TRAFFICABILITY AND ROOTING DEPTH COMPARISONS BETWEEN NO-TILL AND TILLED SOYBEANS

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ABSTRACT

No-tillage production has gained increased popularity in Tennessee due to the following reasons: demand to meet conservation compliance requirements, less time spent in spring planting operations, savings in fuel and labor and improvements in weed control in no-till agriculture. Differences have been measured in soil properties between no-till and conventional tillage. These differences raise concerns about how they affect plant growth and rooting. This experiment was designed to evaluate soybean root distribution under conventional (CT) and no-tillage (NT), to evaluate trafficability of conventional and no-tillage and to evaluate the effect of trafficking on soybean root distribution. The experiment was conducted on long term tillage plots of Lexington silt loam (fine silty, mixed, thermic, Typic Paleudalf) at the West Tennessee Experiment Station at Jackson, Tennessee. Experimental design was a randomized complete block with tillage as the treatment, set up with four replications in 1992. In 1993, the design was a randomized complete block with split plots. Tillage was the whole plot treatment and traffic was the subplot treatment. There were four replications. Soybean root distribution was evaluated using minirhizotrons. Trafficking was done in 1993 using a tractor and evaluated by measuring changes in soil surface profile and bulk density. In 1992, there were no differences in root, distribution until late in the season. In 1993, at 30 days after emergence, no-tillage had greater root length at shallow (< 10 inches) depths and conventional tillage had greater root length below 10 inches. At 60 days after emergence, there were no differences in root length between tillage by depth. At 30 days after emergence, there were greater root lengths within- row in the trafficked zone of the traffic treatment, and by 60 days after emergence there were no differences in root lengths related to traffic. The no-tillage had greater trafficability, as indicated by less soil displacement, and lower bulk density increases than conventional tillage. Due to high soil displacement in conventional tillage from trafficking, soil leveling was required. In 1992, no-tillage had greater yields than conventional tillage. There were no differences in yields from tillage or traffic in 1993. There were no agronomically significant differences observed in yields or root lengths from tillage or traffic in this study.

INTRODUCTION

The ability of the soil to support weight, especially heavy equipment Itrafficability) without compaction and/or rut formation has been observed to differ depending on the tillage systems used. No-tillage INTI seems to greatly increase trafficability even under excessively wet soil conditions.

The effect of no-tillage on soil properties such as bulk density and aggregate stability may partly explain possible changes in soil structural stability. The effects of no-tillage on bulk density have been variable depending on soil type and tillage system with higher (Rhoton, 1993) or very little differences in bulk density measured (Blevins et al., 1983). Changes in bulk density and penetrometer resistance, as a measure of soil compaction may not indicate the need for deep-tillage for maximum yields (Tyler and McCutchen, 1980: Tyler et al. 1983: Bicki and Siemens, 1991). This seems to be especially the situation on medium-textured soils. In contrast, on many soils in the coastal plain, especially the sandier soils, in the southeastern U.S., increases in bulk density and penetrometer resistance can indicate sufficient compaction to reduce yields (Denton et al., 1986; Wagger and Denton. 1989).

In conjunction with bulk density, soil aggregate stability is also affected by different types of tillage systems. It has been found to improve under no-tillage (Kladivko et al., 1986; Sutarman, 1991).

No-tillage systems also result in less trafficking due to fewer equipment passes. This can allow more timely equipment operations that avoid trafficking when the soil is too wet. Observations of improvement in soil structural

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stability with no-tillage as compared to tillage under adverse wet soil conditions was one impetus for this study. The dynamics of rut formulation and subsequent effects on soybean rooting between the tillage systems was also studied. Rooting patterns were evaluated using minirhizotrons (Brown and Upchurch, 1987).

MATERIALS AND METHODS

Tillage Experiment

The experimental plots used in this study were established in 1979 at the West Tennessee Experiment Station, Jackson, Tennessee as part of a long term tillage study. The soil is a Lexington silt loam, a fine silty, mixed, thermic, Typic Paleudalf.

Four replications of two tillage treatments were used in this study. The plots consist of eight 30 in. wide rows, 40 ft. long. One treatment has been continuously moldboard plowed (CT) to a depth of 10 inches followed by disking to a depth of 4 inches each season since 1979. Single-crop soybeans have been planted each season in mid-May. No winter cover crop was present. The other treatment was no-tillage single-crop soybeans (NT) planted in previous soybean crop residue each season since 1983. Details of treatments on these plots prior to 1983 are given in Tyler and Overton (1982) and Tyler et al., (1987). In 1992, soybeans were planted on 18 June. In 1993, soybeans were planted on 7 June. The variety used was TN-486 both years, planted at 160,000 plants/acre. Weed control used was 0.63 lb ai acre paraquat, 0.37 lb ai acre 6:1 ratio of metribuzin and chlorimuron and 2 lbs ai acre alachlor with 0.25% vlv nonionic surfactant prior to planting both years. Post-emergence grass control was accomplished using 0.12 lb ai acre clethodim applied with 0.25 gal acre-' crop oil concentrate.

Wet Trafficking

Trafficking was done on 4 May 1993, after 3 inches of rainfall in the previous two days, with a John Deere 4455 tractor that weighed approximately 8.9 tons. The tractor was equipped with Goodyear Special Sure Grip TD8 20.8R38 rear tires. The original intention was to impose traffic in the late fall following harvesting or during winter, but there was not a large enough rainfall event in that time to sufficiently wet the plots for trafficking. The CT plots were disked twice on 19 April 1993 to simulate tillage before planting. The trafficking was done between row 1 and 2 and 3 and 4 on one half of the plots. Ruts from the trafficking were measured with a pin drop profile meter for measuring irregular surfaces. Prior to trafficking, base pins were driven in to hold the profile meter. An undisturbed cross sectional profile was taken at four locations on each side of the split plots. Height of the drop pins was recorded on a paper chart before trafficking. After the trafficking was done, the new surface was remarked on the same chart. The charts were then put on a digitizing tablet and the points were digitized into a computer and put into a spreadsheet so they could be graphed. Graphs of the before and after profiles were printed and overlaid and the area of soil displaced and heaved during trafficking.

Root Measuring Technique

The polybuterate minirhizotron tubes were 2 in. inside diameter and 4.3 ft. in length. They were installed at a 30° angle from vertical, parallel to row position to a depth of 3.3 ft. The tops of the tubes were wrapped in electrical tape and capped with a PVC cap to prevent surface light from entering the tube. Tubes were installed in probe holes in rows 2, 3, 6, and 7 of each plot in 1992. The probe holes were made with a Concord hydraulic probe mounted on a 100 horsepower tractor. In 1993, CT plots were disked after trafficking to smooth them for planting. The 1993 rows were then planted directly above the tracked zones by offsetting them half of a row width from their 1992 position. The tubes from the 1992 installation were left intact from the previous year, and after row offsetting were between the new rows. Tubes were installed in the new row positions.

The camera used was a Bartz color fiber optic camera with white and UV light that was linked to a VHS recorder/player and a television for monitoring the recording. In 1993, the camera was linked to a Sony Super Eight video camera for recording. The Super 8 cassettes were then transferred to VHS for evaluation. Readings were taken at 2 inch depth increments in the tubes and recorded on VHS tape. Four readings were taken at each depth by rotating the camera 0, 90. 180, and 270°. The 0° reading was oriented toward the soil surface. They were measured using a LASICO model 71A linear probe, by frame advancing the VCR and a 19-inch color television. A piece of plexiglass was placed over the television screen to prevent slippage of the linear probe wheel. Relative length values were determined by tracing the roots on the television screen. These values were used for the statistical analysis. Emergence date in 1992 was 23 June and measurements were taken on 7 July, 6 August and 24 September, 14, 44, and 93 days after emergence respectively. In 1993, emergence was 11 June and measurements were taken on 12 July and 10 August, 31 and 60 days after emergence respectively. A later measurement was not taken in 1993 because plants were at or near physiological maturity and roots would soon start to disintegrate as was determined in 1992 from the late reading. Selected root measuring dates are discussed in this paper.

Yields

Soybeans were harvested with a plot combine. The rows harvested in 1992 were the two middle rows of each plot. In 1993, the harvested rows were the rows oriented over the traffic tracks and corresponding untrafficked rows on each split-plot of each tillage treatment. Both year's yields were adjusted to 13% moisture.

RESULTS AND DISCUSSION

At 44 days after emergence in 1992 tillage had no significant effect on soybean root length (Figure 1.). The majority of observed roots were at depth of 10 to 20 inches. This distribution is similar to that of Upchurch and Ritchie (1983) with lower than expected densities at shallower depth. This is due to the minirhizotron method underestimating roots length at depths down to about 8 inches. At depth below 8 inches, the minirhizotron method results in similar data to that obtained from soil cores (Upchurch and Ritchie, 1983).

Trafficking and Rooting

Trafficking was done on May 4, 1993 after a total of about 3 inches of rain the previous two days. After trafficking, there were very obvious difference in the soil surfaces (Figure 2). No-till plots did not look any different than before trafficking under visual observation. Conventional tillage plots had a large amount of

Table 1. 1993 Soybean Root Lengths Within the Row for Tillage and Traffic Treatments 31 Days After Emergence Averaged Across Depth.

Tillage	Traffickina	Root Lenath
		cm roots cm'' soil
Conventional	No	0.36
Conventional	Yes	0.45
No-Tillage	No	0.27
No-Tillage	Yes	0.45

Table 2. Surface Bulk Densities by Tillage and Traffic Combinations.

Treatment	Bulk Density $Mg\ m^{-3}$
Conventional Tillage Trafficked	1.61a
No-Tillage Trafficked	1.46b
Conventional Tillage No Traffic	1.45b
No-Tillage No Traffic	1.38c

Bulk densities with the same letter are not different a P $\geq$ 0.05.

Table 3. Soybean Yields by Tillage and Traffic 1993.

Tillage	Trafficked	Yield bu acre-'
Conventional	Yes	19
Conventional	No	19
No-tillage	Yes	16
No-tillage	No	18
		NS

No significant differences when tested at a = 0.05.

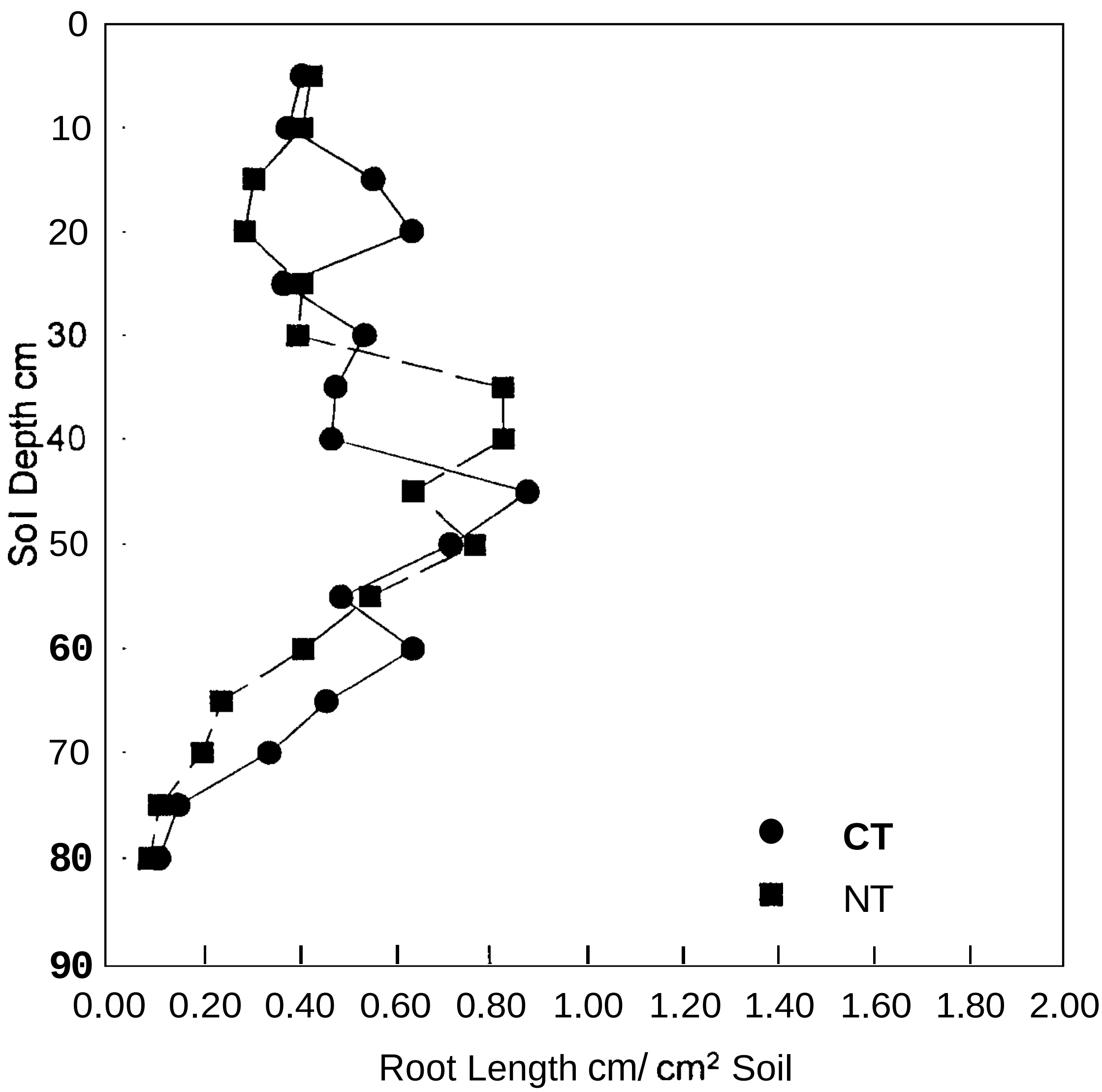

Figure 1. Soybean root length by soil depth, conventional vs no-tillage 44 days after emergence.

soil displaced and had to be disked before they were suitable for planting. At 31 days after emergence, average root length was greater in the trafficked as compared to non trafficked treatments (Table 1). Voorhees (1992) observed similar distributions of greater root density under the row in compacted conditions under CT.

The amount of soil displaced by trafficking was also significantly affected by tillage. Trafficking in CT plots displaced an average cross-sectional area of 38 sq. inches from the original soil surface profile (Figure 2). NT only averaged an area of 8 sq. inches of displaced soil. This displaced soil is the cross sectional area of the track below the original surface that was removed and does not include the heaved soil. The average rut on CT plots was about 26 inches across from peak to peak of the heaved soil, 19 inches across on the inside of the heaved soil and about 6 to 7 inches deep measuring from the top of the heaved soil to the bottom of the rut. The NT plots had only lug marks in the soil from the tractor tires as visible evidence of the trafficking.

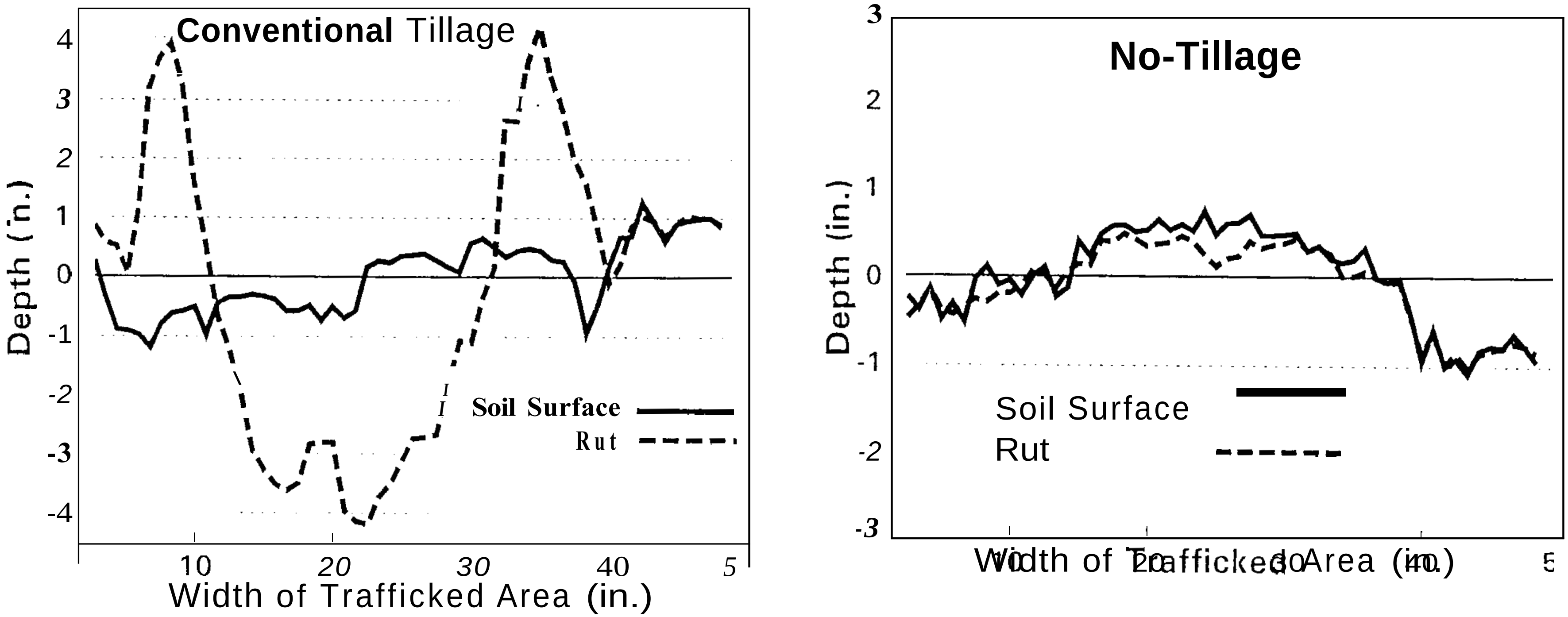

Figure 2. Row areas in conventional and no-tillage as measured by a rill meter before and after trafficking.

An area of soil equal to about 64% of the area of soil displaced was heaved up higher than the original soil surface on the side of the tire ruts in the CT plots. If the bulk density of the heaved soil was the same as the original soil then 36% of the soil displaced was accounted for by compaction to the bottom and sides of the rut. Assuming the heaved soil had a lower bulk density than the original soil, due to the many large cracks in the heaved soil, more than 36% of the soil displaced ended up being compacted.

Differences in tillage response to traffic may be attributed to differences in structural development and aggregate stability in the surface horizons associated with the tillages (Sutarman. 1991). Under NT conditions there is greater structure development and aggregate stability near the surface (Sutarman, 1991; Kladivko, 1986; Blevins, 1983). This increased structural stability in NT allowed the tractor to travel across the soil without deformation and soil displacement. No-till has a greater ability to handle traffic under wet conditions due to better structural development and aggregate stability of the soil surface.

Surface Bulk Densities

Conventional tillage had greater bulk density with no trafficking than NT. Trafficking significantly compacted CT soil from 1.45 to 1.61 mg m^{-3}, more than NT soil. from 1.38 to 1.46 Mg m^{-3} (Table 2.). Bulk density in CT may have been greater than NT because it had recently been disked twice. These differences in bulk density were statistically different, but from a soybean root distribution standpoint were not inhibitory. In some cases, 31 day after emergence the areas of higher bulk density had a greater root density than the areas of lower bulk density. Sixty days after emergence the differences in root distribution due to compaction had disappeared. Voorhees (1992) and Fausey and Dylla (1984) observed similar results in traffic compaction studies on soybean root distribution. There was no observed inhibition of soybean roots from the increases in bulk density from trafficking or tillage.

Yields

In 1992, a year with good rainfall, NT had significantly greater yields than CT. No-tillage averaged 44.6 bu/acre while CT averaged 38.7 bu ac^{-1}. These results are similar to those of Tyler and Overton (1982). and Tyler et al., (1983). Significant yield differences have varied over year between NT and CT. Some years NT may have slightly greater yields and other years there may be no difference in yield (Tyler and Overton, 1982). In 1993, a year of low rainfall, there were no significant differences in yield between CT and NT. CT averaged 19 bu ac^{-1}, while NT averaged 17 bu ac^{-1}. There were also no differences in yields due to traffic. The lack of differences due to traffic indicates that the differences in bulk densities and root distributions observed from the trafficking were not detrimental to yields.

SUMMARY AND CONCLUSION

There were no differences related to tillage in root distribution early in the season in 1992. In 1993, there were differences in root distribution. At 31 days NT had greater root length at shallow depth (< 10 inches) than CT (data not shown). At 60 days there were no differences between NT and CT by depth (data not shown). There was a slight increase in roots above 20 inches at 31 days in the trafficked treatment. By 60 days there was no difference between trafficked and non-trafficked treatments in the top 20 inches of soil. There is no evidence of tillage or trafficking being detrimental to root growth and development.

Increased aggregate stability and better structure development (Sutarman, 19911 apparently led to greater load bearing and better trafficability under wet conditions. NT tractor tracks only had an average cross section area of 8 sq. in^2 of soil displaced while CT had an average cross sectional area of 38 sq. in^2 of soil displaced. Further tillage was required after trafficking CT before planting was possible. Further operations were not needed under the NT conditions. CT had greater increases in bulk density from trafficking. In 1992, NT had greater yields, but in 1993, there were no differences in yields. Neither tillage nor trafficking had detrimental affects on yields or root development in this study. NT had much better trafficability under wert soil conditions as compared to CT.

LITERATURE CITED

Bicki, T. J. and J. C. Siemens. 1991. Crop response to wheel traffic soil compaction. Trans. ASAE. 43:909-913.

Blevins. R. L., M. S. Smith, G. W. Thomas, and W. W. Frye. 1983. Influence of conservation tillage on soil properties. J. Soil Water Cons. 38:301-304.

Brown, D. A. and D. R. Upchurch. 1987. Minirhizotrons: A summary of methods and instruments in current use. p. 15-33 In H. M. Taylor (ed.) Minirhizotron observation tubes: methods and applications for measuring rhizosphere dynamics. ASA Spec. Pub. 50. ASA. CSSA. and SSSA. Madison, WI.

Denton, H. P., G. C. Naderman, S. W. Buol, and L. A. Nelson. 1986. Use of technical soil classification system in evaluation of corn and soybean response to deep tillage. Soil Sci. Soc. Am. J. 50:1309-1314.

Fausey, N. R. and A. S. Dylla. 1984. Effects of wheel traffic along one side of corn and soybean rows. Soil Tillage Res. 4:147-154.

Kladivko, E. J., D. R. Griffith, and J. V. Mannering. 1986. Conservation tillage effects on soil properties and yield of corn and soybeans in Indiana. Soil and Tillage Research 8:277-287.

Rhoton, F. E., R. R. Burce, N. W. Beuhring, C. B. Elkins, G. W. Langdale. and D. D. Tyler. 1993. Chemical and physical characteristics of four soil types under conventional and no-tillage systems. Soil and Tillage Research 28:51-56.

Sutarman, G. 1991. The effect of erosion. tillage, and winter cover crops on soil aggregate stability. M.S. Thesis. University of Tennessee. Knoxville, TN. 52 p.

Tyler, D. D., A. Y. Chambers, and L. D. Young. 1987. No-tillage effects on population dynamics of soybean cyst nematode. Agron. J 79:799-802.

Tyler, D. D. and T. C. McCutchen. 1980. The effect of three tillage methods on soybeans grown on silt loam soils with fragipans. Tennessee Farm and Home Science 114:23-26.

Tyler, D. D. and J. R. Overton. 1982. No-tillage advantages for soybean seed quality during drought stress. Agron. J. 74:344-347.

Tyler, D. D, J. R. Overton, and A. Y. Chambers. 1983. Tillage effects on soil properties, diseases, cyst nematodes, and soybean yields. J. Soil Water Cons. 38:374-376.

Upchurch, D. R. and J. T. Ritchie. 1983. Root observations using a video recording system in mini-rhizotrons. Agron. J. 75:1009-1015.

Voorhees, W. B. 1992. Wheel induced soil physical limitations to root growth. p. 73-95 In J. L. Hatfield and B. A. Stewart (eds.) Advances in Soil Science: Limitations to Plant Root Growth. Springer-Verlag New York Inc., New York.

Wagger, M. G. and H. P. Denton. 1989. Influence of cover crop and wheel traffic on soil physical properties in continuous no-till corn. Soil Sci. Soc. Am. J. 53:1206-1210.