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Assessing and Preventing Soil Compaction in Kentucky

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Kentucky grain farmers commonly use fall subsoiling as a means to overcome soil compaction. They believe that soil compaction is limiting crop growth and yield, especially in a corn-soybean rotation. However, subsoiling may not be advisable in certain situations. This publication will help producers assess their fields to see if subsoiling is necessary and give them techniques to prevent soil compaction in the future.

Soil compaction is the physical compression of soil into a smaller volume. University of Kentucky agronomists and agricultural engineers have been studying soil compaction for more than 10 years and have found that severe compaction can substantially reduce yield, but only one-third of fields surveyed in the state had compaction high enough to affect yield. The challenge for Kentucky grain producers is two-fold. First, to maximize profit, they must identify those fields where compaction is limiting production and determine the appropriate remedy just for those fields. The second challenge is to change production practices to prevent future soil compaction.

There are generally two ways that farmers influence compaction. The first, called traffic compaction, is a result of driving equipment across the soil surface. The second, called tillage compaction, is a result of tillage implements that shear the soil, leaving a dense soil layer at their operating depth.

Traffic Compaction

Traffic compaction can affect plant growth, as the plants in Figure 1 demonstrate. The severity and depth of traffic compaction is a function of the axial load, tire pressure, and soil moisture content. As producers farm more acres, equipment size (axial load) has increased, resulting in higher incidence, severity, and depth of soil compaction. Dual wheels, flotation tires, and tracks can be used to spread heavy axial weight to more soil surface area, reducing down pressure per square inch of soil surface. Operating equipment at the minimum recommended tire pressure will also reduce surface pressure. But spreading weight with dual tires and low tire pressure means that a higher percentage of the field is driven on, and field operations can be conducted at higher soil water content, leading to potentially more severe compaction.

Tillage Compaction

Tillage compaction is a result of the downward force exerted when tilling. Even implements (like a moldboard plow) that lift the soil can cause compaction at the leading edge of their blades. Tractor tires running in the bottom of the open furrow when making the next pass compound compaction problems. These actions can cause the development of a plow pan and reduce the effective rooting depth to the depth of tillage, usually only 5 to 8 inches. Plow pans are also common in tobacco fields as a result of using tractor-mounted roto-tillers to pulverize surface soil.

Figure 1. Corn plants collected from high (left) and low (right) traffic areas.

Survey results from Kentucky (Table 1) show that fields with reduced tillage (primarily discing only) had the highest occurrence of severe compaction (Murdock et al., 1995). Discing results in compaction because of the great downward force at the edge of the blades and is especially damaging when soil moisture is high. Producers commonly think that discing wet soils will speed drying. Actually, this practice causes compaction, reduces the size and continuity of soil pores, and slows infiltration rate and drainage. Fields with a long-term history of no-till production have a reduced chance of compaction and usually do not result in a significant yield increase when subsoiled (Murdock, 1999).

Table 1. Effect of tillage on soil compaction.*

Tillage History	Field		Amount of Compaction			
			Little	Slight	Mod.	Severe
	No.	%	------------------ % ----------------			
No-Till	32	19	50	22	15	13
Disc	37	22	27	3	24	46
Conventional	94	56	45	25	17	13
Subsoil	6	4	67	0	16	17
Total	169	100				

* From Murdock et al., 1995.

Soil Factors Affecting Compaction

Most farmers are aware that the most important factor controlling compaction is soil moisture. If the soil is completely dry, it is almost impossible to compact it. As soil moisture content increases, the water acts as a lubricant, allowing soil particles to slip together and fit more tightly when force is applied. Figure 2 shows how soil compaction potential changes with increasing soil moisture for a Maury silt loam under conventional tillage or no-tillage for 25 years. Under both tillage systems, the potential for soil compaction increases to a maximum as soil moisture increases. As soil moisture continues to increase, compaction potential actually goes down because the larger soil pores fill with water, which prevents compression. Unfortunately, compaction potential is highest at the soil moisture where farmers begin considering tillage and other field operations. Waiting for the soil to dry just a day or two longer would significantly reduce the potential for both traffic and tillage compaction.

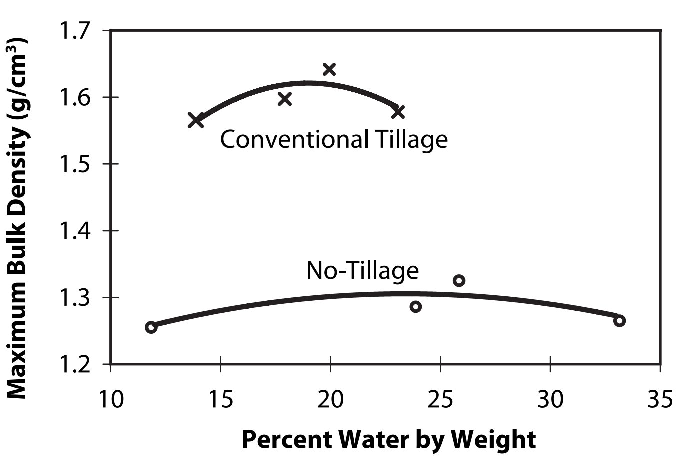

Figure 2. Typical percent water vs. maximum bulk density curves for a Maury silt loam (Thomas et al., 1996).

In addition to soil moisture, soil organic matter content plays an important role in a soil's potential for compaction. Figure 2 shows that the compaction potential is much higher for soils managed with conventional tillage than with no-tillage. In this study of 36 soil samples collected in Kentucky, the difference was well correlated with soil organic matter (Thomas et al., 1996). Although organic matter levels high enough to prevent compaction are not achieved rapidly, this is one of the benefits that long-term no-till can provide.

Compaction Effects on Plant Growth

Compaction mainly affects plant root growth, soil water availability, and perculation. Root growth is reduced not only because of the density of the soil but also because of low soil oxygen infiltration. Slow root growth and poor root exploration can cause compaction-induced nutrient deficiencies (especially potassium and nitrogen), a reduction in the drought tolerance of the plant, and an increase in lodging potential.

Of course, when plant root growth is stunted, yield potential is decreased. Yield potential is also affected by the unevenness of plant stands where larger plants compete with smaller plants for water, light, and nutrients. The smaller plants are effectively weeds because they have no real yield potential.

It is generally agreed that soybean and wheat are more tolerant to soil compaction than corn and tobacco. In a study conducted at the Research and Education Center in Princeton, Kentucky, corn yield was reduced by as much as 98% for soil with very severe compaction from the soil surface to a depth of 12 inches (Murdock and James, 2002). Over the six years of this study, corn and soybean yields were reduced by 24% and 14%, respectively, as a result of extreme compaction at the beginning of the study.

Assessing Soil Compaction

When making an assessment of soil compaction, keep in mind the factors that contribute to its formation. For example, wet-natured soils are far more likely to be affected than well-drained soils. Also remember that compaction is rarely found uniformly in a field. Subsoiling might be needed in the high traffic areas but not in any other area. For these reasons, it is necessary to make assessments in several areas within each field to determine the extent and severity of compaction.

One of the best ways to assess soil compaction is by observing plant growth and root development. Early in the season, look for uneven stands, unexpected nutrient deficiencies, or general overall poor growth (Figure 3). Next, carefully dig plants from both good and poor areas of the field to compare the amount and depth of rooting. Roots that go down and then turn laterally indicate deeper compaction probably caused by tillage implements. The soil at this depth will likely be blocky and layered. When you find compaction, try to determine how it is distributed within the field; it may not be necessary or economical to treat the entire field.

Figure 3. Tobacco research plots that were compacted by discing wet ground (foreground). Uncompacted plots are in the background. Notice the uneven size among adjacent plants growing in the compacted plots.

The soil will also show signs of compaction. Areas with standing water for prolonged periods indicate that soil compaction might exist. Layers with flat, thin, horizontal plates found when digging in the soil indicate compaction. Also, hard layers found when digging or probing the soil indicate compaction. This is especially true if reduced or deformed rooting patterns are also found and the layers remain hard when the soil is fairly moist.

Another method for assessing soil compaction is to use a penetrometer, which can be borrowed from most county Extension offices. This tool actually quantifies the soil's resistance to penetration. While soil resistance is a more accurate measure of soil strength rather than soil compaction, it is a good indicator of compaction when soil moisture conditions are near field capacity. Field capacity is the water content after a fully wet profile has drained for two days. At this point, the soil is too wet to till, but there is no free or standing water. Since the entire profile must be very moist, the best times for this are usually late November through March.

To use the penetrometer, slowly and steadily push it into the soil while watching the pressure gauge (Figure 4). The shaft of most penetrometers is calibrated in 3-inch increments so that you can determine the resistance with depth. As you push the penetrometer, record the highest resistance and the depth where the highest reading was obtained. Continue to push until the resistance drops, and note this depth as well. (A sample data sheet is included at the end of this publication.) If the pressure does not drop, then either the soil profile is not completely wet or you have hit a naturally dense soil layer that will not be remedied with subsoiling. These layers are most likely fragipan, heavy clay subsoils, or dry layers. Repeat the probing in random areas throughout the field. The more data you collect the more accurate the results will be. At a minimum, collect 10 to 20 readings in a small field or 30 to 40 in a large field. You may want to sample field entrances and high traffic areas separately.

Figure 4. Measuring soil compaction using a penetrometer is similar to taking soil samples.

To interpret penetrometer readings, determine the percentage of samples where resistance was higher than 300 psi. These readings are considered severely compacted. If more than 33% of the field is in this category, then corrective action and changes in tillage practices should be considered. When 50% of the field has severe compaction, then changes definitely need to be made. In areas of the field where penetrometer readings are below 300 psi, yields probably would not be improved after subsoiling.

Estimating Effects on Yields

It is important to have an estimate of the amount of yield that will be sacrificed due to unknown or uncorrected compaction. This allows for economic calculations when determining a plan of action for correction or prevention of compaction.

Estimates of the yield loss that might occur with different crops with the more common types of compaction that have been found to occur in Kentucky can be seen in Table 2. These estimates are made using information from multiple experiments in Kentucky and surrounding states.

Table 2. Estimates of yield loss due to different amounts of soil compaction.

Degree of Compaction[1]	Estimated Yield Loss (%)		
	Corn	Tobacco	Soybeans
Extreme	30 to 50	50 to 60	20 to 40
Severe	10 to 20	20 to 40	10 to 15
Moderate	5 to 10	10 to 20	5 to 10

[1] *Extreme*—strongly compacted layer beginning 2 to 3 inches from surface extending to a depth of 10 to 12 inches.
Severe—strongly compacted layer beginning 6 to 8 inches below the surface extending to a depth of 12 to 14 inches.
Moderate—strongly compacted layer as described in severe, but is not continuous and exists in about 50% of the field.

Compaction Remediation

Once you have identified a field or an area within a field with significant compaction, you need to determine the appropriate method to correct the problem. The first step is to select the tillage implement. If compaction is shallow, a chisel-plow or any tool that will get below the compacted layer to disrupt it can be used. If the compacted layer is deep, ripping or subsoiling might be required. When tilling is done, the operating depth must be below the compacted layer.

Once an implement has been selected to treat compaction, timing becomes important. The goal is to shatter the compacted soil as thoroughly as possible. In order to get maximum benefit, the soil must be dry. Typically in Kentucky the soil is only dry enough for subsoiling in the fall right after harvest. If the soil is too wet, subsoiling can cause even more compaction or slice through the soil causing it to be partitioned rather than shattered.

Tillage timing is challenging for Kentucky producers. If a penetrometer is not routinely used, the first indication of compaction problems may be poor plant growth and yield. If this is suspected, digging in those areas can confirm this and subsoiling can be performed after harvest. If a penetrometer is used, the soil is usually not wet enough for proper use until the winter and then the soil will usually not be dry enough to subsoil before planting in the spring. Therefore, use of the penetrometer is a management tool. Each winter, one-third to one-half of the acreage is surveyed to determine fields to be subsoiled the coming fall. This will limit unnecessary tillage and help confirm effectiveness of prevention methods adopted.

Sidewall Compaction

A second, less frequent type of tillage compaction is sidewall compaction that occurs if the crop is planted when the soil is too wet. The planting furrow wall is compacted or smeared as a result of horizontal pressure applied to the soil by the planter's opening discs. The trailing press wheel can increase the compaction with its downward pressure. If the soil stays very moist or wet, the roots will be able to push through the mud at the wall and establish a root system. If the weather turns dry after planting, then the walls harden and the roots are not able to push through the walls, since there are no pores or cracks. This causes the roots to grow within the planting furrow, up and down the row, with very few roots in the rest of the soil. The plants will look normal at emergence but begin to show problems of nutrient and drought stress after the corn is several inches high. This problem may be more common in no-tillage because these soils have better structure and are easier to traffic in a wetter condition.

Sidewall compaction can be prevented by delaying planting until soils are sufficiently dry. 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. Some implement manufacturers also offer spiked closing wheels that are designed to disrupt the sidewall as it closes the soil around the seed. At the time of this publication, data on the impact of sidewall compaction on crop yield or the effectiveness of different press wheel designs on sidewall compaction was not available. However, the spiked closing wheels have been used by many farmers for a number of years and the incidence of sidewall compaction seems to have diminished over this time.

Recommendations to Prevent Compaction

Even with subsoiling, crop yields are seldom fully restored to pre-compaction potential, so it is much better to prevent compaction. The following are steps that you can take:

- Use no-till planting methods to minimize traffic and increase organic matter.
- Decrease axial load and tire pressure to minimum recommendations.
- Consider using dual wheels, flotation tires, or tracked equipment.
- Do not till or traffic when soil conditions are too wet.
- Never disc to help speed soil drying.
- Avoid using implements that are known to cause tillage pans like moldboard plows, discs, and roto-tillers.
- Confine very heavy equipment like fertilizer nurse tanks and loaded grain trucks to field edges so that those areas can be treated separately.
- Avoid planting when soil conditions are too wet.

References

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Field Compaction Data Sheet

Farm ____________________ **Field** ____________________ **Acres** ________

Major Soil Types ____________________ **Year** ________

Site	Highest Resistance	Lower Depth of Compacted Layer	Site	Highest Resistance	Lower Depth of Compacted Layer
1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

SUMMARY

% of readings above 300 psi ________

Lower depth of compacted layer ________

RECOMMENDATION

Deep Tillage Recommended Yes No

Depth of Recommended Tillage ________

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