Tillage Requirements for Corn as Influenced by Equipment Traffic on a Compactible Coastal Plain Soil

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Abstract

Deep tillage and controlled traffic have been utilized to manage soil compaction, but there remains the need to develop tillage systems that integrate conservation-tillage practices, deep tillage, and controlled traffic. In 1988, a study was initiated to determine the interactive effects of traffic, deep tillage, and surface residues on corn (*Zea mays* L.) grown on a Norfolk sandy loam (Typic Paleudult). Corn was planted into a winter cover crop of 'Cahaba White' vetch (*Vicia sativa* L.). Treatments included traffic (none or conventional equipment), deep tillage (none, in-row subsoiling [SS], or complete disruption [CD]), and surface tillage (none or disk + field cultivate). Complete disruption was accomplished by subsoiling 16-17 inches deep on 10-inch centers. When traffic was applied, the increased bearing capacity of no-till (no-surface tillage) plots resulted in reductions in compaction in the top 8 inches of soil of up to one half that found following disking and field cultivation. Soil strength patterns suggest that reductions in rooting and water extraction correlated well with increased soil water measured from tasseling through black layer. Although tillage X traffic interactions affected soil strength and soil water, the only grain yield response was due to a surface tillage X deep tillage interaction. In 1988 (a drought year), surface tillage yields averaged 56, 44, 22 bu/acre with CD, SS, and no deep tillage, respectively. Without surface tillage, respective yields averaged 60, 50, and 18 bu/acre. In 1989, yields with CD, SS, and no deep tillage averaged 124, 113, and 103 bu/acre, and 118, 110, and 75 bu/acre with and without surface tillage, respectively.

Introduction

Deep tillage, especially subsoiling, often results in yield increases for crops grown on coarse-textured Coastal Plain soils (Box and Langdale, 1984; Reeves and Touchton, 1986). Restricting equipment operations to certain areas in the field, i.e., controlled traffic, has also been shown to increase crop yield on these highly compactible soils (Nelson et al., 1975; Williford, 1982). Previous research, however, has generally been with conventional-tillage systems and has focused on single components of the compaction problem, i.e., tillage or traffic. The interactive roles that tillage systems (especially conservation-tillage systems) and traffic have on soil compaction and resultant crop responses have not been clarified.

The objective of this study was to evaluate the roles and interactions of residue management practices, deep tillage, and traffic on soil compaction and crop response, using corn as the test crop, on a highly compactible Coastal Plain soil.

Materials and Methods

This field study was conducted for 2 years (1988-1989) on a Norfolk sandy loam (fine, loamy, siliceous, thermic Typic Paleudult) located in east-central Alabama. The soil is highly compactible and has a well developed hardpan at the 7 to 12 inch depth.

A winter cover crop of 'Cahaba White' vetch was planted in the fall of 1987 and 1988. The cover crop was killed with an application of paraquat (0.94 lb ai/acre) 4 to 7 days prior to planting corn each spring. Pioneer 3165 hybrid corn was planted in 30-inch rows, and thinned to 20,000 plants/acre. The eight-row plots were 70 ft. long. Plots were established on different halves of the test site in 1988 and 1989 to avoid confounding from residual tillage effects. At planting, 30 lb N/acre and 44 lb P/acre was applied over the row in a four-inch band. Four weeks after planting, 120 lb N/acre and 26 lb S/acre was applied in a narrow stream 10 inches from the row. Weeds were effectively controlled with recommended practices.

The experimental design was a strip-split design of four replications. Vertical factors were deep tillage: 1) no deep tillage; 2) in-row subsoiling; and 3; complete disruption. Subsoiling depth was 16-17 inches. Complete disruption was accomplished by subsoiling on 10-inch centers. Horizontal factors were traffic: 1) no-traffic and 2; traffic. All operations were done with an experimental wide frame vehicle, which allows for 20 ft.-wide untrafficked research plots. A John Deere 4230 tractor was driven through appropriate plots to simulate traffic that would have been applied by an operation. Random traffic patterns were applied in the

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fall, simulating land preparation/planting operations for planting the cover crop; uniform traffic patterns were established in corn to simulate operations done by a farmer with four row equipment. Intersection or subplot treatments were surface tillage: 1) no surface tillage; and 2) disk-field cultivate.

Grain yields were determined from 100 ft. of row selected from the middle four rows of each plot. Grain yields were corrected to 15.5% moisture.

In 1989, parallel paired 6 mm-diameter stainless steel rods were installed at three depths (8, 16, and 32 inches) 15 inches on either side of a row in all plots. A Tektronix 1502B TDR cable tester was used to measure soil water using the time-domain reflectometry method as developed by Topp (Topp et al. 1980). Mcasurements were taken 11 times over a 38 day period from tasseling through black layer formation.

Penetrometer recordings were made in 1989, when corn was at tasseling. Readings were made after a period of sustained heavy rainfall, when the soil was saturated. Penetrations were made at three positions within each plot; in-row, and in the middles on either side of the row. In trafficked plots, the middle positions corresponded to wheeled (tire) and non-wheeled (no-tire) positions.

Results and Discussion

Grain Yields

In 1988, yields were limited by an extreme drought. Traffic had no effect on grain yields. There was a deep tillage X surface tillage interaction effect on yields, however (Table 1). Maximum yields, in both surface-tilled and no-surface tilled plots, were obtained with complete disruption of the plowpan. With both complete disruption and in-row subsoiling, yields were greatest when vetch residue was not incorporated by surface tillage. Without the benefit of deep tillage, however, surface tillage increased yields.

Table 1. Influence of deep tillage and surface tillage on corn grain yield in 1988 and 1989.

	1988		1989	
	Surface tillage		Surface tillage	
Deep tillage	yes	no	yes	no
	bu/acre			
None	22.4	17.9	102.6	75.0
In-row subsoil	43.9	50.0	112.8	110.1
Complete disruption†	56.4	60.1	124.2	118.0
LSD 0.10	4.3		9.4	

†Subsoiled 16-17 inches deep on 10-inch centers.

With favorable rainfall in 1989, there was no beneficial effect of surface residues as in 1988 (Table 1). However, yields again increased with the intensity of deep tillage. Also, as in 1988, surface tillage increased yields when no deep tillage was performed.

Soil Water

The detrimental effect of wheel traffic on root growth and water infiltration is reflected in the average soil water content maintained from tasseling through black layer in trafficked plots (Table 2). In the no-tire middles, at the 0-8 inch depth, the lower soil water content with surface tillage can be explained by increased root growth and consequent extraction of water. Soil water was highest in the wheeled or tire middles, especially with surface tillage. Soil compaction in the wheel tracks resulted in reduced root growth and water extraction. Wheel compaction was especially severe with surface tillage as compared to no-surface tillage, as evidenced by increased soil water. In the no-tire middles, the increased soil water at the 16-32 inch depth with no-surface tillage compared to tilled plots probably indicates greater infiltration of water through the zone of maximum extraction by roots (0-16 inch depth). The decrease in soil water with surface tillage, as compared to no-surface tillage, at the 8-16 inch depth in wheeled middles is likely due to reduced infiltration from the greater compaction from wheel traffic in surface-tilled plots compared to no-surface tillage.

Table 2. Influence of interrow position and surface tillage on average volumetric soil water content from tasseling to black layer. Menns from trafficked plots.

	Tire-Middle		No-Tire Middle		
Dcpth	Surface Tillage	No-Surface Tillage	Surface Tillage	No-Surface Tillage	LSD $_{0.10}$
inches	%				
0-8	15.01	13.97	10.23	12.48	0.84
8-16	21.32	22.96	18.96	18.24	0.96
16-32	23.08	22.56	22.48	23.58	0.84

Within no-deep tillage plots, at the 0-8 inch depth, surface tillage had no effect on soil water when traffic was applied (Table 3). However, in the absence of traffic, water content remained higher with no-surface tillage. This is likely due to less water extraction by fewer plant roots as a result of surface compaction. The lowest water content, regardless of surface tillage, was maintained in the complete disruption treatment with no traffic. This treatment would minimize compaction and maximize root growth and water extraction. With in-row subsoiling, surface tillage reduced soil water content, compared to no-surface tillage, in no-traffic plots but increased soil water content when traffic was applied. The decreased soil water due to surface tillage with in-row subsoiling in no-traffic plots is likely explained by increased rooting and water extraction as a result of reducing soil compaction in this soil depth zone. In contrast, traffic applied following surface-tillage recompacts the soil to a greater extent than when applied without surface tillage, resulting in a zone more restrictive to root growth. A consequent reduction in soil water extraction from fewer roots is the likely explanation for increased soil water maintained in surface tilled plots compared to no-surface tilled plots with in-row subsoiling and traffic applied.

Table 3. Influence of deep tillage, traffic, and surface tillage on volumetric soil water content from tasseling to black layer. Means from wheeled interrow position.

		Traffic		No-Traffic	
Depth	Deep Tillage	Surface Tillage	No-Surface Tillage	Surface Tillage	No-Surface Tillage
inches		------------- % -------------			
0-8	In-Row Subsoil	15.85	13.57	11.98	13.34
	Complete Disruption	14.48	13.56	10.54	10.28
	None	14.71	14.78	10.33	12.31
	LSD $_{0.10}$	0.99		0.99	
8-16	In-Row Subsoil	22.65	23.25	22.53	21.20
	Complete Disruption	20.51	23.76	12.53	16.93
	None	20.80	21.87	21.26	21.30
	LSD $_{0.10}$	1.27		1.21	
16-32	In-Row Subsoil	22.61	21.07	23.50	22.51
	Complete Disruption	23.98	23.61	20.06	22.48
	None	22.65	23.00	24.05	23.63
		NS		NS	

At the 8-16 inch depth, with complete disruption, traffic resulted in incrcased water content, regardless of surface tillage, due to less root extraction of soil water (Table 3). No-surface tillage resulted in greater soil water content than surface tillage, regardless of traffic; probably due to lcss soil water extraction from decreased root growth, as well as increased infiltration with no-surface tillage. Maximum root growth and water extraction with the combination of intensive tillage, i.e., complete disruption and surface tillage, and no-traffic is indicated by the extreme decrcase in soil water content in this treatment. Treatments had minimum effect on soil water use below the 16 inch depth.

Soil Strength

Both in-row subsoiling and complete disruption eliminated compaction to the 16-17 inch depth in the row (Figure 1). Subsoiling on 10-inch centers did

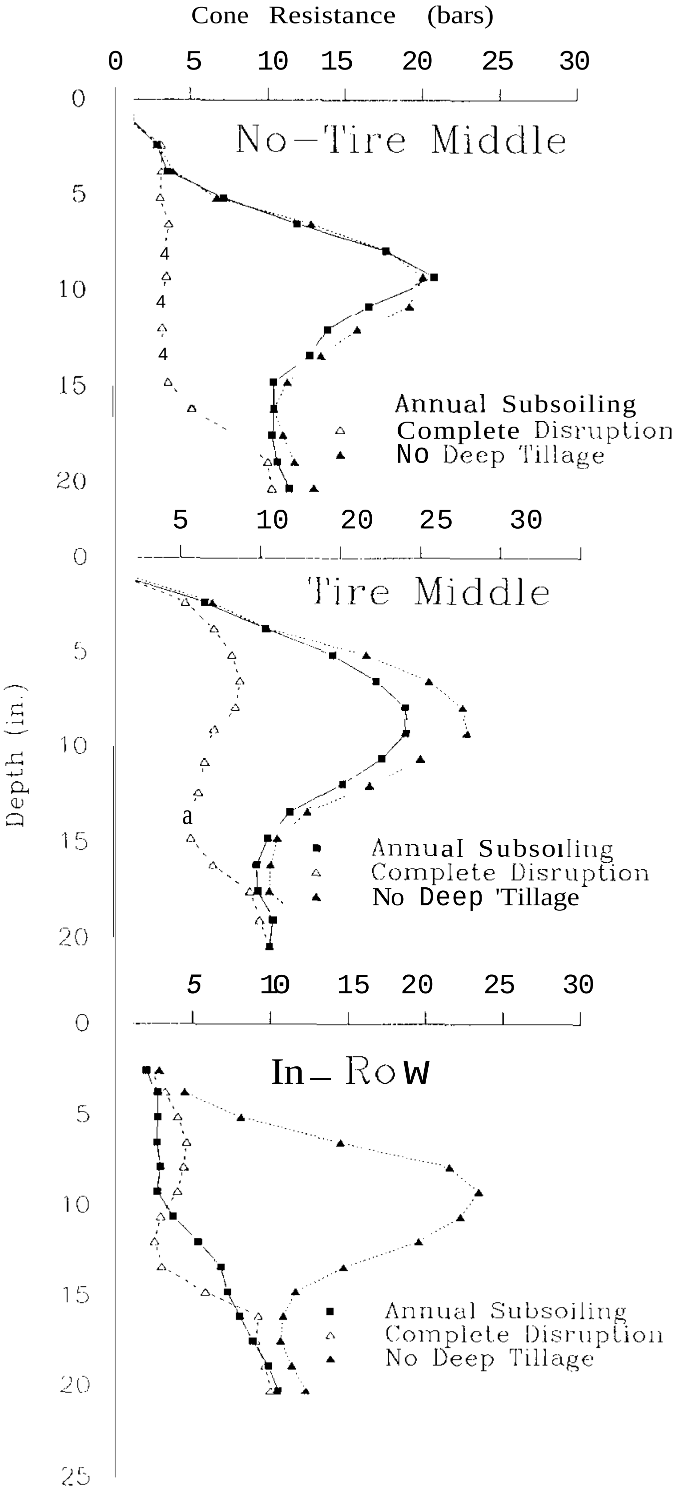

Fig. 1. Soil strength relative to row position as influencedby deep tillage. Means averaged over traffic and surface tillage treatments.

completely disrupt the tillage pan, as evidenced by reduced soil strengths to the 16-inch depth in all measured positions (in-row, tire middle, and no-tire middle). The affect of recompaction from equipment traffic is evident in the slight increase of soil strength with complete disruption in wheeled (tire) interrows as compared to non-wheeled (no-tire) interrows.

The detrimental effect of traffic after surface tillage as opposed to traffic on plots without surface tillage is seen in Figure 2. When traffic was applied, the increased bearing capacity of no-till (no-surface tillage) plots resulted in reductions in compaction in the top 8 inches of up to one half that found following disking and field cultivation. Soil strength patterns suggest reductions in rooting that correlate well with increases in soil water discussed previously.

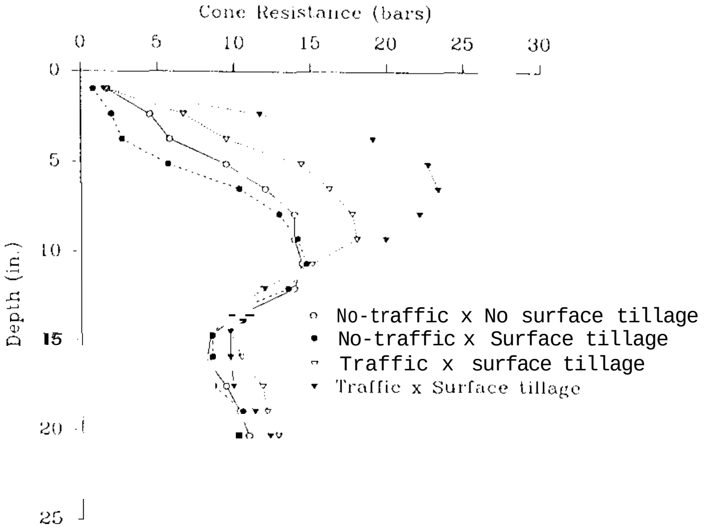

Fig. 2. Influence of traffic and surface tillage on soil strength. Means averaged over deep tillage treatments within tire interrow position.

Recompaction by traffic following surface tillage was not contained within the row middles. Soil strength increased in the 7-11 inch depth under the row following traffic (Figure 3). To a lesser degree, traffic following complete disruption also increased soil strength under the row (data not shown).

Summary

In a drought year, yields increased with intensity of deep tillage; deep tillage without surface tillage optimized yields. In both a drought year and a year of above average rainfall, surface tillage, in the absence of deep tillage, increased grain yield. Soil strength and soil water measurements confirm the detrimental effect of traffic after intensive tillage. The lack of any yield response to applied traffic, however, indicates that corn may compensate for reduced rooting capacity in wheeled interrows by increased rooting in non-wheeled interrows. This study will be continued in order to determine the long-term effects of traffic and tillage interactions on soil properties and crop responses.

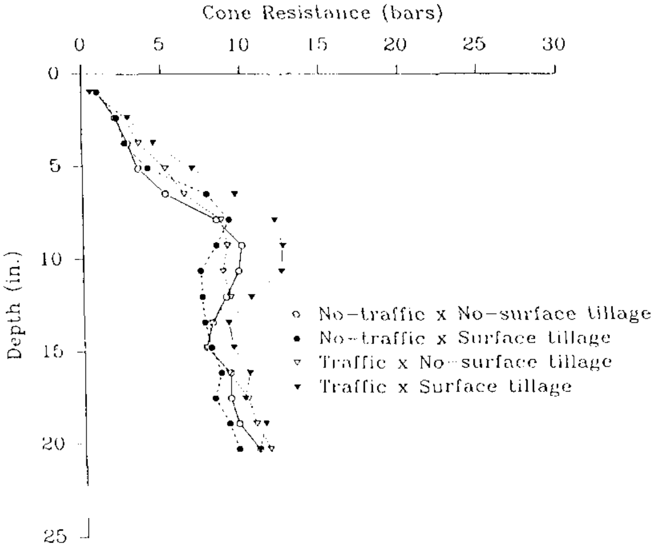

Fig. 3. Influence of interrow wheel traffic and surface tillage on soil strength under the row. Means averaged over deep tillage treatments.

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