lesser amounts.

With the exception of molybdenum (Mo), micronutrient availability decreases as soil pH values approach 8 due to cations being more strongly bound to the soil and not as readily exchangeable. Metals (Cu, Fe, Mn, Ni, and Zn) are very tightly bound to the soil at high pH and are therefore more available at low pH levels than high pH levels. This can cause potential metal toxicities for crops in acid soils. Conversely, 'base' cations (Ca, K, Mg) are more weakly bound to the soil and are prone to leaching at low pH.

In addition to the effects of pH on nutrient availability, individual plants and soil organisms also vary in their tolerance to alkaline and/or acid soil conditions. Neutral conditions appear to be best for crop growth. However, optimum pH conditions for individual crops will vary (Table 1). Soil microorganism activity is also greatest near neutral conditions, but pH ranges vary for each type of microorganism. Specifically, very acid soils (less than 5) cause microbial activity and numbers to be considerably lower than in more neutral soils. Moreover, studies have shown that certain 'specialized' microorganisms, such as nitrifying bacteria (convert ammonium to nitrate) and nitrogen-fixing bacteria associated with many legumes, generally perform poorly when soil pH falls below 6 (Haby, 1993; Sylvia et al., 1998). For example, alfalfa (a legume) grows best in soils with pH levels greater than 6, conditions in which their associated nitrogen-fixing bacteria grow well too. The optimal pH range shown for potatoes is also reflective of a microorganism relationship; the bacteria causing common scab infection are more prevalent as pH rises (Walworth, 1998). Therefore, the optimal pH range for growing potatoes is 5.0 to 5.5 because the risk of common scab infection is minimized at lower pH (due to lower microbial activity). When soil pH is extreme, either too acidic or alkaline, pH modifications may be needed to obtain optimal growing conditions for specific crops.

Table 1. Optimal pH ranges for common crops in Montana and Wyoming

(Havlin et al., 1999).

Crop	Soil pH
Alfalfa	6.2-7.5
Barley	5.5-7.0
Dry Bean	6.0-7.5
Corn	5.5-7.0
Oat	5.5-7.0
Pea	6.0-7.0
Potato	5.0-5.5
Sugar beet	6.5-8.0

Managing Soil pH

Alkaline Soils

In modifying soil pH, the addition of amendments, fertilizers, tillage practices, soil organic matter levels, and drainage should all be considered. A common amendment used to acidify alkaline soils is sulfur (S) (Slaton et al., 2001). Elemental sulfur (S^0) is oxidized by microbes to produce sulfate (SO_4^{2-}) and H^+, causing a lower pH. Ferrous sulfate ($FeSO_4$) and aluminum sulfate ($Al_2(SO_4)_3$) can also be used to lower pH, not due to SO_4, but because of the addition of acidic cations (Fe^{2+}, Al^{3+}) (see Q & A #1). Application rates for these amendments will vary depending upon product properties (particle size, oxidation rate) and soil conditions (original pH, buffering capacity, minerals present). Calcium carbonate ($CaCO_3$), common throughout many Montana and Wyoming soils, consistently buffers soil to pH values near 8. For soils high in $CaCO_3$, larger quantities of amendments will need to be applied to lower pH, generally making pH modifications uneconomical.

Ammonium (NH_4^+)-based fertilizers and soil organic matter (SOM) acidify soil by producing H^+ ions, thus lowering soil pH. NH_4^+-based fertilizers, such as urea (46-0-0) and ammonium phosphates

(11-52-0 or 18-46-0), are oxidized by soil microbes, producing H^+ ions. Organic matter mineralization results in the formation of organic and inorganic acids that also provide H^+ to the soil. However, the acidifying effects of fertilization may be more than compensated for by other land use practices. For instance, a study by Jones et al. (2002) found that over a twenty-year period, fertilized and cultivated soils in Montana experienced, on average, *higher* pH values (average difference of 0.3) than non-fertilized/non-cultivated soils. Possible explanations for these results is that in the fertilized/cultivated soils, practices such as crop removal during harvest and tilling decrease SOM levels and subsequent acid production. Additionally, tillage increases surface and sub-surface soil mixing, moving $CaCO_3$ from the sub-surface closer to the soil surface.

While the addition of some organic matter sources lower pH, not all sources are effective. Many manure sources within Montana and Wyoming are alkaline ("they are what they eat") and may not effectively acidify soils to the degree desired (sometimes the pH may even temporarily increase).

Acid Soils

Although acidic soils are less common in Montana and Wyoming than alkaline soils, there are some areas in which soil acidity is problematic. For example, some soils near Great Falls, Mont. have pH levels near 5.0. A common method for increasing soil pH is to lime soils with $CaCO_3$, CaO, or $Ca(OH)_2$. The liming material reacts with carbon dioxide and water in the soil to yield bicarbonate (HCO_3^-), which is able to take H^+ and Al^{3+} (acid-forming cations) out of solution, thereby raising the soil pH. Companies supplying lime amendments are required to state the effective neutralizing value (ENV), calcium carbonate equivalent (CCE), and particle size on their label. ENV is a quality index used to express the effectiveness of liming materials for neutralizing soil acidity and is based on both purity and particle size. Chemical purity is calculated as CCE and represents the sum of the calcium and magnesium carbonates in a liming material. As CCE increases, the acid neutralizing power in the lime increases. Particle size is measured as the mesh size (number of screen wires per inch) through which ground lime will fall; increasing mesh size corresponds with smaller mesh openings. Fine sized lime (mesh size of 40 or greater) will react more effectively and quickly in the soil, whereas coarser sized lime will dissolve more slowly and remain in the soil for a longer period of time. Many commercial liming products are a mixture of particle sizes to provide both a rapid increase in pH and maintenance of this increase for a period of time (Rehm et al., 2002).

Q&A #1

Gypsum ($CaSO_4$) wasn't mentioned as an amendment to lower pH, yet it is often added to alkaline soils. Why?

The sulfur in $CaSO_4$ (and $FeSO_4$ and $Al_2(SO_4)_3$) is already oxidized and will not react to form acidifying ions, so it does not lower soil pH. Rather, gypsum is added to sodic soils (high in Na^+), which often have pH levels greater than 8.5. Sodium (Na^+) causes soils to disperse, reducing soil water-holding capacity and aeration. The Ca^{2+} in gypsum will replace Na^+ from exchange sites, causing Na^+ to be easily leached from the soil.

TESTING SOIL PH

Soil pH is measured to assess potential nutrient deficiencies, crop suitability, pH amendment needs, and to determine proper testing methods for other soil nutrients, such as phosphorus (P). Soil sampling methods and laboratory selection were described in *Nutrient Management Module 1*. Soil pH is measured in soil slurries with soil to water ratios of 1:1 or 1:2, or in a saturated soil paste. Soil pH values are measured with a pH electrode placed into either the slurry solution or paste. Though most soil testing laboratories utilize the soil to water or saturated paste methods, some research proposes using KCl or $CaCl_2$ solutions to mask the effects of naturally-occurring soluble salt concentrations on pH (Prasad and Power, 1997). By adding a slight concentration of salts (KCl or $CaCl_2$), more exchangeable H^+ ions are brought into solution, and the measured pH is generally 0.5 to 1.0 units less than water solutions. In addition, differing soil-water methods produce slightly different pH values; a reading obtained from a 1:1 soil:water ratio sample is generally 0.15 to 0.25 units higher than that of a saturated paste extract, but lower than a 1:2 dilution (Gavlak et al., 1994). Therefore, it is important to be aware of the soil pH test being used and to be consistent between methods to ensure comparable data over time. Soil testing laboratories usually denote the pH test method employed on the soil test report.

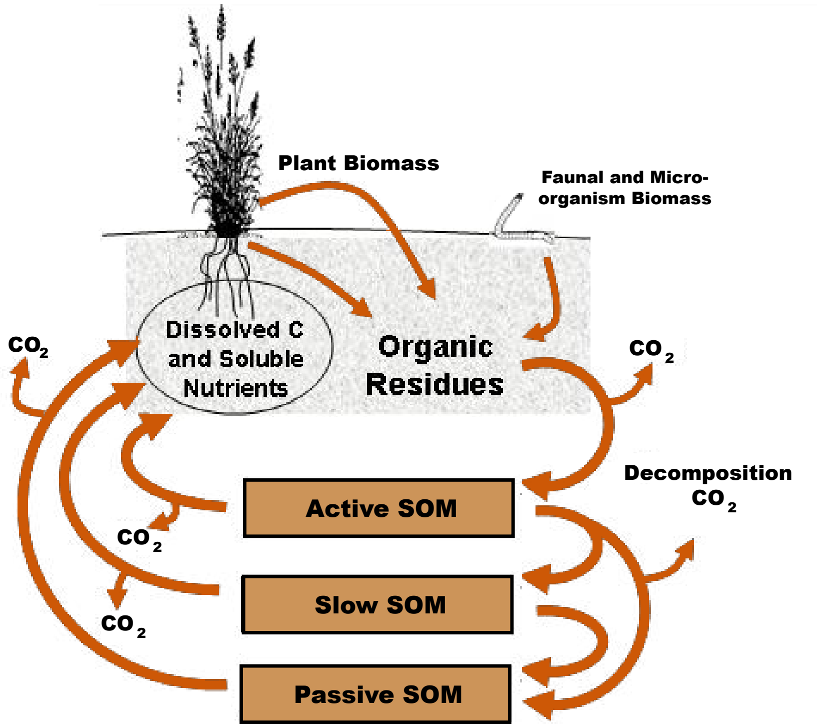

Figure 3. Organic matter cycle (modified from Brady and Weil, 1999).

Soil Organic Matter

ORGANIC MATTER CYCLING

Soil organic matter (SOM) is defined as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances (Brady and Weil, 1999). Though living organisms aren't considered within this definition, their presence is critical to the formation of SOM. Plant roots and fauna (e.g., rodents, earthworms and mites) all contribute to the movement and breakdown of organic material in the soil.

Soil organic matter cycling consists of four main processes carried out by soil microorganisms (Figure 3):

1) decomposition of organic residues;

2) nutrient mineralization;

3) transfer of organic carbon and nutrients from one SOM pool to another; and

4) continual release of carbon dioxide (CO_2) through microbial respiration and chemical oxidation.

The three main pools of SOM, determined by their time for complete decomposition, are active (1-2 years), slow (15-100 years) and passive (500-5000 years) (Brady and Weil, 1999).

Both active and slow SOM are biologically active, meaning they are continually being decomposed by microorganisms, thereby releasing many organically-bound nutrients, such as N, P, and other essential nutrients, back to the soil solution. Active SOM is primarily composed of fresh plant and animal residues and will decompose fairly rapidly. Active SOM that is not completely decomposed moves into slow or passive SOM pools. Slow SOM, consisting primarily of detritus (cells and tissues of decomposed material), is partially resistant to microbial decomposition and will remain in the soil longer than active SOM. An intermediate SOM fraction falling within both active and slow pools is particulate organic matter (POM), defined as fine particulate detritus (Brady and Weil, 1999). POM is more stable than other active SOM forms (i.e.,fresh plant residues), yet less than passive SOM and serves as an important long-term supply of nutrients (Wander et al., 1994).

In contrast to active and slow SOM, passive SOM, or humus, is not biologically active and is the pool responsible for many of the soil chemical and physical properties associated with SOM and soil quality. Representing approximately 35-50% of total SOM, humus is a dark, complex mixture of organic substances modified from original organic tissue, synthesized by various soil organisms, and resistant to further microbial decomposition (Prasad and Power, 1997). Because of this, humus breaks down very slowly and may exist in soil for hundreds or even thousands of years. Due to its chemical make-up and reactivity, humus is a large contributor to soils' ability to retain nutrients on exchange sites. Humus also supplies organic chemicals to the soil solution that can serve as chelates and increase metal availability to plants (*Nutrient Management Module 7* and discussed below). Additionally, organic chemicals have been shown to inhibit precipitation of calcium phosphate minerals, possibly keeping fertilizer P in soluble form for a longer period of time (Grossl and Inskeep, 1991). Physically, dissolved organic chemicals act to 'glue' soil particles together, enhancing aggregation and increasing overall soil aeration, water infiltration and retention, and resistance to erosion and crusting. The dark consistency of humus causes soils high in SOM to be dark brown or black in color, increasing the amount of solar radiation absorbed by the soil and thus, soil temperature.

SOM Decomposition and Accumulation

SOM content is equal to the net difference between the amount of SOM accumulated and the amount decomposed. Factors affecting SOM decomposition and accumulation rates include SOM form, soil texture and drainage, C:N ratios of organic materials, climate, and cropping practices.

As previously noted, varying SOM forms (i.e.,active or passive) accumulate and decompose at different rates. For example, POM levels can fluctuate relatively quickly with changes in land management practices, particularly the adoption of no-till systems. Research has shown POM levels to increase in no-till systems compared to conventional till systems (Albrecht et al., 1997; Wander et al., 1994), yet levels may quickly decline following the first tillage operation or under certain climatic conditions (discussed below). Humus content, on the other hand, is much more constant and fluctuates very little. Since SOM tests do not differentiate between SOM forms, changing POM levels can cause fluctuations to occur in total SOM levels, even though humus content remains the same. This can potentially give producers and farmers a false sense of long-term changes in SOM concentrations in the soil.

Soils high in clay and silt are generally higher in SOM content than sandy soils. This is attributed to restricted aeration in finer-textured soils, reducing the rate of organic matter oxidation, and the binding of humus to clay particles, further protecting it from decomposition. Additionally, plant growth is usually

Q&A #2

What is the difference between organic material and soil organic matter?

Organic material is plant or animal residue that has not undergone decomposition, as tissue and structure are still intact and visually recognizable. Soil organic matter is organic material that has undergone decomposition and humification (process of transforming and converting organic residues to humus). Soil organic matter is commonly defined as the amount of organic residue that will pass through a 2-mm sieve (Brady and Weil, 1999).

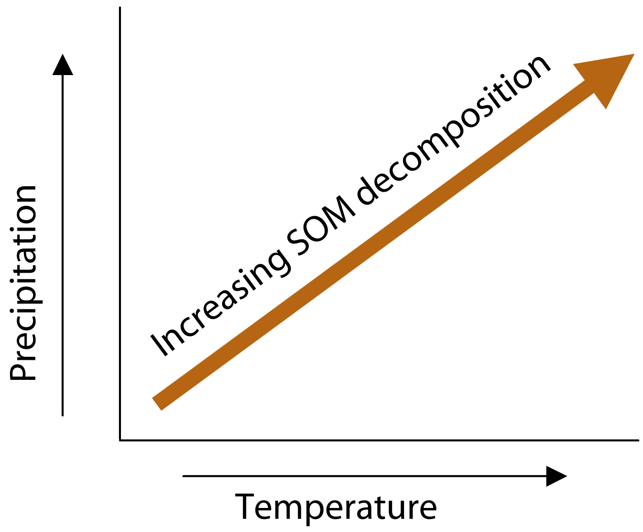

Figure 4. Effects of temperature and precipitation on SOM decomposition.

greater in fine-textured soils, resulting in a larger return of residues to the soil.

Poorly drained soils typically accumulate higher levels of SOM than well-drained soils due to poor aeration causing a decline in soil oxygen concentrations. Many soil microorganisms involved in decomposition are aerobic (oxygen requiring) and will not function well under oxygen-limiting conditions. This anaerobic (absence of oxygen) effect is evident in wetland areas in which the 'soil' is often completely composed of organic material.

The C:N ratios of various organic materials, such as manure, municipal sludge, biosolids, and straw, will affect microorganism activity and subsequent decomposition rates (*Nutrient Management Module 3*). Organic materials with relatively high C:N ratios (greater than 30:1) generally experience slower rates of decomposition than materials with lower C:N ratios. To obtain a desired balance between SOM decomposition and accumulation, different organic materials can be mixed (see Table 4 in *NM Module 3* for C:N ratios of various organics), or N fertilizer can be added to enhance decomposition of high C:N materials such as straw.

Climate impacts decomposition and accumulation by affecting growth conditions for soil microorganisms. High temperature and precipitation results in increased decomposition rates and a rapid release of nutrients to the soil (Figure 4). Some of the most rapid rates of SOM decomposition in the world occur in irrigated soils of hot desert regions (Brady and Weil, 1999). Conversely, decreases in temperature and precipitation cause decomposition rates to slow. This results in greater SOM accumulation and a less rapid release of nutrients. Generally, SOM decomposes above 77°F (25°C) and accumulates below 77°F (Brady and Weil, 1999).

Cropping practices, such as tillage and fertilization, have had long-term effects on SOM levels over the last 75 years. Cultivated land generally contains lower levels of SOM than do comparable lands under natural vegetation. Prairie soils of the Northern Great Plains originally had at least 4% SOM, whereas present day SOM content in most Montana and Wyoming agricultural topsoil generally ranges from 1 to 4% (Jacobsen, unpub. data). Unlike natural conditions where the majority of plant material is returned to the soil, only plant material remaining after harvest makes it back to the soil in cultivated areas. Furthermore, tillage aerates the soil and breaks up organic residues, thus stimulating microbial activity and increasing SOM decomposition. Residue burning lowers SOM levels by reducing the amount of residue available for SOM formation. Fertilizer applications can result in an increase in SOM levels due to greater yields creating a larger return of crop residues to the soil (Albrecht et al., 1997). However, tillage practices typically associated with fertilizer applications may decrease this effect (Jones et al., 2002).

CHELATION

As introduced in *Nutrient Management Module 7*, many organic substances can serve as chelates for micronutrient metals. Chelates (meaning 'claw') are soluble organic compounds that bind metals such as copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn), and increase their solubility and availability to plants (Clemens et al., 1990; Havlin et al., 1999). The dynamics of chelation are illustrated in Figure 5. A primary role of chelates is to keep metal cations in solution so they can diffuse through the soil to the root. This is accomplished by the chelate forming a 'ring' around the metal cation that protects the metal from reacting with other inorganic compounds (Brady and Weil, 1999). Upon reaching the plant root, the metal cation either 'unhooks' itself from the chelate and diffuses into the root membrane or the entire metal-chelate complex is absorbed into the root, and then breaks apart, releasing the metal. Both cases result in the metal being taken up by the root and the chelate returning to the soil solution to bind other metals.

Chelation may be particularly important for regions in which alkaline soils predominate. As previously noted, metal availability is often inhibited under alkaline soil conditions, causing plant micronutrient deficiencies to occur. Iron, for instance, becomes nearly insoluble as soil pH nears 8 and chelation can greatly increase availability (up to 100 fold) (Havlin et al., 1999). Chelation can be increased through the use of commercial chelating agents, synthetic organic compounds such as EDTA (see Q&A #3), or by maintaining and increasing SOM levels (described below).

Carbon Sequestration and Conservation

Carbon (C) cycling is the transfer of both organic and inorganic C between the pools of the atmosphere (carbon dioxide and methane), terrestrial and aquatic organisms (living plants, animals, microorganisms), and the soil. Research within the last few decades indicates C concentrations in the atmosphere have increased with inputs linked to industrial emissions (i.e., extraction and combustion of fossil fuels) and land use changes (e.g. cutting and burning large areas of forest)

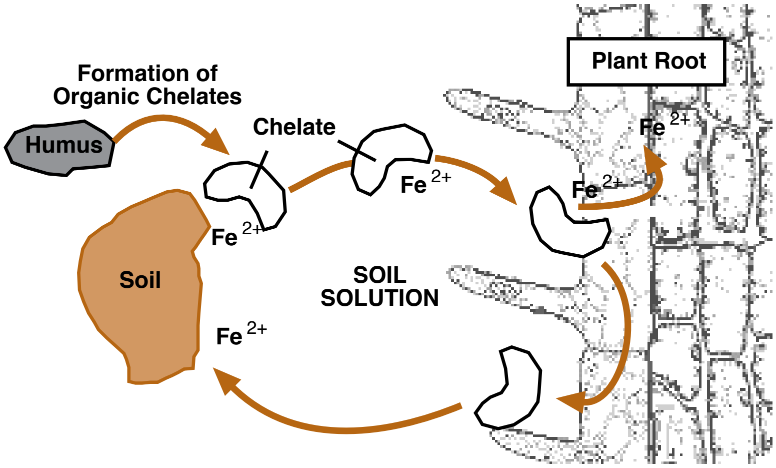

Figure 5. Cycling of chelated iron (Fe^{2+}) in soils.

Q&A #3

I have alkaline soils and low micronutrient availability. Will commercial chelating agents benefit crop production?

Commercial chelating agents can improve metal availability to crops. However, certain factors should be considered before using them. The stability of chelates (how well they complex metals) will depend upon specific micronutrient forms, soil pH, and the presence of bicarbonates and other metals ions in the soil and is related to the 'stability constant.' The stability constant is a value corresponding to how well chelate-metal complexes will form with given metal and chelate concentrations. Stability constants for EDTA complexes typically range from about 14 (Mn^{2+}) to 25 (Fe^{3+}) with higher values corresponding to a greater tendency for metals to stay chelated (Clemens et al., 1990). Stability constants should be on all chelate product labels.

Other factors include product effectiveness and cost. For instance, a chelated metal complex may be X times more expensive than a non-chelated metal, but not X times more effective. Also, a chelating agent that is effective with one metal at a given pH and in a particular soil may not be useful with different metals or at different pH or soil conditions (Clemens et al., 1990). So while chelating agents may improve micronutrient availability, chelating stability, soil properties, and economics need to be considered.

(USDA, 1998). This increase is causing the C balance between pools to shift and may also be affecting global climate change. In response to these concerns, the United States Department of Agriculture (USDA) along with other national and international organizations (see Appendix for additional information) have begun promoting management practices to conserve and sequester (store) C. The goal of C sequestration is to reduce atmospheric C concentrations by taking carbon dioxide (CO_2) out of the atmosphere and storing it in 'sinks' or storage compartments (USDA, 1998).

An important sink within soil is SOM, in which C (organic) levels are over twice as large as the atmosphere CO_2 pool and 4.5 times larger than the C pool in land plants (Delgado and Follett, 2002). Soil C sequestration is accomplished through soil conservation practices that not only reduce soil erosion, but also increase the SOM content of soils. Possible conservation strategies which sequester C include converting marginal lands to native systems (i.e., wildlife habitat), practicing no-till or conservation-till farming, reducing the frequency of summer fallow in crop rotation, and incorporating, rather than disposing of organic amendments such as manure (Lal et al., 1998; USDA, 1998). Figure 6 demonstrates a hypothetical decrease in SOM with time and the effects various management practices will have on future SOM levels.

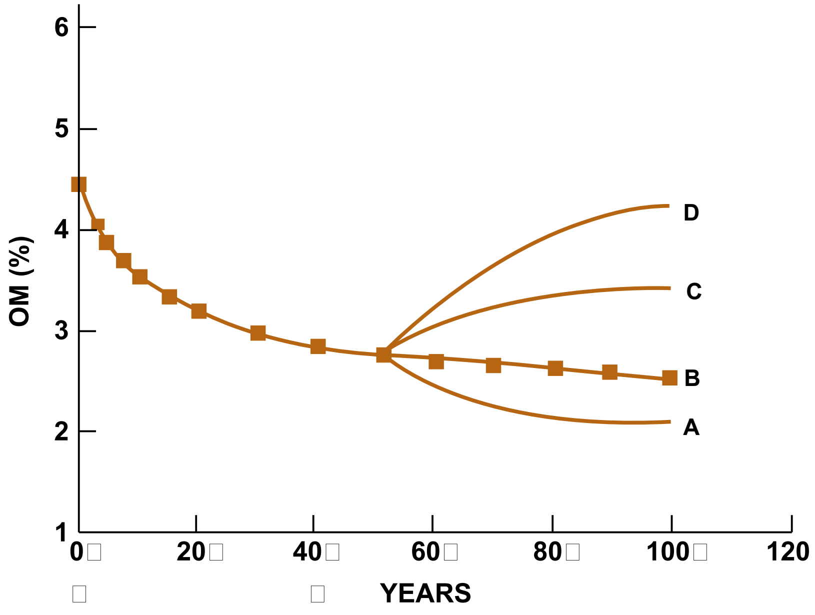

Figure 6. Hypothetical situation of SOM changes with time. At 50 years, changes in soil and crop management system can either decrease (A), continue (B), or increase (C, D) SOM. B represents no change in cropping system, while A represents a change that would accelerate SOM loss (i.e., more intense tillage). C and D represent the adoption of one or more SOM conservation practices. Combinations of conservation practices may yield the highest SOM gains (D). (From Havlin et al., 1999)

SOM TESTING

Soil organic matter tests are useful in establishing SOM's influence on soil properties and determining fertilizer or organic matter application needs. In sampling for SOM, the top 6-inch soil sample should be collected and organic material on the surface (i.e.,duff or visible plant parts) should be excluded, as it is not part of SOM and can result in invalid readings. Soil testing laboratories will return results as a SOM percentage for the total soil sample. In interpreting SOM tests, it is important to understand what is being tested for and what testing method was performed. Most SOM values are derived from organic C because the direct determination of SOM has high variability and questionable accuracy (Nelson and Summers, 1982). Organic C represents approximately 50% of SOM, so a conversion factor of 2 is often used to estimate SOM concentrations (e.g. SOM = 2 x organic C). Two common methods for testing SOM are Walkley-Black acid digestion method and weight loss on ignition method. It is important to note that both of these methods test for total SOM and do not distinguish between different SOM forms. For example, two soils may have similar quantitative SOM contents, yet SOM influenced soil fertility and properties may differ considerably between the two soils due to differences in SOM forms.

Summary

Soil pH is a measure of a soil solution's acidity and alkalinity that affects nutrient solubility and availability in the soil. Factors influencing soil pH include organic matter decomposition, NH_4^+ fertilizers, weathering of minerals and parent material, climate, and land management practices. Availability of nutrients for plant uptake will vary depending on soil pH. The availability of cation nutrients is often hindered by decreased solubility in highly alkaline soils and increased susceptibility to leaching or erosion losses in very acidic soils. For anion nutrients, availability is generally the opposite. Soil pH levels near 7 are optimal for overall nutrient availability, crop tolerance, and soil microorganism activity. Soil pH can be modified by using chemical amendments; however these treatments may only be effective for a relatively short amount of time and are generally not economically viable.

Soil organic matter (SOM) is an essential component of soil, contributing to soil biological, chemical, and physical properties. SOM exists in three pools in the soil, with each pool affecting the amount and rate of SOM decomposition and nutrient mineralization. In addition to nutrient storage, SOM aids nutrient availability by increasing the soil's CEC, providing chelates, and increasing the solubility of certain nutrients in the soil solution. Furthermore, the humus fraction of SOM improves soil structure by increasing soil water-holding capacity, infiltration, and aeration. By incorporating SOM conservation into management plans, farmers and producers sequester atmospheric C and benefit from an overall increase in soil quality and possibly lower input costs.

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APPENDIX

Books

The Nature and Properties of Soils, 12th Edition. N. Brady and R. Weil, 1999. Prentice-Hall, Inc. Upper Saddle River, NJ. 881p. Approximately $125.

Soil Fertility and Fertilizers, 6th Edition. J.L. Havlin et al. 1999. Upper Saddle River, N.J: Prentice Hall. 499 p. Approximately $100.

Soil Fertility Management and Sustainable Agriculture. R. Prasad and J.F. Power. Boca Raton, FL: CRC Press LLC. 356p. Around $70.

Extension Materials

Nutrient Management Modules (1-15) can be ordered (add $1 for shipping) from:

MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040

All are online in PDF format in the category of ag and natural resources, at http://www.msuextension.org/publications.asp

See **Web Resources** below for online ordering information.

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Web Resources

http://www.omafra.gov.on.ca/english/crops/pub811/2limeph.htm#soil

A "Soil Acidity and Liming" Factsheet, including how to correct soil acidity and alkalinity. Source: Canadian Ministry of Agriculture and Food, Ontario, Canada

http://www.nrcs.usda.gov/feature/outlook/Carbon.pdf

Informational page about soil carbon sequestration and USDA programs involved in conserving soil organic carbon. Source: United States Department of Agriculture

http://www.msuextension.org/publications.asp

Montana State University Extension Publications ordering information for printed materials.

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