THE ROLE OF SOIL PHYSICAL PROPERTIES IN MANAGING REDUCED TILLAGE SYSTEMS

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Soil management involves the integration of all soil and plant science areas to solve practical problems related to crop production and the development of new tillage-planting systems with the least amount of soil erosion and degradation. An understanding of the physical condition of any soil is essential for proper implementation of the other management practices. Differences in crop growth cannot be adequately explained without a knowledge of the environment that is found below the soil surface.

Texture, moisture, aggregation, bulk density, strength, air space porosity, and temperature are physical properties unique to each soil. Texture cannot normally be modified, but through proper management practices we can significantly change the other six factors. The intensive tillage practices over the last 50 years have virtually destroyed many of the good physical conditions that were found under native sod. This has created many of the soil erosion and management problems experienced today.

Energy, erosion and environmental concerns have directed soil management emphasis into new areas. The reduced or no-till systems are expanding and have given producers another soil management option. An understanding of the short and long term changes that occur under reduced tillage is essential to make proper soil management recommendations. The Department of Soil Science has been conducting a number of long term cooperative tillage trials since 1977. The soil properties are being monitored in studies that compare conventional with reduced tillage-planting systems under various crop rotations. The differences in physical properties of the soil that have been observed among tillage sytems will be discussed in this article with emphasis placed on the role of these physical properties for management of reduced tillage systems. Additional research information on these no-till and reduced tillage systems can be obtained from the sources listed at the end of the article.

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Soil Temperature

Temperature of the soil is an important property because it influences the chemical, physical and biological processes associated with crop growth. Microbial and chemical activity and the release of soil nutrients for root uptake and plant growth are controlled by soil temperature with each factor enhanced by warmer temperatures. Since seeds require an optimum temperature for germination, soil temperature is often used as a planting date guide. Also, winter survival of crops like winter wheat is partially determined by soil temperature. Soil temperatures fluctuate with season, time of day, and local climatic conditions. In addition, temperature of a specific soil is modified by such factors as soil type, soil moisture and the amount, type and distribution of residue on the surface.

There is some concern that the introduction of reduced tillage, which leaves more residue on the surface and creates wetter conditions, will decrease the soil temperature regime in comparison to conventional tillage (black soil) and cause management problems. Delayed planting, slow emergence and increased use of starter fertilizer are often mentioned. These concerns are not always justified and may only be a factor in certain years, especially years with wet springs.

Soil temperatures have been monitored on numerous tillage trials that compare no-till and reduced tillage with conventional tillage-planting systems (include primary and/or secondary tillage prior to planting) under various cropping systems. Soil temperature differences among systems have varied considerably with years. Maximum soil temperatures at the 4-inch depth on the conventionally tilled plots have generally ranged from 2 to 6°F higher than found under no-till. However, minimum temperatures usually were lower under conventional by similar amounts. The mean soil temperatures were not greatly different among tillage-planting systems. Mean soil temperatures were found to fluctuate with previous air temperature cycles. The no-till soils were warmer after an extended cool period (little sunshine); the conventional tilled soils were warmer after an extended hot period with adequate sunshine. On a daily basis, the conventionally tilled (black soil) exhibited greater fluctuation in temperature, extreme highs and lows, in comparison to the reduced tillage plots with residue. The extremes were avoided under no-till as a result of residue cover and higher soil moisture levels. The moderate fluctuation in soil temperatures under no-till may provide a distinct growth advantage because, combined with the better moisture conditions, faster early growth (especially sugarbeets and sunflowers) was obtained on the reduced tillage systems in comparison to conventionally tilled soils.

Soils that had no fall tillage (residue left) were warmer throughout the winter, had shallower frost depth, and thawed much faster than bare tilled soils. The degree of difference varied with years and was controlled by residue amounts and snow trap.

Soil temperature results thus far indicate that mean soil temperatures are not always lower with reduced tillage but are year dependent. Also, residue distribution is important with respect to soil temperatures, as standing residue will create different conditions than residue that is matted on the soil surface. Individual farmers utilizing reduced tillage systems may need to consider monitoring soil temperatures if future management decisions are based on this soil property.

Soil Moisture

One of the most limiting factors for crop production in North Dakota is soil moisture. Soil management practices that increase water infiltration, decrease runoff or loss by evaporation, recharge the soil moisture supply during the non-growing season (snow trap), or increase the efficiency of moisture use by plants will greatly enhance yield levels. Conventional farming methods (with excessive tillage) do not make efficient use of the limited moisture received because runoff and evaporation are increased with incorporation of residue into the soil.

Data collected on the tillage trials over the past six years indicate that 50 to 60 percent of the non-growing precipitation can be stored in the soil with residue left standing over winter. In the western portion of the state, 2 to 3 inches more moisture was stored in the soil profile where residue was left standing in comparison to bare fallow ground. The no-till and reduced tillage systems in the Red River Valley gained 1 to 2 inches more than the conventional fall plow system with accompanying secondary tillage. This stored soil moisture made a significant difference in yield of small grain, sunflower and sugarbeets during the dry years of 1980 and 1982.

Soil moisture in the profile was higher in the spring and fall under the no-till small grain system when compared to other conventional systems. Since a large portion of the moisture found in the fall under no-till was in the lower soil profile depths, it appears that root growth may be impeded (see section on bulk density and soil strength) and moisture utilization throughout the profile was lower than with other conventional methods. This moisture difference was not as evident with deep tap-rooted crops like sunflower and sugarbeet. The additional moisture in the surface under no-till was a benefit for emergence and early growth in comparison to soil that was tilled for seedbed preparation. The difference was more pronounced in years where adequate spring moisture was absent after planting.

Soil Aggregation

A knowledge of the degree of aggregation of any soil is an important factor in a soil management system because this property determines soil structure or tilth. The physical behavior of the soil and how it reacts to tillage and planting operations is determined by the number, size, arrangement and stability of the aggregates. Soils containing a large portion of stable aggregates resist breakdown from tillage operations and allow for rapid infiltration and movement of water into the soil profile.The porosity or aeration of the soil also increases with aggregation, which provides a more favorable environment for plant root growth and microbial activity. The microbial activity is responsible for organic matter decomposition and the release of soil nutrients essential for plant growth. Generally, the higher the portion of water stable aggregates, the less susceptible the soil is to erosion by wind and water and the less chance for crust formation. Crust formation is often a management problem during plant emergence. The excessive number of primary and secondary tillage operations performed during many of today's conventional farming systems has destroyed much of the aggregation in the surface soil and created conditions that have caused the management problems in erosion and crusting being experienced today.

The switch to reduced tillage or no-till planting systems has provided the opportunity for improving the aggregation or structure of our soils. Recent measurements of aggregation in the surface 3 inches on a number of long-term tillage studies being conducted throughout the state have showed a large increase in aggregation (percentage greater than 2 mm diameter) with no-till followed by slightly lower increases with the sweep or chisel plow operations. The lowest aggregation was measured on the fall and spring plow tillage planting system with continuous cropping. The percentage of aggregation under the alternate crop fallow was three to five times lower than observed under the continuous cropping systems. The stability of the aggregates increased as the number and degree of tillage operations decreased. The no-till and sweep or chisel plow systems provide stronger soil aggregates with less chance for breakdown by secondary tillage or climatic elements (precipitation, freeze-thaw and wet-dry cycles) as compared to the plow or fallow systems. The data indicate that the continued use of some type of reduced tillage system will enhance soil aggregation and improve soil structure to a point where many of the soil management problems encountered today will be eliminated in the future.

Soil Density and Soil Strength

The soil acts as a support for the plant and is the medium in which plant roots grow. In order for roots to elongate, they must overcome the physical resistance in the soil. Resistance to growth is diminished as the soil moisture increases, provided the soil has good structure, sufficient air space, and no physical barriers. Bulk density (expressed as weight per volume) and soil strength or resistance (expressed as force per area) as measured with a penetrometer give some indication of the resistance roots will encounter. These two terms are more commonly referred to as the amount of compaction. As compaction increases, so does bulk density and soil strength with a subsequent reduction in soil pore space, aeration, and root growth. When the diameter of the pores in the soil are decreased below the diameter of the roots, then the roots must exert a greater force to elongate. Depending on soil type, root growth may be restricted at volume weights between 1.3 and 1.8 grams per cubic centimeter or penetrometer resistance that ranges from 115 to 725 pounds per square inch. Crops also differ in their rooting patterns (fibrous versus tap) and root diameters. Each type will vary in growth response with respect to changes in bulk density and soil strength.

Bulk density and penetrometer values collected on long term tillage trials in North Dakota indicate measurable differences in tillage-planting systems. Conventional tillage systems had the highest values in the soil profile at tillage depth or directly below. The no-till systems exhibited higher values in the surface, especially in the 0 to 6-inch depth. Bulk density values at this depth after four or five years ranged from 1.08 to 1.60 grams per cubic centimeter for the no-till and 1.14 to 1.35 grams per cubic centimeter for the conventional plow tillage planting system. Penetrometer values ranged from 68 to 240 pounds per square inch on the no-till to considerably lower values on the plow system that ranged from 18 to 60 pounds per square inch. The higher values were obtained at sites located on the western portion of the state. Higher values on the no-till suggest some root growth restrictions which may partially explain the slightly delayed growth pattern in some years with small grain, a crop which has a small diameter fibrous root system that is predominantly located in the surface 12 inches. Since research results have shown greater early growth with sunflower and sugarbeet plants that have a tap root system, the increased resistance attributed to no-till may have less of an effect on these crops. This may also explain why certain crops do better than others, assuming other management factors are not limiting growth.

Summary

The long term (greater than five years) results of no-till and reduced tillage-planting systems on soil physical properties are just beginning to be realized. The improvements in soil aggregation and increased infiltration with residue cover and associated influence on erosion reductions by these systems cannot be overemphasized. Research needs to be continued in the reduced tillage area since many questions remain unanswered with respect to long term fertility status and release of nutrients, especially in conjunction with crop rotations and the inclusion of legumes as a nitrogen supply. Future emphasis by the Department of Soil Science and cooperating parties will be directed towards expanding our knowledge of no-till and reduced tillage-planting systems and answering these associated soil management questions.

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