Influence of Long-Term No-Tillage on Crop Rooting in an Ultisol

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The Ultisols predominantly found in Georgia are sandy in texture with poorly developed structure. Our previous research has shown that continuous no-tillage over at least a 3-year period often results in greater bulk density and mechanical impedance in the soil surface (0 to 4 inches) compared to conventional tillage (NeSmith et al., 1987a,b; Tollner et al., 1984). Due to the sandy texture, low organic matter content, and poor structural stability, the surface soil tends to compact under no-tillage. However, it has been our observation that in long-term (11 years) no-tillage plots on a Cecil soil, summer crop performance has been good in years 5 through 11 even though dense compacted layers are present. It is our hypothesis that some large continuous pores through the compacted layers have been established and preserved through no-tillage management, which has allowed root proliferation into the subsoil.

Efforts to characterize the soil physical condition and, in particular, the pore size distribution, in these long-term studies have been made and are described in a companion paper in these Proceedings (Golabi et al., 1988). Results indicated that conventional tillage provided a superior rooting environment due to less density and mechanical resistance. This is difficult to reconcile with our observation of greater plant growth by summer crops with no-tillage. Greater soil water storage has also been documented with no-tillage compared to conventional tillage and may account for the greater plant growth (Golabi et al., 1988). However, the influence of soil compaction on root growth and the distribution of roots may influence the plant accessibility to the additional water stored under no-tillage.

The objective of this study was to measure doublecropped wheat ***(Triticum aestivum*** L.) and soybean ***(Glycine** max* L. Merr.) root growth in a long-term (11 years) field experiment comparing no-tillage and conventional tillage practices. Quantification of root growth was used to document whether the measured physical parameters indeed impede root growth.

Methods

This study was conducted in an on-going, long-term tillage study initiated in fall 1974. The experimental site was a Cecil sandy loam Typic Hapludult) located near Griffin, GA, which had been doublecropped to either wheat and soybeans or wheat and grain sorghum [*Sorghum bicolor* (L.) Moench] for 11 years prior to these observations. A detailed description of the experimental design and management of the study can be found in Hargrove et al. (1982). Briefly, the treatments were either continuous moldboard tillage (CT) or continuous no-tillage (NT) for all of the 11 years prior to these observations. The tilled treatment was plowed both before planting wheat and again before soybean.

Wheat (cv. Stacy) was planted on November 5, 1986 in 10-inch rows. The entire experimental area received 550 lb/acre of 10-20-30 fertilizer prior to planting. An additional 45 lb of N/acre as ammonium nitrate were applied as a topdressing on March 4, 1987. Wheat grain was harvested on June 4. Due to rainy, wet weather in June, tillage treatments were not conducted nor soybeans planted until June 30. Soybeans were harvested on October 29.

Measurements of roots were made using a video camera/minirhizotron technique described by Upchurch and Ritchie (1983). Minirhizotron tubes were installed as described by Box and Johnson (1987) on December 10, 1986, for the wheat crop and on July 15 for the soybean crop. Root counts were made February 10, March 11, April 22, and May 5 for wheat, and August 2, 19, and 31, and September 20 for soybeans. Wheat top growth and soil water content were also measured on March 8 and 23. Soybean top growth and soil water content were measured August 4, 20, and 31, and September 9.

Results and Discussion

Wheat root counts per 4-inch depth increment for each of four dates are shown in Figures 1-4. On the first date (February 10) the plowed soil had a significantly greater root density on the face of the minirhizotrons than the no-till soil at a depth of 4 to 12 inches (Figure 1). Cone index measurements indicated the presence of a compacted zone at a depth of 4 to 8 inches in the NT treatment (Golabi, et al., 1988). Also, bulk density was significantly greater at this depth under NT compared to CT (1.60 vs 1.40 g/cm^3). This, coupled with the generally greater water content of the NT soil and cooler soil temperatures as a result of mulch cover, increases the likelihood of significant oxygen stress and/or root disease caused by *Pythium* spp. in the NT soil.

On the next measurement date (March 11), no significant differences were found for root counts, although the plowed

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soil had slightly higher root counts again in the 4 to 12-inch soil depth (Figure 2). On the two subsequent dates (April 22 and May 5), a proliferation of roots occurred in the surface 8 inches of the NT soil (Figures 3 and 4). The NT treatment also had more roots than the CT treatment at soil depths between 16 and 40 inches, though the numbers were not statistically significant. It was apparent that plants continued to produce roots during reproductive development in the NT treatment; whereas, the plants did not in the CT treatment. This partitioning of carbon to root growth during anthesis and grain formation is probably a detriment to grain yield.

Soybean root counts per 4-inch depth increment are shown for four dates in Figures 5-8. Initially, root counts were not very different between CT and NT with the exception that CT had more roots between a depth of 8 and 12 inches (Figure 5). By August 19 (about the time of flower initiation), the CT treatment had considerably more roots in the surface 16 inches of soil (Figure 6). We surmise that this was a result of low mechanical impedance in the plowed soil and a relatively high soil moisture content, which resulted from several small rainfall events during the first 2 weeks of August (3 inches total in five events). However, by the next measurement on August 31 and on September 20, the NT treatment had significantly more roots in the surface 12 inches of soil and tended to have more roots (but not statistically significant) at depths greater than 24 inches (Figures 7 and 8). In fact, counts on August 31 (Figure 7) show a considerable decline for the conventional tillage treatment compared to 12 days earlier (August 19, Figure 6). We believe that root death occurred as a result of a period of about 4 weeks with no rainfall (August 11 to September 5) in which the soil surface dried rapidly. However, soil moisture data (not shown) in-

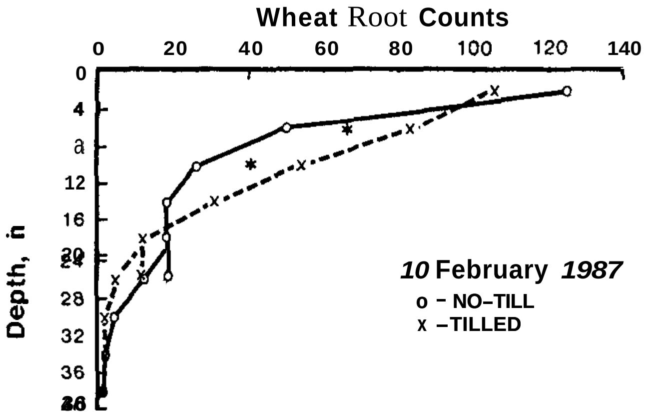

Figure 1. Wheat root counts per Cinch soil depth February 10, 1987. Asterisk (*) denotes a significant different at a = 0.05.

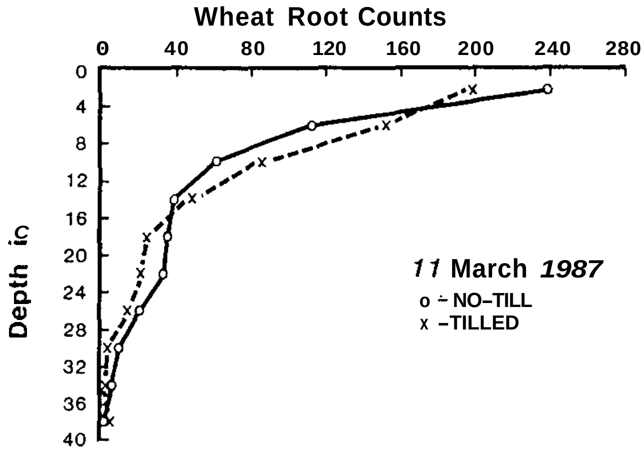

Figure 2. Wheat root counts per 4-inch soil depth March 11, 1987. Asterisk (*) denotes a significant difference at a= 0.05.

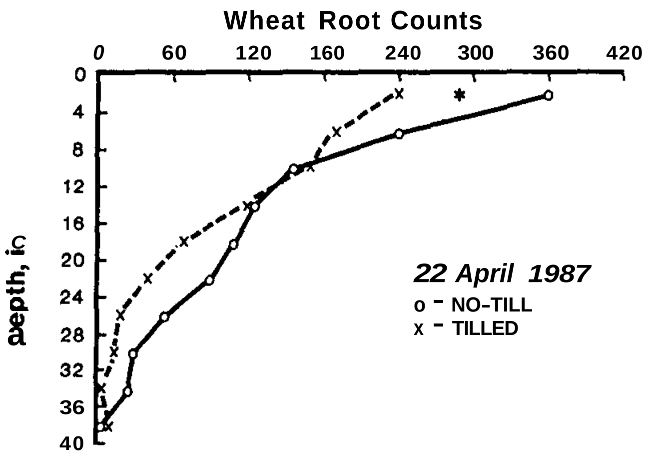

Figure 3. Wheat root counts per 4-inch soil depth April 22, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

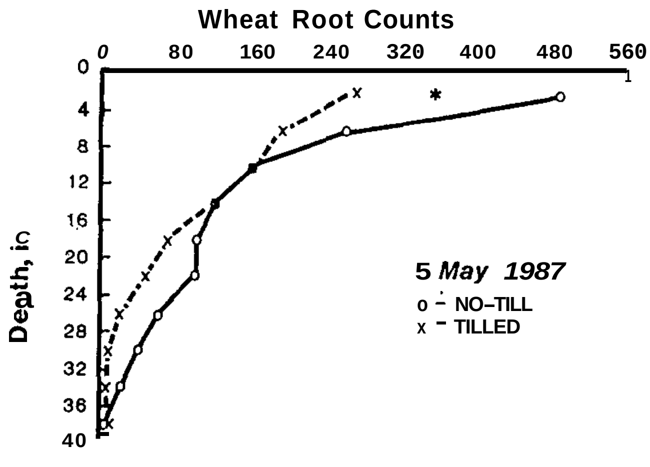

Figure 4. Wheat root counts per Cinch soil depth May 5, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

dicate that more water was stored under the no-tillage treatment. This apparently supported more root growth under the no-till treatment compared to the conventional treatment, but did not result in significant differences in top growth or N content (data not shown).

Perusal of crop yield data over the 10-year period of this experiment shows that for the summer crop, whether it be soybean or grain sorghum, NT results in greater yields than CT in years when significant moisture stress occurs (1979, 1981, 1983, 1985, 1986, 1987) and in equal yields in years when rainfall distribution is better (1982, 1984).

The reverse is true, however, for wheat. In years of high rainfall (1980, 1981, 1982, 1983, 1987), wheat yields were less with NT compared to CT, but in years with less than average rainfall in the winter and spring months (1984, 1985, 1986) yields were equal. The reason for less wheat yield with NT is probably related to a complex array of factors including oxygen stress, mechanical impedance, and root diseases (Box, 1986; Rothrock, 1986). In separate studies, fumigation with methyl bromide alleviated depressed wheat yields under NT, indicating the importance of root diseases. *Pythium* spp. were the most common pathogens isolated from roots of wheat seedlings and were isolated more frequently from plants under NT.

Results from this long-term experiment indicate that the greatest total production would be achieved with fall tillage prior to planting wheat in doublecropping followed by no-till soybeans or grain sorghum. Since the fall is the period of least erosion hazard in Georgia (because of less total rainfall and less rainfall energy), tillage should be done at this time to maximize production in doublecropping systems. No-till production of summer crops would both protect the soil from erosion and result in more rainfall capture for crop use.

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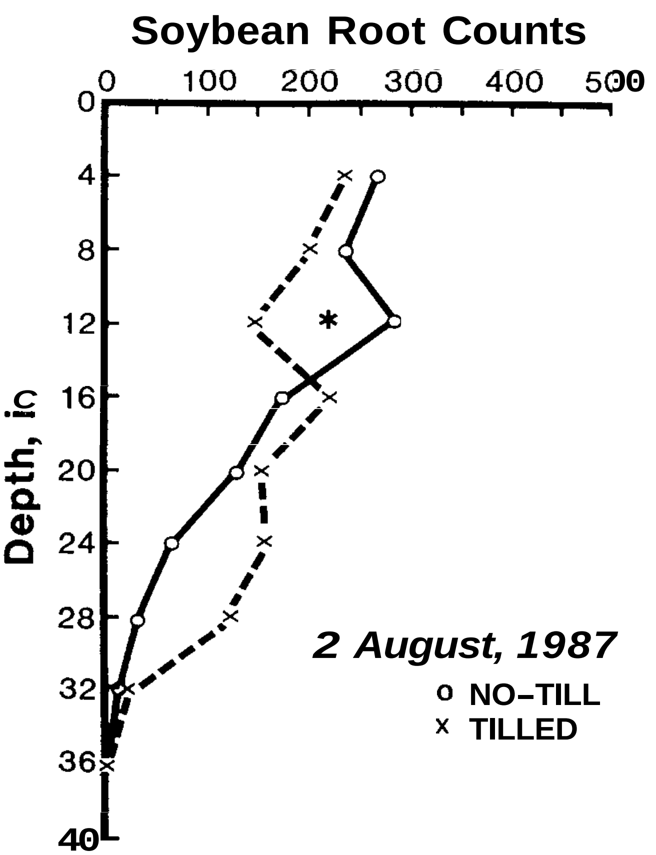

Figure 5. Soybean root counts per 4-inch soil depth August 2, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

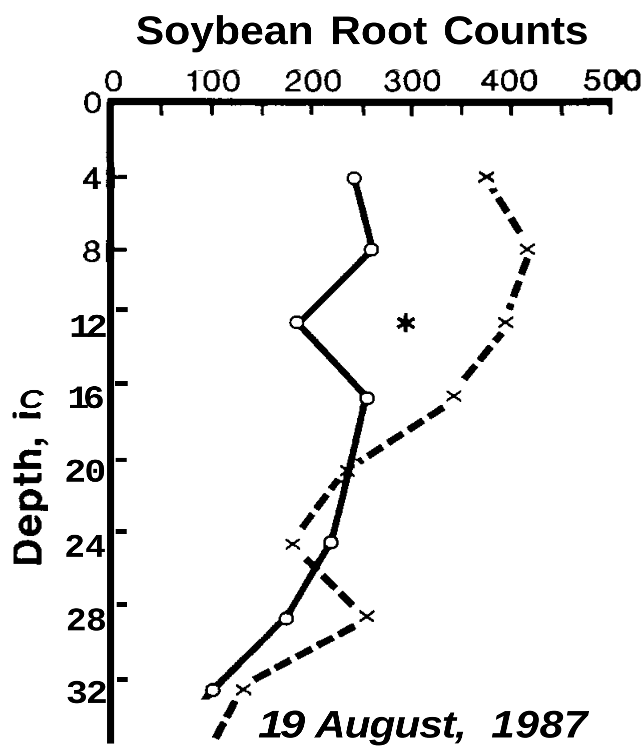

Figure 6. Soybean root counts per 4-inch soil depth August 19, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

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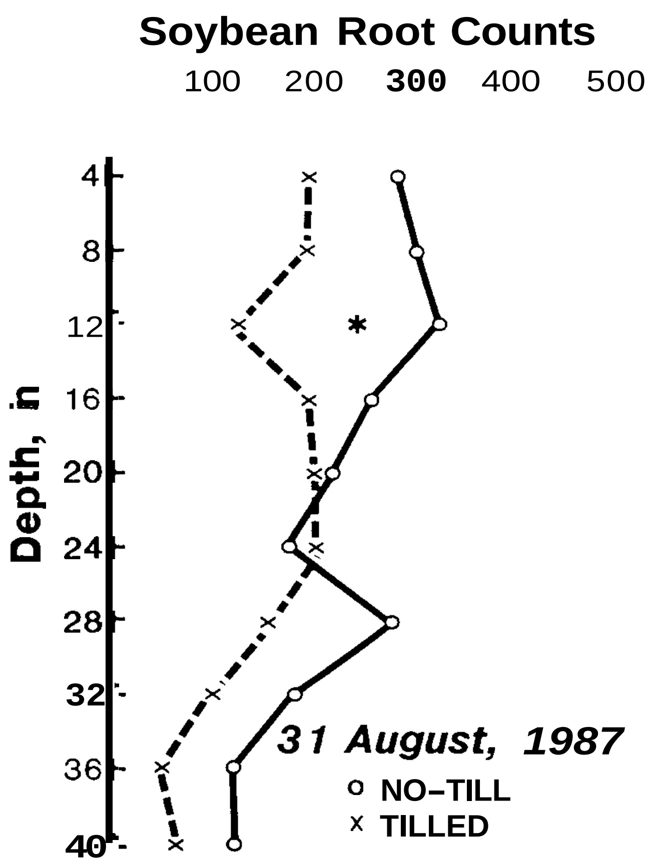

Figure 7. Soybean root counts per 4-inch soil depth August 31, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

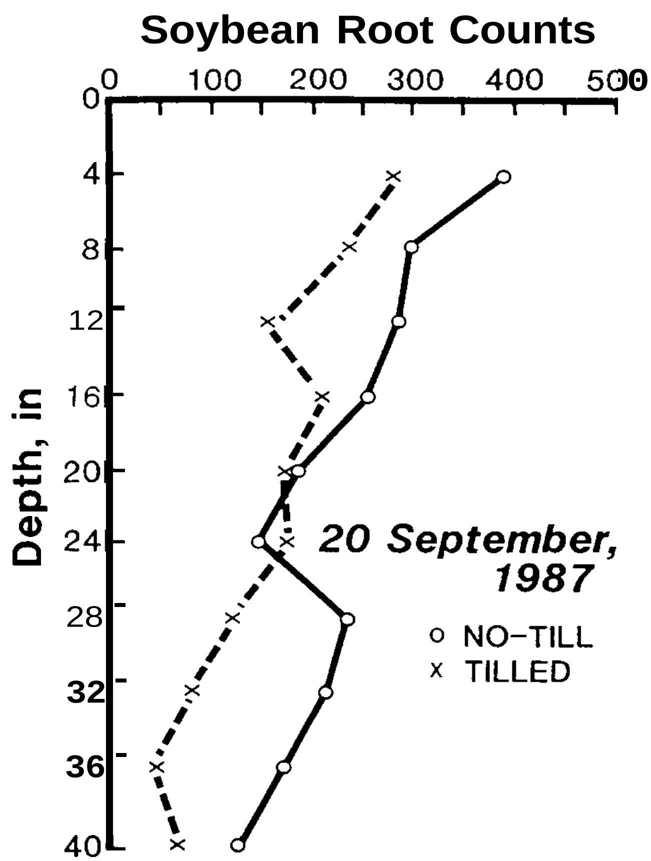

Figure 8. Soybean root counts per 4-inch soil depth September 20,1987. Asterisk (*) denotes a significant difference at $\alpha = 0.005$.