SOIL RECOMPACTION AFTER INTENSIVE DEEP TILLAGE

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ABSTRACT

For many Coastal Plain soils, high soil strength within subsurface horizons requires that deep tillage be performed to provide a suitable rooting environment. Longevity of deep tillage effects have been seen for three years with older tillage equipment. Newer equipment often disrupts more of the profile; tillage effects may last longer. We used soil strength results from experiments that were deep tilled twice a year or annually to examine longevity of soil loosening from tillage. Within these experiments, tillage disruption was measured from 9 days to 6 years after tillage. Effects of disruption, as measured by a leveling off of soil strength with time, began to disappear after three years; yet strengths continued to build up for another two years. Though strengths continued to build up for five years, tillage would still be necessary annually or seasonally because yield reducing soil strengths built up after a year or less with incomplete recompaction.

INTRODUCTION

High soil strength, especially in the E horizon, impedes plant growth and reduces crop yields in many southeastern Coastal Plain soils. In these soils, high strengths are reduced and yield improved through deep tillage (Busscher et al., 2000). Though residual effects of deep tillage may be seen for years afterward, deep tillage is recommended annually, either in spring (Threadgill, 1982; Busscher et al., 1986) or fall (Porter and Khalilian, 1995) or perhaps both (Frederick et al., 1998), because soil reconsolidation between growing seasons, although incomplete, can be enough to increase soil strength to yield-reducing levels. Using slit tillage and in-row subsoiling, previous studies showed that residual deep tillage effects were often no longer seen after three years, under conditions of normal rainfall and traffic (Busscher et al., 1995).

Strength problems are compounded by low available soil water content in sandy soils. Lack of rain for a two week period causes yield-reducing crop stresses (Sadler and Camp, 1986). In the southeastern Coastal Plains, most growing seasons have two week or longer periods with no rainfall (Sheridan et al., 1979). Deep tillage helps alleviate stress by making more of the profile available for root exploration.

Tillage tools now often disrupt more of the profile than the slit-till or in-row subsoiler. They may maintain a softer profile longer than three years. In a set of experiments in the same plots, we developed a series of tillage treatments where shallow and deep tillage were linked to yield (Frederick et al., 1998; Busscher et al., 2000) and where times between tillage and measurement of soil strength ranged from 9 days to about 6 years. Because of the increase in amount of disruption, we hypothesized that soil strength would remain low in these plots for more than three years.

MATERIALS AND METHODS

In spring 1993, before plot establishment, an experimental field at the Pee Dee Research and Education Center near Florence, SC, was planted to soybean using conventional techniques of 30-in-spaced rows with in-row subsoiling. Between fall 1993 and 1996, field plots at Clemson University=s Pee Dee Research and Education Center near Florence, SC, U.S.A. were planted to wheat (Triticum aestivum L.) and soybean (Glycine max L. Merr.) double crop using deep tillage with a paratill and 7.5-in-spaced drilled rows for both crops (Frederick et al., 1998). Between 1997 and 1999, the same plots were used to grow corn (Zea mays L.). Plots were 10-ft wide and 50-ft long. Plots were located on a Goldsboro loamy sand (fine loamy, siliceous, thermic Aquic Kandiudult) that had an E horizon below the plow layer.

The day before planting, two surface tillage and four deep tillage treatments were imposed onto the plots. Two surface tillage treatments involved not disking (planting into the stubble of the previous season=s crop) or disking twice before planting. Between 1993 and 1996 the four deep tillage treatments involved deep tilling every spring, every fall, both spring and fall, and no deep tillage. Between 1997 and 1999, the four deep tillage treatments involved not deep tilling and deep tilling at least once every three years. For 1997, deep tillage treatments included no deep tillage, deep tillage 1.5 years before planting (fall 1995), deep tillage 1 year before planting (spring 1996), and deep tillage immediately before planting the corn crop. For 1998, deep tillage treatments included no deep tillage, deep tillage 2.5 years before planting (fall 1995), deep tillage 2 years before planting (spring 1996), and deep tillage immediately before planting the corn crop. For 1999, deep tillage treatments included no deep tillage, deep tillage 3 years before planting (spring 1996), deep tillage 1 year before planting (spring 1998), and deep tillage immediately before planting the corn crop. All treatments were replicated four times in a randomized complete block design.

Surface tillage, deep tillage, and planting were done in separate operations. All tillage and harvesting equipment followed the same wheel tracks as closely as possible. Surface tillage was done with a 3-m-wide Tufline2 disk (Tufline Mfg. Co., Columbus, GA) pulled by a John Deere 4230 (Deere and Co., Moline, IL) 100 hp tractor with wheels on 64-in centers. Deep tillage was done with a four-shank paratill (Tye Co., Lockney, TX). Shanks were set 26-in apart. The paratill was pulled with a Case 2670 (now Case-IH, Racine, WI) 220-hp, 4-wheel-drive tractor with dual front and rear wheels on 75-in and 122-in centers. Shanks deep-tilled soil to approximately 16 in (the bottom of the E horizon).

Between 1993 and 1996, plots were planted to soft red winter wheat cultivar >Northrup King Coker 9134= and >Hagood= soybean, a Maturity Group VII cultivar. Both wheat and soybean were drilled in 7.5-in-spaced rows with a 10-ft-wide John Deere 750 No-till Planter pulled by a Massey Ferguson 398 (Massey Ferguson, Inc., Des Moines, IA) 80-hp tractor with wheels on 75-in centers. Wheat was drilled on November 18, 1993, November 23, 1994 and November 21, 1995 at a rate of 20 seeds ft-1 and harvested on May 27, 1994, May 30, 1995, and May 24, 1996. Soybean were drilled on May 30, 1994, June 1, 1995, and June 7, 1996 at a rate of 4 seeds ft-1 and harvested on November 3, 1994, November 3, 1995, and November 8, 1996.

Between 1997 and 1999, plots were planted to corn (DeKalb 687). Corn was planted on 15-in row widths with a John Deere 750 drill in 1997 and with an 8-row Monosem planter

[2] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture or Clemson University.

(A.T.I. Inc., Lenexa, KS) in 1998 and 1999 pulled by the Massey Ferguson 398. Corn was planted on April 1, 1997, March 31, 1998 and April 5, 1999 at a rate of 0.9 seeds ft-1 and harvested on August 28, 1997, August 18, 1998, and August 24, 1999.

To determine yield, corn grain was hand harvested from 39 ft of the middle 4 rows in each plot. Grain for the rest of the plot was harvested with a Case-IH (Case-IH, Racine, WI) 2366 combine with a 15-ft wide corn header and wheels on 10-ft centers. Since the corn header was designed for 30-in-row widths, two 15-in-row widths were harvested with each header opening.

For yield of wheat and soybean, whole plant samples were harvested from six 3-ft sections of row in each plot. When in wheat, grain for the whole plot was harvested with an Allis Chalmers (now Deutz-Allis, Norcross, GA) F3 Gleaner with a 13-ft-wide header and wheels on 7.8-ft centers. When in soybean, grain from the whole plot was harvested with an IH (now Case-IH, Racine, WI) 1420 axial flow combine with a 13-ft-wide header and wheels on 7.5-ft centers.

Cone index data were taken with a 0.5-in-diameter cone-tipped penetrometer (Carter, 1967) on June 21, 1994, June 16, 1995, and June 13, 1996 in soybean and on December 20, 1994 and December 12, 1995 in wheat and on April 22, 1997, April 29, 1998, and April 13, 1999 in corn. Cone indices were measured by pushing the penetrometer into the soil to a depth of 22-in at nine positions spaced 3.75-in apart starting at the middle of the plot and moving outward to one side of the plot into a wheel track. Cone index data were digitized into the computer at 2-in depth intervals and log transformed before analysis according to the recommendation of Cassel and Nelson (1979). Data for all positions across the plot and depth were combined to produce cross-sectional contours of soil cone indices using the method of Busscher et al. (1986). Gravimetric soil water content samples were taken along with cone indices. They were taken at the first and fifth positions of cone index readings. Water contents were measured at 4-in depth intervals to the 2-ft depth. These water contents were taken as representative of the plot. Rainfall data were collected at a weather station located approximately 2200 ft from the field plots.

Mean profile cone indices were used to compare buildup of soil strength over time after tillage. Mean profile cone indices consisted of the average of readings taken to a 22-in depth across the rows. Because different means were taken at different times, mean profile cone indices were not taken for the same environmental conditions; they were not taken at the same soil water contents. Means were corrected to a common water content based on a simplified correction (Busscher et al., 1997). Means were corrected using the equation CIc/CIo = WCo/WCc, where WCo is the original mean profile water content on a dry weight basis, WCc is the common water content to which all readings are corrected, CIo is the original mean profile cone index in atmospheres, and CIc is the mean profile cone index corrected to the common water content.

Mean profile cone index, rainfall, and time of measurement data were analyzed using regression analysis in TableCurve v3.05 (Jandel Scientific of SPSS Inc., Chicago, IL) and in GLM (SAS Institute, 1990). Data were tested for significance at the 5% level.

RESULTS AND DISCUSSION

Though complicated by rainfall at critical times during the growing season, yields within the wheat-soybean double-cropped plots and the corn plots were reduced by increases in mean profile cone indices (Frederick et al., 1998; Busscher et al., 2000).

Mean profile cone indices used to compare buildup of soil strength over time after tillage were corrected to a common water content of 13% was used. Correction to a softer, wetter soil was found to be better (Busscher et al., 1997) than correction to a dryer, harder one though correction to 11.5%, which was the mean of all the water contents, yielded results similar to those for the 13% correction.

Using GLM, the original cone index data for all readings, 1993 to 1999, were significantly correlated to both water content and time between tillage and measurement. After correction to a common water content, the correlation with water content was no longer statistically significant.

Because previous research found that soils recompact within three years, cone index data were analyzed for the first part years of the experiment, 1993 to 1996, the period when wheat and soybean were double cropped in the plots. Cone index was significantly correlated with the square root of time between tillage and measurement. Cone index data for these years (Figure 1) showed an abrupt increase appearing to level off with a maximum value of about 18.3 Atm approximately two years after tillage. The decrease in cone index seen in the last two sets of readings were probably associated with field variability and inaccuracies of the correction for water content differences. Cone index regression with time since tillage was 0.72 for 1993 to 1996.

For the later part of the experiment, 1997 to 1999, when corn was grown in the plots, cone index data for the same plots had a larger range of times between tillage and strength measurement. Times between tillage and measurement of cone index ranged from 9 days to 5.87 years. Cone indices continued to increase with time between tillage and measurement for all treatments, even those that had been tilled more than three years earlier. Cone index data (Figure 2) showed an abrupt increase with time giving readings at 17.8 Atm or less for the first three years, but continuing to increase after three years, and appearing to level off with a maximum value of about 19.4 Atm five years after tillage. It is possible that the readings continued to increase even after three years because somewhat controlled traffic limited compaction earlier in the experiment. For 1997 to 1999, cone index regression with time since tillage was 0.85.

Since plots had the same type of tillage and same traffic patterns for all years, data sets were combined. Though it should have increased precision of data analysis, combined data had a lower regression (0.79) than the latter data set, though the regression value for the combined set was between the values for the individual data sets (Figure 3). Data for the combined set showed a rapid initial build up of cone index with a continued increase lasting 5 years.

It is logical to assume that recompaction was a function of rainfall rather than time between tillage and measurement. Cumulative amounts of rainfall and time between tillage and time of measurement were highly correlated ($r2 = 0.99$) and correlations of the two with cone index were essentially the same (see for example Figure 4 where $r2 = 0.77$ for rainfall while the comparable value in Figure 3 was $r2 = 0.79$ for time).

CONCLUSIONS

In previous studies, recompaction was complete after three years, while in this study it took about five years, possibly because of limited area for traffic in the plots. In these soils that require deep tillage to provide a proper rooting environment, lower recompaction does not mean that less tillage is needed, because even after one year mean cone indices were as high as 15 to 17 Atm when corrected to 13% water content and at or above a root-limiting value of 20 Atm (Blanchar et al., 1978; Taylor and Gardner, 1963) before correction.

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FIGURES

Figure 1. Mean profile cone indices plotted as a function of number of days since deep tillage with a paraplow for the wheat-soybean double cropped experiment 1993 to 1996.

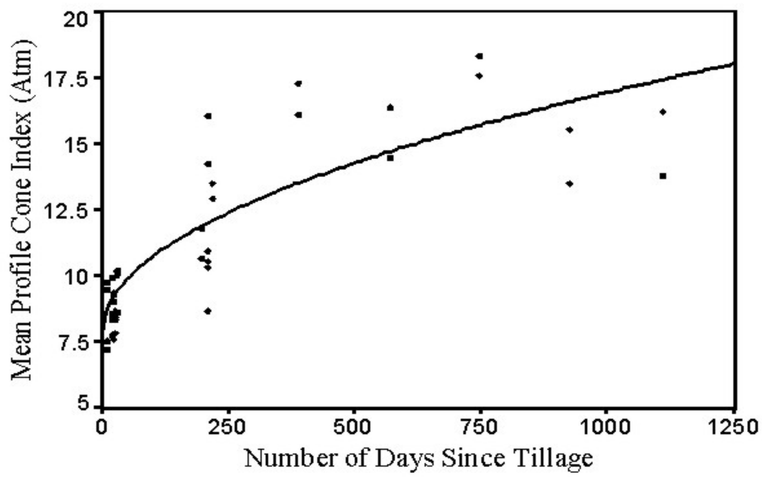

Figure 2. Mean profile cone indices plotted as a function of number of days since deep tillage with a paraplow for the corn experiment 1997 to 1999.

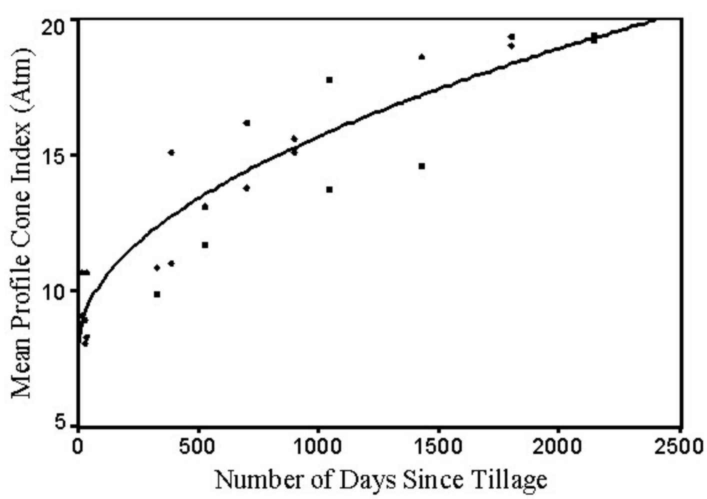

Figure 3. Mean profile cone indices plotted as a function of number of days since deep tillage with a paraplow for both experiments.

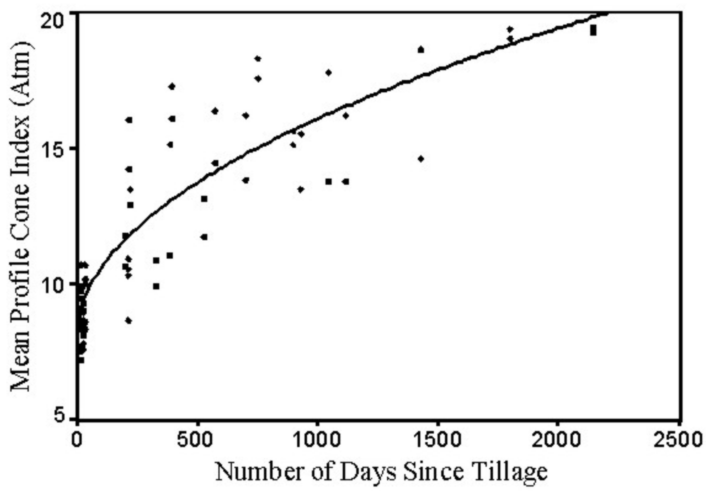

Figure 4. Mean profile cone indices plotted as a function of cumulative rainfall since deep tillage with a paraplow for both experiments.