Interactive Effects of Wheel Traffic and Tillage System on Soil Carbon

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Introduction

The carbon-conserving nature of reduced or no-till soils as compared to conventionally tilled soils is well documented (Blevins et al., 1983; Havlin et al., 1990; Wood and Edwards, 1992). With no-till, plant residues remaining on the soil surface decompose more slowly, resulting in more carbon (C) being retained in the soil than when residues are incorporated into the profile (Holland and Coleman, 1987).

The negative effects of soil compaction on plant growth have been attributed primarily to a restriction of root growth. It has been suggested that soil compaction could affect the size and activity of the microbial biomass, and therefore, result in changes in cycling patterns of nutrients needed for plant growth (Griffin, 1978; Dick et al., 1988).

Soil compaction may affect microbial biomass dynamics via changes in available pore space (Dick et al., 1988). These microbial shifts lead to changes in rates of decomposition and mineralization of nutrients into plant available forms. However, there remains a lack of research investigating the biological effects of soil compaction and its interaction with tillage systems. The purpose of this study was to determine seasonal changes occurring in the cycling of C caused by to tillage and compaction.

Materials and Methods

This study was part of a continuing long-term (initiated in 1987) project designed to determine the interactive effects of tillage method and wheel traffic (compaction) on crop yields, crop quality, and soil properties. The study site soil is a Norfolk loamy sand (fine, loamy, siliceous, thermic Typic Kandiudult) located at the E. **V.** Smith Research Center of the Alabama Agricultural Experiment Station near Shorter, Alabama. Tillage and compaction treatments initiated in 1987 include conventional tillage (disk/field cultivate) and no-tillage, and wheel traffic or no-traffic, respectively. The experimental design is a randomized complete block with four replications arranged as a split plot. Wheel-traffic treatments are main plots, and tillage treatments are subplots.

The cropping system at the study site is a corn *(Zea mays* L.) 'Dekalb 689'-soybean *[Glycine max* (L.) Merr.] 'Delta and Pineland 105' rotation with crimson clover *(Trifolium incarnutum* L.) as a winter cover crop. The study reported here was conducted during June 1993 to June 1994 to determine seasonal dynamics of soil organic C, respiration, and microbial biomass C as impacted by tillage system and compaction. Soybean was the summer crop of 1993, followed by a winter crimson clover crop. Corn was the summer crop of 1994.

Field activities were carried out using an experimental wide-frame tractive vehicle (WFTV) (Monroe and Burt, 1989). The WFTV spans the 6.1-m wide research plots and performs field operations without applying traffic to the plots. To simulate normal wheel traffic on traffickedplots, a 4.6-Mg tractor was utilized. The tractor was driven in trafficked plots during spring field preparation and planting, simulating operations used by a grower employing four-row equipment, i.e., every other row received wheel traffic.

Soil samples (0-20 cm depth) were collected biweekly during the growing season and monthly during the winter months for determination of microbial biomass C (Vance et al., 1987). Organic C was determined with a LECO CHN-6OO analyzer on soil samples (0-20 cm depth) collected in July and October of 1993, and in January and May of 1994. All samples or measurements were taken in row middles, and measurements made in trafficked plots were taken in row middles that had received wheel traffic.

Soil respiration was measured biweekly during the growing season and monthly during the winter. Four measurements were taken per plot. Respiration was measured using an Environmental Gas Monitor (EGM) (PP Industries Stotford, Hitchin, Gertts SG5 4LA UK). Analyses of variance were performed using the SAS package (SAS Institute, 1988). Because time was a factor, data were analyzed as a split-split plot with wheel traffic as main plots, tillage as subplots, and time as sub-subplots. All statistical tests were performed at the *a=0.05* level.

Results and Discussion

After 6 years of tillage and traffic treatments, over all sampling dates, there were no significant differences in organic C concentrations attributed to tillage or wheel traffic (data not shown). This is contrasted by findings of a study conducted by Wood and Edwards (1992) in northern Alabama, which showed higher levels of soil organic C with reduced

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tillage (0-10 cm). Our findings also differ from those of Dick et al. (1988), who showed significantly lower levels of organic C (10-20 cm) as a result of compaction in skid trail soils.

Microbial biomass C (MBC) levels were significantly affected by the interaction of traffic, tillage, and sampling date (Figure 1). Data from this study suggest a trend for higher levels of MBC from conventional tillage (CT) than from no-tillage (NT) (Figure 1). However, there was no consistent effect observed from treatment interactions on MBC, except on sampling dates immediately following tillage (Figure 1).

Five measurements were taken in the 3 weeks immediately following tillage and traffic events to investigate immediate effects of tillage and compaction on MBC. Tillage method had a significant effect on MBC during 1994 field operations (Figure 2). CT soils had significantly higher levels of MBC than NT soils (Figure 2). Before wheel-traffic application, CT in combination with traffic (TRAF) had highest MBC levels immediately following tillage (Figure 2). Five and nine days later, MBC from the CT-TRAF treatment remained highest, though the difference was not significant (Figure 2). These results are similar to findings of Lynch and Panting (1980), who found higher microbial biomass (0-5 cm) following tillage compared to NT. However, their study showed higher microbial biomass from NT compared to CT during all other sampling dates in the 0-5 cm depth.

A study conducted by Dick et al. (1988) showed that compaction results in decreased MBC (10-20 cm). However, results from MBC measurements taken during our study have shown no detrimental effects on MBC owing to compaction. Biomass C has been shown to have significant negative correlations with bulk density (Dick et al., 1988). Van der Linden et al. (1989) found soil compaction to result in decreased available pore space, which slows the rate at which organic substrates are incorporated into and released from microbial biomass, on a silt loam soil but not on a loamy sand. Even though bulk densities from TRAF soils were significantly higher than nontrafficked (NONTRAF) soils in our study (data not shown), it appears that soil texture (loamy sand) played a significant role in lack of effects from compaction on MBC. Because of the coarse texture of this Coastal Plain soil, available pore space was apparently not decreased enough to affect MBC.

Soil respiration was significantly affected by tillage and there was a trend for a wheel-traffic effect. Conventional tillage soils had significantly higher rates of soil respiration than NT soils on many measurement dates (Figure 3). There was a trend for a traffic to decrease soil respiration, but response was dependent on time of wheel-traffic application.

In this study, soil respiration was stimulated by tillage, but CT soils maintained a higher level of soil respiration than NT soils over most of the observation period (Figure 3). Higher rates of soil respiration (C mineralization) from CT soils compared to NT soils should result in higher levels of organic C being retained in NT soils. However, as previously discussed, there were no significant differences in organic C between CT and NT soils.

Eight soil respiration measurements were taken immediately encompassing tillage and traffic events to monitor direct effects of tillage and traffic on soil respiration. Equipment failure delayed the first measurement to 6 days after tillage had occurred. Soil respiration was influenced by a significant traffic x tillage x measurement date interaction. A large flush of CO_2 was observed 8 days following the tillage operation and 2 days following wheel-traffic application for the

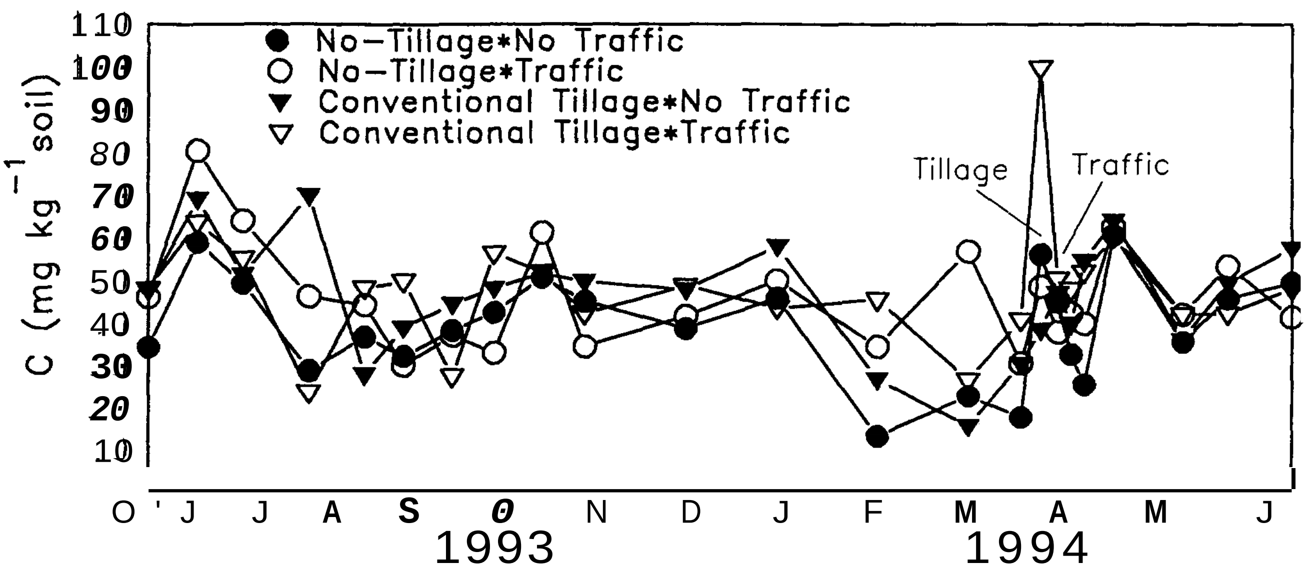

Figure 1. Microbial biomass C concentrations as affected by traffic, tillage, and sampling date for 1993-1994. $LSD_{0.05}$ =260 for comparison of two traffic means at the same combination of tillage treatment and day. $LSD_{0.05}$=25.1 for comparison of two tillage means at the same combination of traffic treatment and day. $LSD_{0.05}$=24.1 for comparison of 2-day means at the same combination of traffic and tillage.

CT soils (Figure 4). This flush fluctuated but remained significantly higher than that observed in NT soils. These results agree with the hypothesis of Blevins et al. (1984) concerning the immediate effect of tillage, but soil respiration was equal or higher from CT soils comp ared to NT soils over the remainder of the observation period (Figure 3).

Compaction was expected to slow soil respiration, but on these soils the effect of compaction appeared to be dependent on measurement date. Mean bulk density was 1.61 Mg m^{-3} for CT-TRAF soils and 1.32 Mg m^{-3} for CT-NONTRAF soils. In September 1993, CT-NONTRAF soils had a higher rate of soil respiration than CT-TRAF soils (Figure 3). This also occurred 5 days after traffic was applied and again in June 1994 (Figures 3 and 4). Immediately following the April 1994 wheel-traffic application, soil respiration was significantly higher from CT-TRAF soils compared to CT-NONTRAF soils (Figure 4). Soil respiration was significantly higher from CT-TRAF soils than CT-NONTRAF soils 2, 3, and 7 days after traffic application, but **5** days after traffic there was a large flush of CO, from CT-NONTRAF soils (Figure 4).

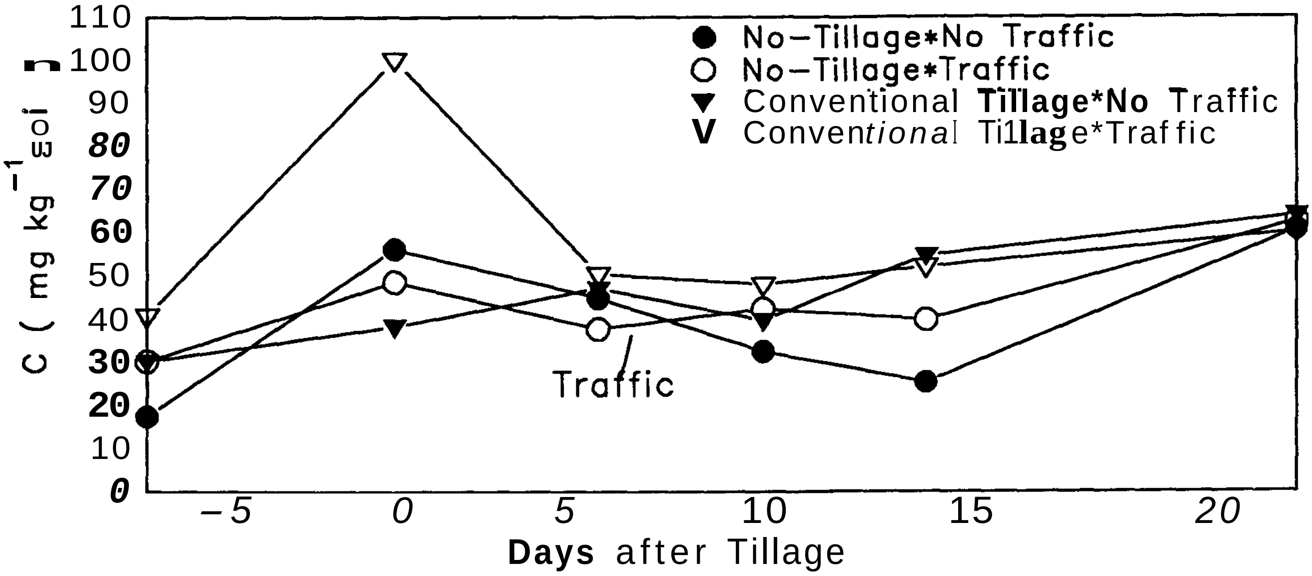

Figure 2. Microbial biomass C concentrations as affected by traffic, tillage, and sampling date during 1994 tillage and wheel-traffic operations. **$LSD_{0.05}$=31.6** for comparison of two traffic means at the same combination of tillage treatment and day. **$LSD_{0.05}$=24.6** for comparison **of** two tillage means at the same combination of traffic treatment and day. **$LSD_{0.05}$=25.2** for comparison **of** 2-day means at the same combination of traffic and tillage treatments.

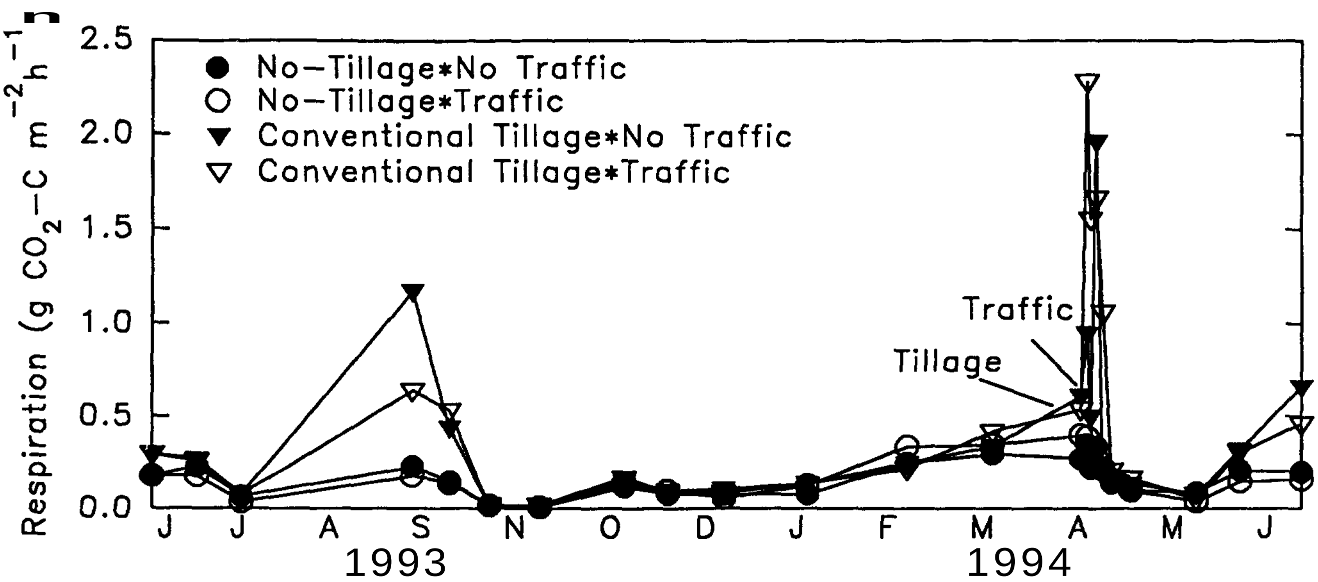

Figure 3. Soil respiration rates **as** affected by traffic, tillage, and sampling date for 1993-1994. **$LSD_{0.05}$** =0.18 **for** comparison of two traffic means at the same combination of tillage treatment and day. **$LSD_{0.05}$=0.17** for comparison of two tillage means at the same combination of traffic treatment and day. **$LSD_{0.05}$=0.17** for comparison of 2-day means at the same combination of traffic and tillage.

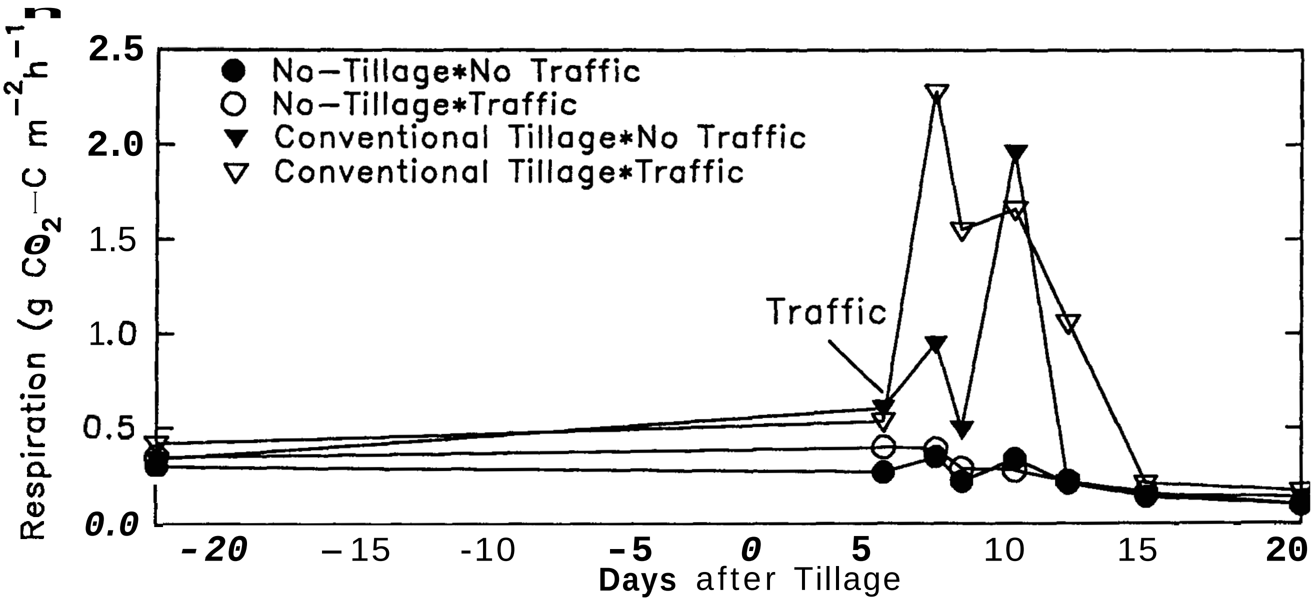

Figure 4. Soil respiration rates as affected by traffic, tillage, and sampling date during 1994 tillage and wheel traffic operations. $LSD_{0.05}$ =0.29 for comparison of two traffic means at the same combination of tillage treatment and day. $LSD_{0.05}$=0.25 for comparison of two tillage means at the same combination of traffic treatment and day. $LSD_{0.05}$=0.21 for comparison of 2-day meam at the same combination of traffic and tillage treatments.

It appears that immediate traffic effects on microbial activity had decreased or disappeared by 10 to 15 days after wheel traffic was applied. Soil respiration could have been increased in CT-TRAF soils via increased soil-substrate contact. The flush of microbial activity that occurred 11 days after tillage from CT-NONTRAF soils (Figure 4) could have resulted from incorporation of organic substrates. This flush may have been delayed compared to CT-TRAF soils because there was a lack of traffic induced contact with soil microorganisms.

Conclusions

Although respiration was significantly greater from CT soils than from NT soils, soil organic C was unaffected by tillage or traffic treatments. Microbial biomass C showed no consistent effect attributable to traffic and tillage treatments, which agrees with organic C data. Both tillage and wheel traffic stimulated soil respiration during April 1994 field operations, but wheel traffic did not cause increased soil respiration during other measurement periods as did tillage.

Surprisingly, compaction due to wheel traffic had no negative effect on microbial biomass carbon. It is believed that the coarse texture of this Coastal Plain soil played a significant role in the lack of negative impacts due to traffic-induced compaction on soil C.

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