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Compaction, Tillage Method, and Subsoiling Effects on Crop Production

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Introduction

No-tillage is the preferred method of crop production for most Kentucky farmers. No-tillage has been proven to increase soil quality and decrease the risk of soil compaction as compared to crop production using annual tillage. However, with the use of heavy farm equipment, soil compaction is always a threat with either tillage or no-tillage. The possibility of soil compaction and its effect on crop production is a constant concern to many farmers using no-tillage. If soil compaction occurs, is there a difference between the two tillage systems on how it affects crop production and the recovery of the soil with and without subsoil tillage? The following study was conducted to help producers and advisors understand soil compaction and its effects on corn and soybean production as well as the ability of the two tillage systems to recover from soil compaction.

Method

The study occurred on a Zanesville silt loam soil. This is a somewhat poorly drained soil with a fragipan about 25 inches below the soil surface. The plot design was a randomized complete block. The trial area was fallowed and mowed in 1995. In 1996 soybeans were grown in assigned no-tilled and tilled plots with appropriate tillage. The designated compacted plots were severely compacted when the soil moisture was 17% by weight in April 1997. A John Deere 7700 tractor with an additional 2000 lb weight added to the rear of the tractor completely trafficked each plot to be compacted four different times. In addition, a 14-ton front end loader completely trafficked each compacted plot. The designated plots were compacted to a 12-inch depth as determined by a soil penetrometer. There was also visual decrease in soil elevation, which helped confirm soil compaction. In the fall of 1999, selected compacted plots were subsoiled with a paraplow subsoiler where the soil was dry enough for good fracturing of the soil. All tilled plots were tilled to a 4–6 inch depth for planting each spring using a large disc. The no-tillage plots were planted without tillage.

Corn was grown in 1997, 1999, 2000, and 2002 and soybeans in 1998, 2001, and 2003. The trial area was soil sampled each year and fertilized according to University of Kentucky Cooperative Extension Service (UKCES) recommendations (AGR-1). Corn or soybeans were planted and grown according to UKCES recommendations. A 40-ft length of the two center rows was harvested by hand for corn and with a Hege small plot combine for soybeans.

The treatments used in the trial were:

1. Compacted in 1997 and tilled each year prior to planting (CT)
2. Compacted in 1997 and no-tilled planted each year (CN)
3. Compacted in 1997 and tilled each year prior to planting and subsoil tilled prior to fourth crop year (CTS)
4. Compacted in 1997 and no-tilled planted each year and subsoil tilled prior to fourth crop year (CNS)
5. No compaction and tilled each year prior to planting (NCT)
6. No compaction and no-tilled planted each year (NCN)

Soil resistance was measured using a penetrometer when the soil was at or near field capacity in moisture. Four readings were made in the harvest area of each plot each winter after harvest and recorded in 3-inch depth increments.

Results

The actual yields of the different treatments are shown in Table 1. The non-compacted treatments were the highest yielding in almost all years. The yields of the no-till non-compacted treatment were slightly higher in 5 of the 7 years than the tilled non-compacted treatment. The average yields of the non-compacted treatments were very similar between tilled and no-tilled, as can be seen in Table 2.

Table 1. Effect of soil compaction and tillage on corn and soybean yields.

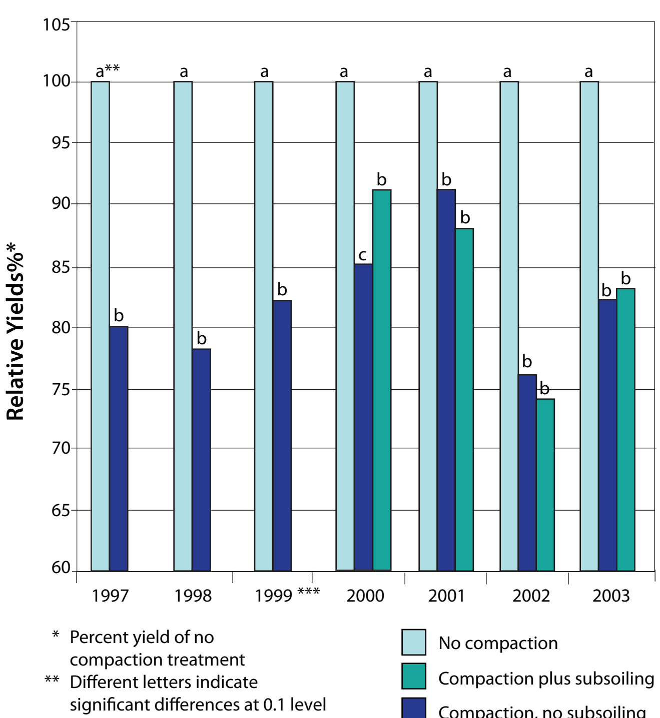
Treatment			Yield (bu/a) @ 15.5% Moisture						
Tillage	**Compaction**	**Subsoiling***	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Tilled	No	No	98.0 ab	39.9 ab	174.4 ab	134.9 a	83.5 ab	135.3 a	43.5 b
Tilled	Yes	No	75.6 b	31.2 cd	147.8 de	114.3 cd	76.1 cd	102.6 bc	35.7 c
Tilled	Yes	Yes	82.1 ab	31.1 cd	138.9 e	122.9 bc*	73.5 d	98.2 c	36.1 c
No-Till	No	No	103.7 a	42.0 a	179.8 a	117.4 cd	89.0 a	129.6 a	50.6 a
No-Till	Yes	No	1.8 c	35.8 bc	158.6 cd	109.0 d	81.5 bc	115.9 b	49.1 a
No-Till	Yes	Yes	1.9 c	33.4 cd	163.4 bc	130.4 ab*	80.9 bc	133.6 a	49.7 a
		LSD @ 0.1	**20.8**	**5.7**	**15.3**	**11.1**	**6.8**	**13.3**	**4.6**
		Crop	**Corn**	**Soyb.**	**Corn**	**Corn**	**Soyb.**	**Corn**	**Soyb.**

* One subsoil tillage was performed in fall of 1999 after harvest.

Table 2. Average yield of the non-compacted treatments by crop and tillage method (1997-2003).

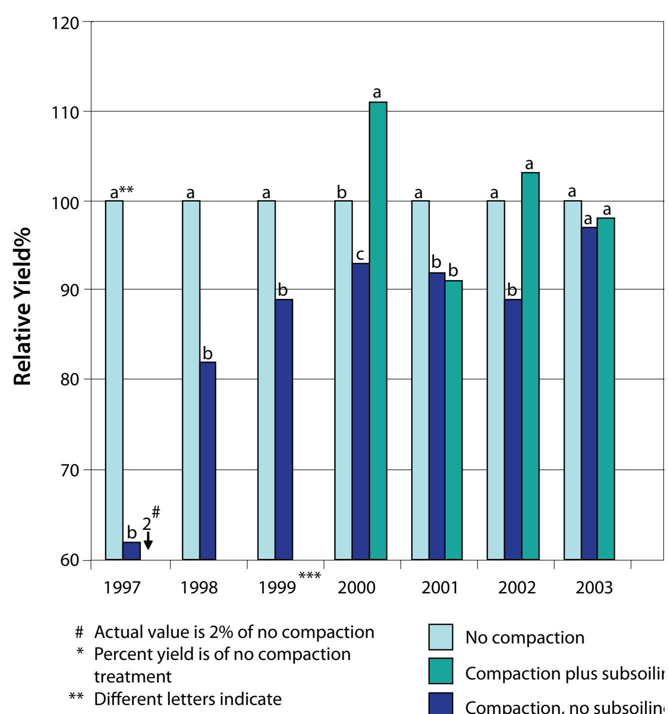
Crop	Years	Tilled	No-Tilled
Corn	4	135.7	132.7
Soybean	3	55.6	60.5

The effect of compaction and subsoil tillage can be more easily seen when the data is presented as relative yields for the tilled treatments (Figure 1) and the no-till treatments (Figure 2).



* Percent yield of no compaction treatment
** Different letters indicate significant differences at 0.1 level
*** Only one subsoil treatment which was applied in the Fall of 1999

Figure 1. Effects of soil compaction and tillage on relative yields of tilled corn and soybeans.



\# Actual value is 2% of no compaction
* Percent yield is of no compaction treatment
** Different letters indicate significant differences at 0.1 level
*** Only one subsoil treatment which was applied in Fall of 1999

Figure 2. Effect of soil compaction and tillage on relative yields of no-tilled corn and soybeans.

Tilled Treatments

Severe compaction existed in a 6-inch thick layer that began 6 inches from the surface and ended 12 inches below the surface. It reduced the yields to 75–80% of the non-compacted treatment in the first two years after compaction occurred (Figure 1). The yields improved to about an 80–90% range of the non-compacted treatment in the 3- to 7-year period after compaction. This may have been due to slight deterioration of the compacted layer. However, yields seem to be stable in the 3- to 7-year period after compaction, averaging 84% of the non-compacted treatment. This indicates that compaction in a system with routine tillage is slow to deteriorate and the effects linger for years.

Subsoiling the compacted treatment improved the yields for only one year. After that year, the yields from this one-time subsoiling were no better than the compacted treatment without subsoiling.

No-Tilled Treatments

Severe compaction existed in the top 12 inches of the soil in the first year and this is reflected in the very low yields (Figure 2). The surface soil recovered quickly. The compaction was completely removed in the top 3 inches by the second year and yields improved greatly. The yield of the compacted treatment relative to the uncompacted treatment continued to improve with time and reached a high of 97% in the last year. Unlike the tilled treatments, the no-till treatments resulted in a loosening of the compacted layer with time, resulting in an almost complete recovery over the 7-year period.

Subsoiling the compacted treatment resulted in a large yield increase in the first year after subsoiling. The effects of this one-time subsoiling seemed to persist after the first year and were evident again in the yields in 2002. It seems that subsoil tillage in a no-till environment results in a more complete and persistent correction of the compacted layer as compared to the tilled treatments.

Soil Resistance

A soil penetrometer was used to measure soil resistance as an indirect measure of compaction. The results are shown in Table 3. A soil resistance of 300 psi (lb/sq inch) was used as the critical value at which little or no root growth would be expected in soil layers with readings at this level or above. Therefore, measurements above 300 psi were considered to be compacted.

The non-compacted treatments had a low percentage of readings at or above 300 psi for both tillage systems. However, critical resistance was observed less frequently in no-till treatments than the tilled uncompacted treatment over the years.

The tilled and compacted treatments that were not subsoiled had a high percentage of readings above 300 psi (94–100%). The tilled treatment readings remained high over time and showed no signs of correction over the 10-year period of the measurements. The no-till treatment readings were lower beginning in the third year and showed signs of a downward trend from 100% to 65% over the 10-year period of measurements. The 10-year measurements were taken in 2006 after the area had been fallowed in 2004 and 2005.

Table 3. Soil Resistance as the Percentage of Sites within each Treatment with 300 psi or More, Top 15 Inches of the Soil Profile.

Treatment			Measurements 300 psi or Above (%)							
Tillage	Compaction	Subsoiling	1997	1998	1999	2000	2001	2002	2003	2006
Tilled	No	No	0	6	6	13	13	63	19	0
Tilled	Yes	No	94	94	94	100	100	100	100	95
Tilled	Yes	Yes	M	100	100	44*	56	81	69	70
No-Till	No	No	0	0	0	6	0	6	0	0
No-Till	Yes	No	100	100	88	75	88	88	88	65
No-Till	Yes	Yes	M	94	100	6*	31	38	25	35

M = Missing   * = One subsoil tillage performed in fall 1999 after harvest.

The compacted treatments that were subsoiled showed much lower soil resistances after the subsoiling. The tilled treatment was reduced to 44% in 2000, then increased to relative higher levels. The critical resistance in the no-till treatment decreased from 100% to 6% in 2000, then increased but remained at half or less of the readings in the tilled treatment.

The soil resistance measurements agree with the yield data and indicate that soil compaction in a no-tillage environment will correct itself over time, but in a tillage environment, the correction is very slow or does not occur.

Soil and Root Observations

A soil probe was used to remove cores for observations on rooting and soil structure. The observations made in March 2004, after 7 years of treatment, are shown in Table 4 (page 4). These observations support the yield and penetrometer data, which indicates that the no-tillage treatments were having a more rapid and positive effect on the compacted soil zone.

Summary and Conclusion

The effect of soil compaction on yield and the recovery of a compacted soil is quite different in a no-tilled environment compared to a tilled environment.

When no-tillage was used on this compacted soil, the effects on crop production were extremely severe the first year due to compaction at the very surface. The compaction began an immediate natural correction and the crop productivity continued to improve to almost a 100% recovery of yields by the seventh year. The compacted layer corrected itself at the surface and in channels and pockets in the compacted layer, allowing rooting through the compacted layer to the subsoil below. If the compacted, no-till area was subsoiled, the recovery to 100% productivity was immediate and lasted for years.

Table 4. Rooting and soil observations.

Depth (inches)	Compacted Treatment with Tillage
0-5	Topsoil with good granular structure with many roots above compaction zone.
5-12	Heavily compacted with horizontal layers and a small amount of rooting with an occasional large root.
12-18	Uncompacted subsoil with some fine roots.
	Compacted Treatment with No-Tillage
0-4	Uncompacted granular structure with prolific rooting.
4-12	Compacted soil with horizontal layers. Some zones with small amount of fine roots but also zones with numerous roots and large rooting channels causing significant reduction to probe resistance in these areas.
12-18	Uncompacted subsoil with zones of significant rooting as well as areas of few fine roots.
	Compacted Subsoiled Treatment with Tillage
0-6	Topsoil with granular structure with prolific rooting.
6-12	Massive compacted structure with occasional rooting but some zones with numerous roots.
12-18	Uncompacted soil with some fine roots.
	Compacted Subsoiled Treatment with No-Tillage
0-6	Topsoil with granular structure and prolific rootings.
6-12	Zones of granular and subangular structure mixed with massive compacted zones. Rootings ranged from occasional to pockets with massive rooting.
12-18	Uncompacted with few to moderate root numbers.
	Non-Compacted Treatment with Tillage
0-6	No compaction with a granular structure with numerous roots.
6-18	No compaction with numerous fine roots.
	Non-Compacted Treatment with No-Tillage
0-9	No compaction with a granular structure and many roots and large pores.
9-18	Subsoil with good structure and many roots and large pores.

When tillage was used on this compacted soil, the crop productivity was in the 75–90% yield range and did not improve much over time. The productivity, the soil resistance, and the rooting and soil structure showed little change over the 7 years of the trial. Even if the compacted, tilled area was subsoiled, the recovery was small and lasted only the one year after the subsoiling occurred.

It seems that no-tillage has a definite advantage compared to tilled soils because of its ability to improve the soil structure of compacted soils. This advantage may be due to the activity of many different types of organisms in the soil. It is possible that the driving force of this change and the effect of the organisms are due to the organic matter at the surface of the soil. When the organic matter is mixed into the soil with tillage, the effects become almost non-existent.

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