Tillage Systems

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Traditionally, tillage has been practiced for the purpose of mixing surface residues deeper into the soil, loosening the soil prior to seedbed establishment and to aid in weed control. The primary tillage implement for many years was the moldboard plow. The rough surface left by primary tillage was smoothed by secondary tillage implements, usually a disk harrow followed by one or more passes of another fine-toothed harrow for final smoothing of the surface in preparation for seeding. These techniques have been described as "conventional tillage." Another traditional application of secondary tillage has been the use of a myriad of cultivating tools to provide mechanical weed control and to break up surface crusts. However, the advent of widespread use of chemical weed control during the late 1950s greatly reduced the amount of secondary tillage used for weed control. The major disadvantages of these conventional tillage techniques were increased risk of soil erosion on sloping land and breakdown of soil structure.

Largely due to massive nationwide loss of topsoil from conventional tillage, additional primary tillage techniques were developed to leave varying amounts of the residues from the previous crop lying on the soil surface for the purpose of lowering the erosion potential. Several implements, mostly a variation of the chisel plow, were developed to accomplish this. When followed by a shallow harrowing, these conservation tillage techniques provided a seedbed smooth enough for successful planting of corn but still left some residue cover.

Further developments in chemical weed control and planting equipment that could successfully plant through surface residues resulted in development of no-tillage seeding techniques. The only tillage involved in no-tillage seeding is the narrow, in-row disturbance made by the coulter and furrow-opener on the planter. No-tillage results in most prior crop residues remaining on the surface, which causes a dramatic reduction in soil erosion and increased water infiltration. No-till techniques, pioneered by farmers and researchers in Kentucky, are now so widely used in Kentucky that they dominate seeding methods for corn and soybeans (Figure 1). When combined with other conservation tillage practices, greater use of no-till has resulted in only a small percentage of Kentucky's corn and soybean crop being established by conventional techniques (Table 1).

No-tillage has a number of advantages, including less soil erosion as compared with clean-tilled systems, and fuel, machinery, and time savings are all impressive. There is also a tendency toward better crop yields on soils that are moderately well drained to well drained, due to higher water capture and conservation often associated with the mulch of crop residue maintained on the soil surface.

No-tillage is best suited to soils that are moderately well drained to well drained. The residue cover keeps soils cooler and wetter throughout much of the growing season under no-till conditions. This is particularly true with heavy residue. Surface residues that leave somewhat poorly drained soils wetter can be an advantage during dry periods, but no-till planting on such soils during cool, wet springs can cause delayed emergence and reduced stands that reduce yields.

Management practices that can improve the performance of no-till corn in cool, wet conditions are the use of in-row (pop-up) fertilizer (see fertility section) and row cleaners. The row cleaners aid in warming and drying the soil over the row, and the in-row fertilizer improves plant growth under stress early in the season. Seed treatments that protect against root shoot rots (*Pythium ultimum*) are quite helpful and are often routinely added by seed companies.

Conservation tillage is a better choice for poorly drained soils. The tilled surface allows these soils to

Figure 1. Percent of Kentucky's corn, soybean, and wheat acreage established with no-till technology.

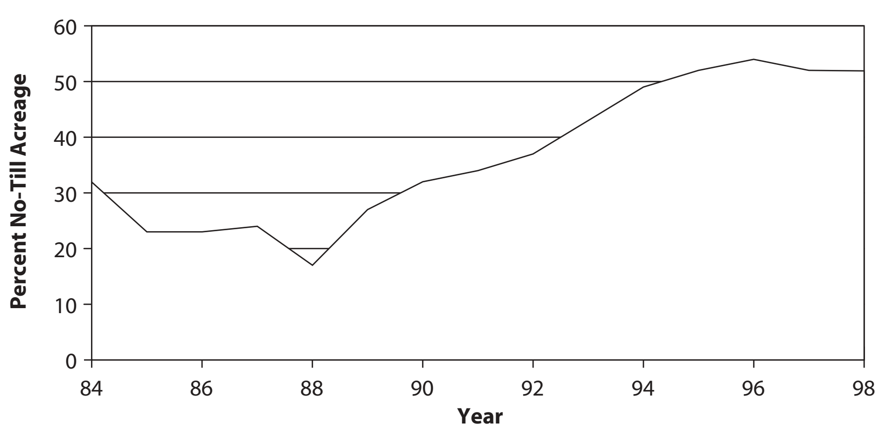

Table 1. Tillage systems used for corn, soybean, and fall-seeded small grain in Kentucky, 1998.[1]

Crop	Total Acres	% Planted		
		No-Till	Conservation Till[2]	Conventional Till[3]
Full Season Corn	1,345,000	51.8	34.5	13.7
Double Crop Corn	62,100	64.4	29.3	6.3
Full Season Soybeans	882,700	51.3	30.8	17.9
Double Crop Soybeans	474,700	86.7	12.4	0.9
Fall-Seeded Small Grains	603,000	24.6	62.0	13.4
All Crops	3,852,500	47.6	33.5	18.9

[1] Conservation Technology Information Center data.
[2] Greater than 15 percent of residues left on surface.
[3] Fewer than 15 percent of residues left on surface.

warm and dry faster in the spring. However, conservation tillage practices used on sloping fields that are prone to erosion should leave at least 30 percent of the soil surface covered by residue at planting to protect the field from excessive erosion. This can be done by reducing the amount of secondary tillage that is done on the field. Secondary tillage is costly, time consuming, and frequently a major culprit in causing soil compaction. It also contributes to erosion, water pollution, and subsequent crop drought stress. Protection against loss of topsoil is of much economic importance. Recent research by the University of Kentucky indicates that each inch of topsoil on a Crider soil, up to the first 8 inches, increases annual corn yield by more than 10 bushels per acre.

Soil Compaction

Soil compaction comes in a number of forms and from several causes, but in Kentucky the most common causes are either traffic or tillage when the soil is too wet. There is a water content at which any soil is most easily compacted. In the words of one expert, "This is when it is a little too wet to work, but I am going to do it anyway."

Sidewall Compaction

Sidewall compaction can result from planting a crop when the soil is a little too wet. This damaging effect can be even greater on soils with a relatively high clay content at the surface. It occurs when the double disc opener leaves the side wall of the planting furrow smooth and compacted (slick as opposed to shattered) as it pushes the soil aside. The trailing press wheel then increases the compaction with its downward force. If the soil stays very moist or wet, the roots may be able to penetrate the compacted mud at the sidewall and expand further into the soil. However, if the weather turns dry after planting, the sidewalls then harden, and roots are not able to push through since there are no pores or cracks. This causes the roots to grow within the planting furrow, along the direction of the row. Although plants may look normal at emergence, they will begin to show nutrient and drought stress after the corn is several inches high. This problem may be more common in no-tillage because no-tillage soils have better structure, and it is easier to traffic them in a wetter condition. The old adage of "waiting on no-till" is a good one. Sidewall compaction can also occur with conventional tillage. If you can mold the soil into a ball in your hand and the soil ball will not easily crumble apart, it is too wet to plant.

Deeper Compaction

Wheel tracks on a wet field can also contribute to a compaction problem. The trend to larger and heavier equipment means that axle weights have increased. A four-wheel drive tractor, a large combine with a full grain hopper, a loaded manure wagon, a fertilizer buggy or truck, or a loaded grain cart can all exert great pressure on the soil below the wheel. These weights, in combination with greater tire pressures, can compact the soil 12 to 18 inches deep. When the degree of compaction is sufficient to diminish pore space to the point that oxygen diffusion, water movement, and root penetration into and through the soil are restricted, crop yields are likely to be lowered.

Disc harrows are tillage tools that can cause severe compaction on wet soils. The weight of a disc transmitted to the soil at the bottom edge of each blade creates enough pressure in a wet soil to compact a zone 4 to 6 inches thick just below the disc blades. This is most common in disc-only tillage systems or where soils are excessively tilled and a disc is used when the soil is a little too wet.

How Common is Compaction in Fields?

A survey of 175 fields in Kentucky in 1992 and 1993 indicated that 46 percent had no compaction, 18 percent were slightly compacted, 18 percent were moderately compacted, and 18 percent were severely compacted. This survey used soil penetrometers to classify the amount of compaction. Limited research indicates that the moderate and severe categories should be considered possible yield-limiting situations. This means that about 30 to 40 percent of Kentucky's cropped fields are compacted enough to possibly limit the growth and yield of some crops. The more poorly drained fields had the most compaction, with 77 percent of the poorly drained soils being moderately or severely compacted, while only 20 percent of the well-drained soils were in this range. When the primary tillage was discing, fields were twice as likely to have moderate or severe compaction as those where a chisel or moldboard plow was used. The least likely fields to have compaction were no-till fields.

When compaction was found, it was most likely to begin at depths between 6 and 9 inches and to terminate between 12 and 15 inches. However, compaction was found at other depths and depth thicknesses.

Effect of Compaction on Yield

The effect of compaction on yield varies with the crop, weather conditions, and soil type. Corn is more sensitive to soil compaction than soybean or wheat. Based on research in Kentucky and surrounding states, the estimated yield reduction for corn is 30 to 50 percent with extreme compaction such as that found under end rows and at field entrances, 10 to 20 percent for fields with severe compaction, and 5 to 10 percent for those with moderate compaction.

What to Do about Compaction

The best way to solve compaction is to prevent it. Some simple things can make a difference.

- Tire pressure is important. Lower tire pressure increases the size of the tire print and lowers compaction. Many farmers carry 20 to 25 psi in radial tires that are designed for 7 to 12 psi. The proper tire pressure will not only reduce compaction but will decrease slippage by 10 percent.
- Restrict heavy equipment (loaded grain carts, trucks, etc.) to the smallest areas of the field as is possible. Use the same tracks with each pass in the field, if possible.
- No-till means less compaction. There are fewer trips over the field, and the soil has better structure. This may not be evident until the field has been no-tilled for three to five years. By planting in the same rows each year, a controlled traffic pattern will result, restricting the wheel traffic to between certain rows.
- The most important management practice is to prevent traffic on wet soils. Take soil from the tillage zone and squeeze it in your hand. If the soil ball cannot be easily crumbled apart, then the soil is too wet for traffic.

How to Identify Compaction

Sometimes soils are deep-tilled when there is no compaction. This is costly and does not improve yields. The best way to identify compaction in a field is by using a soil penetrometer (soil compaction tester), a tiling rod, or a 3-ft length of 1/2- to 3/4-inch diameter steel rod sharpened on one end with a T-handle on the other end. These tools should be marked (notched) for depth and should only be used when the soil is at field capacity after a rain (too wet to till, but not sloppy muddy). This is best done in December through March when the profile is wet throughout. Under these conditions, compacted layers can be found and the depth and thickness of the compacted zone can be identified. Each Cooperative Extension Service office in Kentucky has a soil penetrometer with instructions on how to use it and a form to record the results. The form also has a method to classify the amount and type of tillage found in the field. When readings reach 300 pounds per square inch, the compaction is considered root limiting. If one-third of the field has readings of 300 or more, a corrective action and change in tillage practices should be considered. When one-half of the field has readings of 300 or more, corrective action and changes in tillage practices definitely are needed.

After moderate to severe compaction (lesser amounts of compaction are not harmful) has been identified, there is more than one way to correct it. When tillage or subsoiling is used, be sure the compacted zone is dry enough to shatter. Fall is generally the best time because the subsoil is usually drier and will shatter better. This means that fields with identified problems will be cropped for another summer prior to compaction alleviation. Rotations to some other crops can also help alleviate compaction. Alfalfa, sweet clover, and fescue all have root systems that are helpful but are rather long-term solutions.

Summary

Compaction can be caused by traffic and some tillage operations and can cause yield reductions in some crops. The yield reduction may not be easily seen unless the compaction is extreme. A lot of money is wasted on deep tillage done in response to fear of compaction that does not exist. The key is using a total management system that prevents compaction but also monitors fields for the problem and then corrects it when and where it is found.