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Soil Conditioners

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Soil physical condition is one factor that can limit crop production. Poor soil physical condition can restrict water intake into the soil and subsequent movement, plant root development, and aeration of the soil. Producers and researchers alike are interested in improving the physical condition of the soil and, thus, enhance crop production. These goals can be accomplished in part through the use of good management techniques. In addition, there are amending materials that claim to improve the soil physical condition. Such materials are called soil conditioners.

Soil conditioners are not new; however, recent emphasis on maximum economic yields has renewed interest in them. Soil conditioners vary greatly in their composition, application rate, and expected or claimed mode of action. Claims for various products include, but are not limited to:

- improved soil structure and aeration;
- increased water-holding capacity;
- increased availability of water to plants;
- reduced compaction and hardpan conditions;
- improved tile drainage effectiveness;
- alkali soil reclamation;
- release of "locked" nutrients;
- better chemical incorporation;
- better root development; and
- higher yields and quality.

With the diversity of soil conditioners on the market today, it is important to understand the nature, use, and practical benefits of these products.

This report is one in a series of five publications created by the North Central Regional Research Committee on Nontraditional Soil and Plant Additions (NCR 103), focusing on the use of non-traditional materials for crop production. The other publications consider soil wetting agents (10), biological inoculants and activators (12), plant growth regulators, and low volume/low analysis fertilizers (11). The Committee has defined soil conditioners as materials added to the soil, with the primary function of improving the physical condition of the soil.

Types of Soil Conditioners

Soil conditioners vary in both their origin and composition. Soil conditioners can be synthetic or naturally occurring; organic or inorganic.

Organic Soil Conditioners

The beneficial effects of organic matter (humus) in the improvement or maintenance of soil physical properties has long been known. Soil organic matter serves as a reservoir for nutrients; improves soil structure, drainage, aeration, cation exchange capacity, buffering capacity, and water-holding capacity; and provides a source of food for microorganisms. Generally speaking, soils higher in organic matter have improved soil physical conditions as compared to similar soils lower in organic matter. For these reasons, many marketed soil conditioners try to emulate organic matter for improving soil physical properties.

The effectiveness of organic soil conditioners can be partly evaluated by examining several properties of soil organic matter. Soil organic matter is defined as the organic fraction of the soil and includes plant and animal residues at various stages of decomposition, cells and tissues of organisms, and compounds synthesized by the soil organism population. Soil organic matter contains a wide array of compounds ranging from fats, carbohydrates, and proteins to high molecular weight humic and fulvic acids. Both the diversity of compounds and the interaction of the different com-

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pounds are important in the beneficial effect attributed to organic matter.

Soil organic matter is usually less than 10 percent of the total weight of mineral soils. However, when the weight of organic matter is expressed on a pounds per acre basis, the results are surprising. An acre of soil to a depth of 6 inches (acre furrow slice) weighs approximately 2,000,000 pounds. A soil with 2 percent organic matter, then, contains 40,000 (2,000,000 x 0.02) pounds of organic matter per acre. Therefore, to actually change the organic matter content of a soil, very large amounts of organic materials must be applied. Research has shown that it takes 5 to 15 pounds of fresh plant residue to produce 1 pound of stable humus (1,5) under environmental conditions of the North Central Region. Assuming it takes 10 pounds of residue to make 1 pound of humus, 200,000 pounds of residue per acre are required to increase the organic matter content by 1 percent or 20,000 pounds per acre.

The ratio of carbon to nitrogen (C:N ratio) of organic matter in surface soils commonly ranges between 8:1 to 15:1, with the median C:N ratio between 10:1 and 12:1. The C:N ratio of organic materials (Table 1) added to the soil is important in the availability of nitrogen and the rate of decay of the organic material. Competition for available nitrogen in the soil occurs when organic materials with wide or large C:N ratios are added to soil.

Humate. Stevenson (9) described commercial humates as products derived from oxidized lignites, an earthy, coal-like substance associated with lignite outcrops. Oxidized lignites often occur in shallow deposits and usually overlay soft coal deposits. Large deposits are known to occur in Texas, New Mexico, Idaho, and North Dakota. Humates marketed for agricultural purposes may be soluble or insoluble and maybe fortified with commercial fertilizer.

Commercial humates contain between 30 and 60 percent humic acids. The humic acids are very complex and easily immobilized by soil mineral matter. Commercial humates contain very little fulvic acid and biologically important materials such as proteins and polysaccharides. In this sense, commercial humates do not resemble soil organic matter and, therefore, cannot be expected to perform the same function. In addition, the low rate of application (200-600 pounds/acre) normally recommended is insignificant in comparison with organic matter already present in most soils. Even at high application rates (up to 100,000 pounds/acre), research over a 3-year period showed that a commercial humate product did not serve as an effective soil conditioner under widely varying soil and environmental conditions (2).

Mixed humates contain 1.2 to 1.5 percent nitrogen, of which only a small portion is available to plants in a given year. At the recommended application rate, commercial humates would add less than 1 pound of nitrogen per acre.

Table 1. Approximate C:N ratios of organic material and soil microbes (3).

Material	C:N Ratio
Crop Residues	
Alfalfa (young)	13:1
Clovers (mature)	20:1
Bluegrass	30:1
Corn Stalks	40:1
Straw (small grain)	80:1
Sewage Sludge	10-12:1
Cattle Manure	30:1
Peat Moss	58:1
Sawdust	
Hardwood	295: 1
Pine	729:1
Soil Microbes	
Bacteria	5:1
Actinomycetes	6:1
Fungi	10:1

Animal manure. Animal manures can be important contributors to soil organic matter levels as well as suppliers of various nutrients. Manure is largely composed of partially decomposed plant material plus a wide variety of organisms. Many of the organic compounds in manure are similar to those found in soil organic matter. An application of 10 tons/acre of manure would result in 0.5 to 2 tons of organic matter after decomposition by soil organisms. Manure, however, contains soluble salts which can be detrimental to soil physical properties and crop growth when added in high amounts, especially to arid soils.

Other organic conditioners. Other materials that can serve as soil conditioners include crop residues, compost, sewage sludges, green manure crops, and sawdust. The effectiveness of the material varies with the amount of material added and the C:N ratio. Sewage sludges may contain potentially harmful levels of heavy metals and other toxic materials and should be analyzed for these materials before using.

Synthetic Binding Agents

Several polymers have been shown to improve various soil physical properties. Polymers received a lot of attention in the 1950s when a particular polymer (Krilium) was marketed. The product was shown to improve physical properties and even crop yields on certain soils. However, the application rate at which the benefits were found was not economical, and interest in the compound declined.

Recently, new polymers applied at much lower rates have been promoted as soil conditioners. These polymers include natural polysaccharides, anionic and cationic polymers, and polyacrylamides. The compounds are very high molecular weight, long-chain, polymeric, organic compounds, which bind particles together and form stable aggregates. Research is being conducted to identify polymer types as well as application methods and rates to alleviate, maintain, or improve soil physical conditions on different soils (5). Results to date, under field conditions at low rates of application, have not shown consistent, significant improvement in soil physical condition.

Mineral Conditioners

Gypsum. Gypsum has long been recognized for its benefits on high sodium-containing soils. Gypsum is a mineral with the chemical composition $CaSO_4*2H_2O$. It occurs in nature as soft crystalline rock and varies in purity. Gypsum has been shown to displace exchangeable sodium from the cation exchange sites of soils high in sodium. With irrigation or dryland, gypsum can be used to reclaim saline areas or slick spots, soften and crumble alkali hard pans, supply calcium on low exchange capacity soils, and improve infiltration for some puddled soils. Gypsum is not recommended on soils containing native gypsum or areas irrigated with water containing abundant amounts of calcium and magnesium.

The amount of gypsum to apply depends on the purity of the gypsum and the quantity of sodium present in the soil. Actual rates should be based on a salt-alkali soil test. Application rates normally vary between 1 and 10 tons/acre. Gypsum applied at less than 500 pounds per acre will likely be of little benefit as a soil conditioner, but may work as a calcium or sulfur nutrient source.

Other mineral conditioners. Limestone, crushed rock, and other products high in calcium and/or magnesium will improve the physical condition of some soils, when applied at several tons per acre. Other inorganic compounds, which contain a small amount of a wide variety of essential and non-essential elements, applied at low rates have been promoted as soil conditioners. However, no consistent response of improving soil physical conditions has been documented. Most of these products at the rates recommended will not supply enough calcium and/or magnesium to change the cation composition of the soil exchange complex.

Others

Several other categories of soil conditioners have claimed to improve soil physical properties. Among these are surfactants, for example, ammonium alkyl ether sulfate. These compounds are discussed in "Soil Wetting Agents: Their Use in Crop Production" (10). Another category of soil conditioners includes microorganisms and activators. These products are discussed in "Biological Inoculants and Activators: Their Value to Agriculture" (12).

Changing Soil Physical Properties

A wide variety of conditioners, which claim to improve a number of soil physical properties, are commercially available today. Some of the claimed benefits include improved water holding capacity, infiltration, drainage, soil structure, aeration, aggregate stability, organic matter content, and certain chemical properties. The interrelating nature of these soil properties makes it difficult to single out the exact effect of a specific soil conditioner. All conditioner promotions, however, imply improved plant growth in response to their soil conditioning effect.

Soil conditioners will not behave in the same manner and with the same results on all soil types. Different soil types vary greatly in physical, chemical, and biological properties, which influence the effectiveness of soil conditioners. For instance, gypsum may improve infiltration on high-sodium soils but may be of no benefit on non-sodic soils or soils already high in gypsum. The addition of large amounts of organic material will be more effective on soils with very low organic matter levels than on higher organic matter soils. The use of low rates of polyacrylamide applications was effective in improving infiltration when problems were associated with surface flaking and crusting, but not when the infiltration was limited by the low permeability of shrink-swell clays in the soil profile (6). For these reasons, it is very important to know the soil properties under which the product was evaluated.

Recommended application rates of soil conditioners range from less than a pound/acre for some synthetic or biological soil conditioners to several tons/acre for gypsum or manure. For soil conditioners that attempt to emulate soil organic matter, the application rate should be evaluated in comparison to the amount of organic matter already present in the soil. Similarly, the application of microorganisms as soil conditioners should be evaluated with respect to the current microbial population. In many situations, the cost of the product plus application may be uneconomical for the production of agronomic crops. However, application may be feasible in special situations such as in terrace channels, eroded areas, or lawns and gardens.

Measuring Soil Physical Properties

A variety of soil physical measurements can be used to evaluate the effectiveness of soil conditioners. These measurements include infiltration rate, air permeability, porosity, aggregate stability, penetration resistance, or bulk density. Reliable standardized procedures are needed to compare and / or evaluate the effect of soil conditioners on soil physical properties. For example, many companies rely on penetrometer measurements to evaluate their product, but do not standardize their measurements with respect to moisture content or bulk density. Such non-standardized observations may easily lead to erroneous claims about the product. Also, be cautious of studies relying on measurements that are not easily quantified such as soil tilth, stickiness, tightness, or hardness. An excellent source of standardized procedures for soil physical measurements is available from the American Society of Agronomy (4).

Grower Approach to Soil Conditioners

The first advice to growers considering the use of soil conditioners is to proceed with caution. Insist on replicated research data from an unbiased source to evaluate the product in question. Evaluate the conditioner's effectiveness in research done on different soils, including soils that resemble your soils. Avoid products and programs that rely entirely on testimonials and do not utilize factual data to support their claims. One source of research data is the Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production (including Supplement 1) published by the NCR-103 Committee on Non-Traditional Soil Amendments and Growth Stimulants. The compendium is available for sale through Publication Distribution at Iowa State University, Ames, IA 50011. Many county, area, and state extension offices have copies of this compendium, which contains research reports for 16 soil conditioners.

If you're still interested, run field checks on a limited acreage. You may treat a strip in the field and leave the rest of the field untreated or leave an untreated strip in a treated field. Remember to maintain all factors the same other than the addition of conditioner. Because year-to-year and field-to-field variation occurs, compare yields in the same year in the same field and on the same soil type within the field.

Finally, keep an open mind and avoid emotional involvement in the evaluation of any product.

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