SOIL STRENGTH FOR VARYING SOIL TYPE AND DEEP TILLAGE IN A COASTAL PLAIN FIELD WITH HARDPANS

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REFERENCE: J.E. Hook (ed.) *Proceedings of the 22nd Annual Southern Conservation Tillage Conference for Sustainable Agriculture,* Tifton, GA. 6-8 July 1999. Georgia Agriculture Experiment Station Special Publication 95, Athens, GA.

SUMMARY

When a double crop management system with drilled soybean and wheat led to high yields in deep-tilled small plots, we decided to evaluate the management system in large plots in a field with variable soil types. Double-cropped soybean and wheat were drilled in 7.5-inch row widths using all combinations of surface tillage (disked or none) and deep tillage (paratilled or none) with one extra set of paratilled treatments that were rotated with corn using in-row subsoiling. Cone indices were measured at two places in each plot to assess soil strength differences within and among treatments. Cone indices were higher for soil types with shallower B horizons. Subsoiled treatments had higher cone indices than paratilled treatments, partially as a result of drier soil. When compared to non-disked treatments, disked treatments had equal or higher mean profile cone indices even if treatments were deep tilled after disking. In fact, at the position of maximum disruption by deep tillage, treatments had higher cone indices if they were disked than if they were not disked. A reduction in the loosening effect of the final deep tillage can be affected by earlier surface tillage.

INTRODUCTION

High soil strength, enough to prevent root growth and reduce yield, is found in many southeastern Coastal Plain soils. Though the strength builds up naturally, it can be accelerated by traffic. High strength in these soils is often associated with an E horizon, located just below the Ap.

Currently accepted management of the high-strength layer reduces its strength by deep tillage. Since the hard layer reconsolidates within a year, soils are generally deep tilled annually (Threadgill, 1982, Busscher *et al.*,1986; Porter and Khalilian, 1995), even for double crops. Recently, when the hard layer was disrupted by deep tilling before both wheat and soybean, yields increased significantly (Frederick *et al.*, 1998).

Currently, some deep-tillage management schemes include surface tillage (disking) and some do not. Regardless of whether the soil is disked or not, deep tillage that follows disking loosens the profile to depths of 14 to 16 inches. Implicit in this management practice is that the deep tillage will reduce soil strength to a point that is conducive to root growth regardless whether the surface is tilled or not.

Our purpose was to use an intensive management system that deep tills before every crop, compare soil strengths measured at two places within and among treatments in large plots, and determine whether disking would affect subsequent deep tillage.

METHODS

In fall of 1996, we established wheat-soybean, double-cropped plots using cultivar Northrup King Coker 9134[1], soft red winter wheat, and Hagood soybean. Plots were 30-ft wide and 500-ft long.

Plots were located in a field that had Bonneau (Arenic Paleudult), Goldsboro (Aquic Paleudult), Noboco (Typic Paleudult), and Norfolk (Typic Kandiudult) as its major soil types. Soils had E horizons below the plow layer that hardened and restricted root growth.

Plots had two surface tillage and two deep tillage treatments in three randomized complete block replicates. The two surface tillage treatments were either not disked or disked twice before planting. Each surface tillage treatment also had a deep tillage treatment of either no paratilling or paratilling before both soybean and wheat planting. Deep tillage treatments were duplicated so that one set could be rotated into corn in the second year of the experiment.

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[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agric. or Clemson University and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

For wheat and soybean, surface tillage, deep tillage, and planting were done in separate operations. Before planting wheat or soybean, plots were deep tilled with a paratill. Corn was planted and in-row subsoiled with a 45° forward-angled, 1-inch-wide, straight-shanked subsoiler in one operation. All tillage and harvesting equipment followed the same wheel tracks as closely as possible.

Both wheat and soybean were drilled in 7.5-inch row widths with a 10-ft-wide no-till drill. Wheat was drilled in mid November at a rate of 20 seeds/ft and harvested in late May or early June. Soybean were drilled in early June at a rate of 4 seeds/ft and harvested in early November. In the second year of the experiment, corn was rotated into the extra set of deep-tilled treatments. After a fallow winter for these treatments, corn was planted in mid-March at a rate of 24,000 seeds/a.

All plots were fertilized following Clemson soil test recommendations (Clemson University, 1982). Weeds were controlled with Roundup (glyphosate) before wheat planting or Bronco (alachlor plus glyphosate) before soybean planting. Disked treatments were sprayed with Lasso before soybean emergence. After soybean planting, broadleaf weeds and nutsedge were controlled with Classic, and annual grasses were controlled with Poast Plus.

Within two weeks after planting either wheat or soybean and several weeks after planting corn, data were taken with a cone penetrometer (Carter, 1967). Cone indices were measured to a depth of 22 inches at 4-inch depth intervals at 9 positions across the rows beginning between the wheel tracks and ending in a wheel track, centering on the zone of maximum disruption of a deep tillage shank whenever appropriate. Cone indices were taken at two locations 50 to 100 ft from each end of each plot. Data were digitized into the computer and log transformed for analysis (Cassel and Nelson, 1979). Soil water contents were taken along with cone indices. They were measured at 4-inch depth intervals from the surface to 24-inches deep.

Data were analyzed using ANOVA and the least square mean separation procedure (SAS Institute, 1990). Cone index and water content data were analyzed using a split-split plot randomized complete block design where main effects were surface and deep tillage. The first split was on position across the row; the second, on depth. Data were tested for significance at the 5% level unless otherwise specified.

RESULTS

Water contents were generally not different and did not affect soil cone indices except as mentioned below.

Cone index analyses were separated into two parts: before rotation with corn and after rotation. Before rotation, data from treatments that were to be rotated were averaged with the deep-tilled treatments.

For the readings taken before rotation, paratilled treatments had lower cone indices than the treatments with no deep tillage. Cone indices for fall 1996 and spring 1997 were 11.6 (1.099) and 10.4 atm (1.059) for the paratilled treatments while they were 17.6 (1.269) and 20.7 atm (1.336) for non-deep tilled treatments (LSD's at 5% were 0.044 and 0.034). (Note: Numbers in parentheses are logs of the cone indices plus 1 atm. The addition of 1 atm prevents us from taking log of zero. Logarithms are shown along with cone indices because analyses are based on log transforms.) In the depth by deep tillage interaction, cone indices for deep-tilled treatments were lower than non-deep-tilled treatments to a depth of 14 inches; tillage was generally to 16 inches. Lower cone indices would encourage root growth and improve yield (Sojka *et al.*, 1991).

The depth by surface tillage interaction was significant because of a disk pan. In the 8- to 10-inch depths of the disked treatments, cone indices were at least 2.2 atm higher than in the non-disked treatments (Fig. 1). Despite disruption by the disk, cone indices for the disked treatments were not always lower than the non-disked treatments in the zone above the pan. Disking always increased cone indices in the pan but did not always reduce cone indices above it.

The depth by location of measurement interaction was significant because cone indices for the Goldsboro and Noboco soils at one measurement site, one end of the plots, were lower near the surface, above 8 inches, and higher in the lower part of the profile, below 8 inches, than the cone indices for the Bonneau and Norfolk soils at the other measurement site, the other end of the plots. This difference was at least partly a result of soil type because we noted at the time of measurement that the B horizon for the Goldsboro and Noboco soils appeared to be harder and closer to the surface than for the Bonneau and Norfolk. The difference was not a result of soil softening by increased water content because harder soils, above 8 inches in the Bonneau and Norfolk and below 8 inches in Goldsboro and Noboco, were also wetter.

The interaction of position and deep tillage was significant because it showed where the deep tillage had lowered cone indices (Fig. 1). Though the shanks had been set at 26-inch intervals, a recommended interval for complete loosening, cone indices revealed where the shanks had disrupted the soil and where high strength remained between the shanks: remnants of the pan. The profile was not uniformly disrupted across the profile.

Cone indices for the three way interaction of position by surface tillage by deep tillage was significant because disking increased cone indices, even for the treatment that was deep tilled after disking. In both fall and spring, cone indices for non-disked, paratilled treatment were lower than for the disked, paratilled treatment at the position where the shank disrupted the soil at its deepest point (Table 1), a sort of hysteresis effect for tillage.

In fall 1997, the rotated treatments were fallow. Paratilled treatments again had lower cone indices than non-paratilled treatments. Cone indices were 20.5 atm (1.332) for treatments with no deep tillage, 15.0 atm (1.205) for treatments that were fallow (but had been paratilled the previous spring), and 11.3 atm (1.091) for treatments that had been paratilled for the winter wheat (LSD at 5% was 0.048). No deep-tillage in treatments that had been deep tilled in the previous spring increased cone indices, but not as much as no deep tillage at all.

Corn was planted into the rotated treatments in March with in-row subsoiling. By the time of cone index measurement, June, soil in the rotated treatments had partially dried as a result of evapotranspiration. The mean water contents were 10.5% for the paratilled treatment, 10.1% for the non-deep-tilled treatment planted to soybean, and 8.4% for the rotated treatment (LSD at 5% was 1.1%).

Even though the rotated treatment had been subsoiled, its dryness caused it to have a high mean cone index (22.7 atm - 1.374). It was as high as the treatment that had not been deep tilled (22.0 atm - 1.361) and both were higher than deep-tilled treatment (16.7 atm - 1.249, LSD at 5% was 0.060).

The depth by surface tillage interaction was significant because of both the loosened zone by disking and the disk pan. In fall 1997 and spring 1998, this was seen by the lower cone indices at the 2-inch depth and higher cone indices at the 6- to 8-inch depths. For the two dates of measurement, cone indices within the pan of the disked treatments were 3.2 atm to 4.1 atm higher than non-disked treatments, with maximum cone indices within the pan at 20 and 30 atm which were at or above root limiting values (Blanchar *et al.*, 1978; Taylor and Garner, 1963).

As with the readings before rotation, depth by location of measurement cone indices were significantly different. In fall 1997, cone indices were lower for the Goldsboro and Noboco soils above 6 inches and higher below 6 inches than for the Bonneau and Norfolk soils and, in spring 1998, lower above 6 inches and higher below 14 inches. As before, higher cone indices also had the same or higher soil water contents; so water content was not a factor in reducing cone index. Goldsboro and Noboco soils had higher cone indices in heavier textured B horizons closer to the surface.

Cone index interaction of position with deep tillage were significant because of lower readings where the soil had been deep tilled. Fewer positions across the soil had low cone indices for the subsoiled (rotated) treatment than for the paratilled treatment (Fig. 2). In fall, this was caused by a lack of deep tillage and represented only remnants of deep tillage done the previous spring. In spring, this was caused by drier, harder soil for the subsoiled treatment, soil settling or reconsolidation during the almost three months between tillage and cone index reading, and a shallower, narrower zone of disruption with the subsoil shank than with the paratill (Busscher *et al.*, 1988). Nevertheless, we expected that the corn root growth would not have suffered from lack of tillage because roots would have been able to penetrate the hard layers in March when the soil would have been softer.

As seen in the data before rotation, cone indices for the three way interaction of position by surface tillage by deep tillage was significant because disking increased cone indices, even for the treatment that was deep tilled after disking. Cone indices for treatments that were either subsoiled or paratilled were higher for the disked than for the non-disked treatment at the position of maximum disruption by the shank (Table 1).

Both before and after rotation, disked treatments had equal or higher mean profile cone indices than non-disked treatments. Before rotation, non-paratilled treatments had higher mean profile cone indices than paratilled treatments. After rotation, non-deep tillage treatments had higher mean profile cone indices than subsoiled treatments (in the zone of disruption) which had higher cone indices than paratilled treatments. Higher cone indices in the subsoiled than in the paratilled treatment was a result of dryer soil. The subsoiled treatment had been deep tilled about three months before cone index measurements were taken and soil was drier in that treatment because it had dried by evapotranspiration.

Before and after rotation, Goldsboro and Noboco soils had lower cone indices shallow in the horizon and higher cone indices deeper in the horizon than Bonneau and Norfolk soils. This was partly a result of the heavier textured B horizons closer to the surface of the Goldsboro and Noboco.

Disking increased cone indices, even for the treatment that was deep tilled after disking, as measured at the position of maximum disruption by the paratill or subsoil shank, indicating to a possible hysteretic effect for tillage.

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Table 1. Cone indices for the surface tillage by deep tillage by position interaction (at the point of maximum disruption of the deep tillage) showing hardness of disked treatments even after deep tillage.

Date of Measurement	Surface Tillage	Deep Tillage: None	Paratill	Subsoil
			- - - - - Cone Indices - Atm (log)* - - - - -	
Fall 1996	Disked	17.9 (1.276)	11.1 (1.084)	- -
	None	18.2 (1.283)	9.4 (1.017)	- -
Spring 1997	Disked	21.0 (1.342)	7.4 (0.923)	- -
	None	20.2 (1.325)	5.2 (0.793)	- -
Fall 1997	Disked	19.8 (1.319)	7.2 (0.915)	10.3 (1.054)
	None	20.8 (1.339)	5.3 (0.797)	9.9 (1.037)
Spring 1998	Disked	22.0 (1.361)	13.8 (1.172)	19.9 (1.320)
	None	19.1 (1.302)	12.8 (1.141)	15.6 (1.221)

* The numbers in parentheses are logs of the cone indices in atmospheres plus 1 atm. The addition of 1 atm prevents us from taking log of zero. Logarithms are shown along with cone indices because analyses are based on log transforms. The LSD's for the logs are 0.058 at 10% for Fall 1996, 0.067 at 5% for Spring 1997, 0.072 at 5% for Fall 1997, and 0.062 at 5% for Spring 1998.

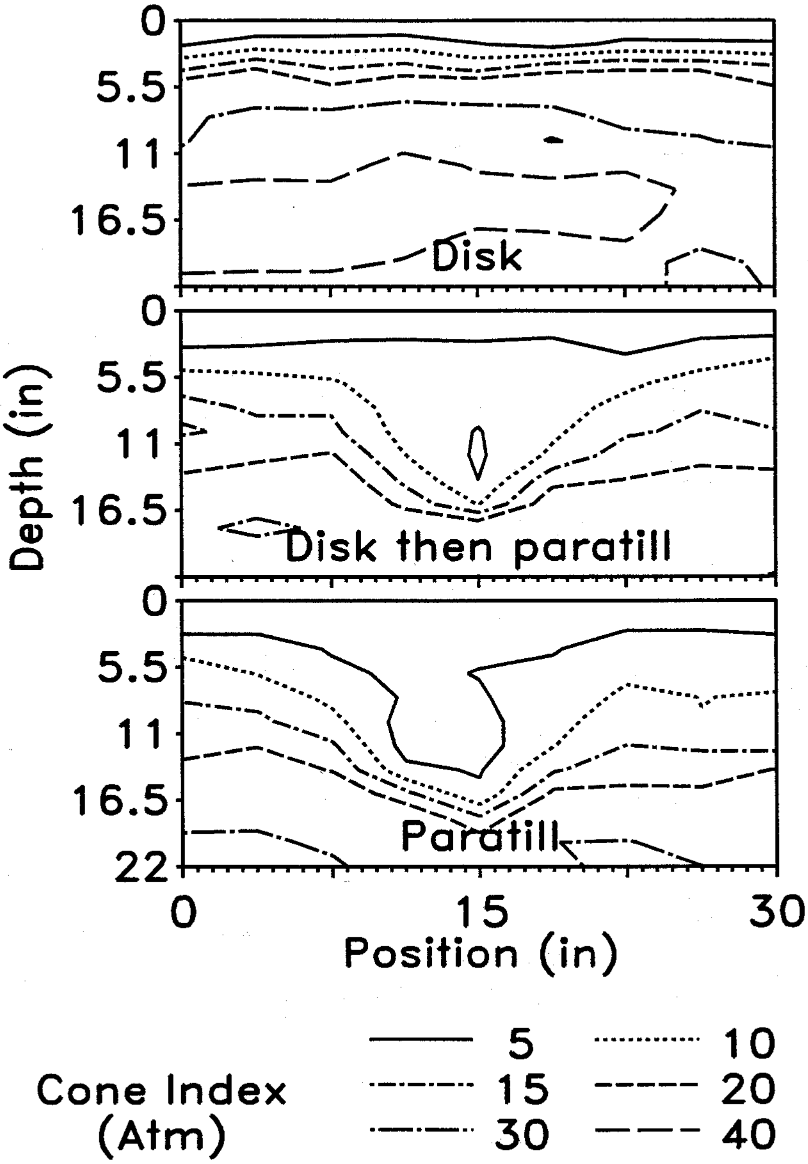

Figure 1. Cone index contours in June 1997. Tillage treatments are disking only, disking followed by paratilling, or paratilling only.

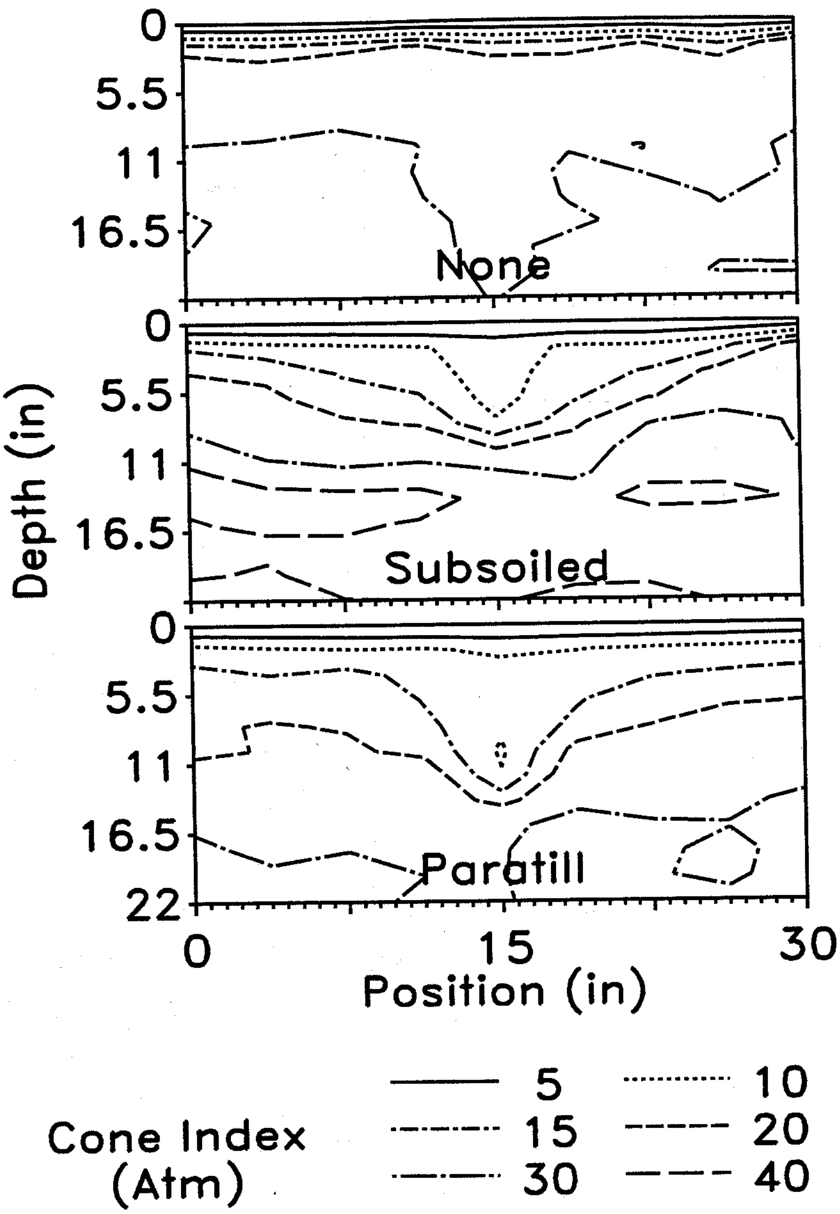

Figure 2. Cone index contours in June 1998 (non-disked treatments only). Deep tillage treatments are none, subsoiled, or paratilled.