Organic Matter in No-Till Production Systems

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Introduction

There are many properties influencing soil quality, but one that requires increased attention is soil organic matter. Organic matter is directly related to a number of vital soil functions and can be altered by land management practices. Surface residues protect the soil surface from the detrimental impacts of wind and water erosion. Also, organic materials incorporated into the soil provide an energy source for biological activity, a nutrient source for plants and microbes, and serve as a structural component that improves soil permeability. This Fact Sheet will provide a discussion of these benefits as well as management strategies that increase crop residues and soil organic matter.

What is Organic Matter?

Soil organic matter is composed of plant and animal tissue that is at different stages of decomposition within the soil. Soil organic matter must be separated into three basic components to provide a proper discussion of its benefits and management strategies in a no-till system. These three components include surface residues, belowground residues and humus. Humus is most often discussed, however, it is directly tied to surface and belowground residues, and each must be discussed in order to properly understand the role that organic matter plays in a soil system. Surface residues are aboveground plant matter which can be anchored by means of root mass, or simply laying on the soil surface. Belowground residues are partially decomposed organic material, which are located beneath the soil surface, such as roots, dead animals or residues buried by animals. Humus is the stable fraction of organic matter that has undergone humification, where microbes decompose organic residues into dark colored complex structures.

Importance of Organic Matter

Each component of soil organic matter benefits a no-till production system in a different way. Understanding the importance of these components is critical to maintaining a no-till production system.

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Surface residues help combat erosion by protecting the soil from water and wind, while simultaneously eliminating the formation of crusts. Prevention of crusting increases infiltration and can improve stand establishment. Surface residues can also reduce evaporative water loss which in turn may increase water availability and potentially increase crop performance. However, all residues are not created equal in regard to soil surface protection (Figure 1). When there are equal amounts of residue, crops like wheat and oats will cover more of the soil surface than a crop like sunflower, due to the fact that sunflower stalks are larger and cannot be distributed as evenly across a field.

Belowground residues are beneficial when it comes to soil structure. They directly influence soil structure by preventing compaction under traffic. In fact, a network of undisturbed roots can serve as a skeleton for the near surface soil. Live roots are much more effective at this function; therefore, intensification of cropping systems so that active root growth is maximized helps reduce traffic compaction. Belowground residues also supply energy for microbes and invertebrates. The decomposition of both above and belowground residue results in the release of proteins and carbohydrates that serve to bind soil particles and improve aggregation. Better soil aggregation means improved permeability for water and roots. All crop residues provide food for macroinvertebrates,

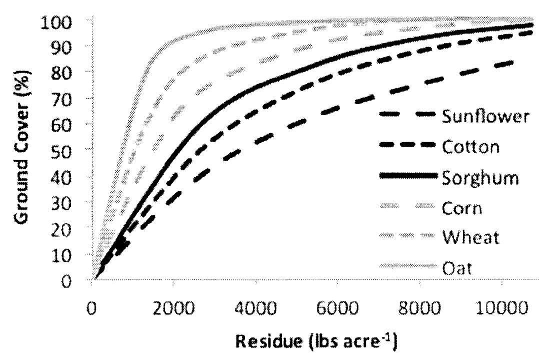

Figure 1: Relationship between residue mass and soil cover for several crops (adapted from Steiner et al., 1995).

Worm casts on the surface of a 10 year old no-till soil. Surface residues provide food for earthworms as well as protection of pores created by their activity.

such as earth worms, which in turn form biopores that lead to improved permeability of the soil.

Roots that are anchored in the soil tend to contribute a greater percentage of their weight to the formation of humus than aboveground residues. This is due to the fact that crop roots contain more lignin which makes it difficult to break down. For example, Magdoff and Van Es (2009) found that after one year of oat production 33 percent of surface organic matter (residue) was present compared to 42 percent of root organic matter.

The decomposition of organic residues also releases and/or immobilize plant nutrients, in particular nitrogen. Immobilization of applied nitrogen can be detrimental to the current crop, however this nitrogen can be released through mineralization and utilized later in the growing season or by the following crop.

Humus provides several beneficial properties to no-till production systems. Humus decreases crusting and clodding, improves drainage and water infiltration, increases water and nutrient-holding capacity, and reduces erosion. All of these benefits are achieved by means of clay reacting with humus. The surface charges of humus, like those of clay, attract and hold both nutrient ions and water molecules. This interaction allows clay and humus to act as a bridge between larger soil particles. This connection is imperative to the formation of well-structured soil aggregates, which in turn, produce high quality crops.

Factors Controlling Organic Matter Content of Soils

Soils in Oklahoma are very diverse due to rainfall and temperature gradients, as well as the wide range of parent materials from which they are formed. Therefore, the amount of organic matter found in Oklahoma soils can vary greatly. In fact, the organic matter content of Oklahoma's historically cultivated cropland soils ranges from 3.5 percent in the silty clay soils of northeast Oklahoma near Miami, to as little as 0.5 percent in the loamy sand soils in southwest Oklahoma near Fort Cobb.

Native vegetation plays a direct role in the organic matter present within a specific soil system. Soils formed under grassland systems will contain deep layers of organic matter due to the growth and die-back of roots under prairie grasses. In contrast, much of the organic matter in forest systems is deposited on the surface from leaf litter and therefore organic matter contents will be shallower than that of a grassland system. Typically, soils formed under grassland systems will contain a higher overall organic matter content.

Soil texture directly influences the amount of organic matter contained within a soil system. Coarse textured soils are more aerated, and will have less organic matter due to the presence of oxygen resulting in rapid decomposition. Sandy soils generally have low productivity therefore crop residue input is lower in very sandy soils. In contrast, fine textured soils will contain more organic matter due to the fact that they are more productive; therefore, more residues are available. Aeration is also lower, particularly in soils containing high levels of clay. Lastly, organic matter can form complexes with clay particles which decrease its susceptibility to microbial decomposition.

The amount of organic matter found in soils is also influenced by soil moisture and temperature. First, moisture influences plant growth, therefore, if all else is equal, organic matter concentrations decline in Oklahoma as we move from east to west due to decreased productivity from lack of rainfall. Additionally, anaerobic conditions caused by excessive wetness will slow the decay due to a lack of oxygen; this is why organic matter can accumulate in wetland soils.

The most substantial loss of organic matter in Oklahoma cropland soils is from tillage. The Magruder plots, a long-term continuous wheat trial established in 1892, found that after more than 100 years of tillage, 55 percent to 67 percent of organic matter was lost (Davis et al., 2003). Tillage increases aeration and soil temperature, thereby increasing the rate of organic matter decomposition. Also, replacing perennial grassland with continuous wheat decreased the amount of residues deposited in the soil system annually, which contributes to this decline. In addition, organic matter has been lost from our cropland soils as a result of erosion. There is no reliable data available to assess the magnitude of this loss mechanism. Yet, the impact of erosion on organic matter concentrations in soils can be observed when highly eroded soils are compared to similar soils where erosion was minimal.

Managing Organic Matter and Crop Residues

Carefully managing organic matter and crop residues is a critical part of maintaining or increasing productivity in a no-till system. There are a variety of specific ways to increase organic matter and crop residues including the intensification of crop rotation, establishment of cover crops, and the reduction or elimination of grazing.

Intensification of your crop rotation will generally increase below and above ground residue input into the soil system. The inclusion of cover crops where cash crops are not practical can be used to increase residue as well. Keep in mind that crop type is an important consideration for residue management.

Table 1 provides estimates of below and above ground residue for crops commonly grown in Oklahoma. Crop type influences the distribution of above and below ground residues. For example, a 120 bushel corn crop will produce more

Table 1: Average yields, amount of surface residue and roots in the top 4 inches producer per pound of yield and average amount of residue and roots left after common crops in Oklahoma.

Crop	*Average yield*		*Surface Residue*		*Roots in Top 4 inches*	
		lbs acre^{-1}	*lbs lb^{-1} of yield*	*lbs acre^{-1}*	*lbs lb^{-1} of yield*	*lbs acre^{-1}*
Wheat	30 bu	1800	1.7	3370	0.5	890
Canola	36 bu	1450	2.0	2740	1.0	1370
Corn	125 bu	7000	1.0	5040	0.2	760
Sorghum	47 bu	2600	1.0	2520	0.3	740
Sunflower	52 bu	1300	2.2	2860	0.4	460
Cotton	1.4 bale	680	3.0	1620	0.5	170
Soybean	25 bu	1400	2.0	2760	0.3	380

Average yields are the Oklahoma 10 year (2001-2010) average yields reported by the National Ag Statistics Service except for Canola and Sunflower which are from 2009-2010.

aboveground residue compared to a 30 bushel wheat crop or 36 bushel canola crop. However, on a per pound of yield produced basis wheat and canola produce approximately two times the above ground biomass of corn. In addition, canola will produce 1 lb of root biomass in the top 4 inches of soil for every lb of grain, in contrast to corn which produces only 0.2 lbs of root mass per lb of grain yield.

The C:N ratio also plays a factor in residues, the higher the ratio the more resistant that residue is to being broken down by soil microbes. Soybeans have a low C:N ratio (30:1) and will break down faster compared to residues of other crops. The structural characteristics of surface residues are also important in determining decomposition rates. For example, residues that are lying on the ground will tend to decompose quicker than upright residues because they are in direct contact with the soil surface. This is another reason to minimize traffic on no-till fields. When possible, efforts should be made to maximize harvest height.

No-till production systems can be successfully grazed, in fact, recent studies in the southeast United States (Franzluebbers and Stuedemann, 2006) have shown that moderate to light grazing of cover crops can improve microbial activity. However, caution should be taken, especially in graze-out situations, to ensure that sufficient residues remain to cover the soil surface. No studies have been conducted to determine the specific amount of residue needed after graze-out, but a good rule of thumb would be to leave sufficient residue to cover 80 percent of the soil surface. This will prevent crusting and allow for water infiltration and the alleviation of compaction after the cattle are removed. If graze-out results in limited residue, a high residue cover crop, such as forage sorghum, will provide beneficial cover to the soil surface and provide summer grazing potential or an additional hay crop.

Summary

Although there are a number of specific ways to manage organic matter and crop residues, producers must not forget to look at the big picture. Continuous no-till along with intensified crop rotations that minimize fallow periods will optimize the accumulation and maintenance of organic matter. Of course, this interest must be weighed against forage needs and crop water availability. Therefore, it is clear that the same practices cannot be used for every production system. Also, it is imperative to understand that these practices work together to improve soil function. The main goal of a no-till production system should be to improve organic matter, soil quality, and soil function. Producers should examine their needs and the risks/benefits of each management strategy. Every situation is different and must be treated accordingly.

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