THE GREATER CARBON SEQUESTRATION IN NO-TILL SOILS DEPENDS UPON ITS DISTRIBUTION WITH DEPTH

M. Diaz-Zorita[1,2] and J.H. Grove[2]

AUTHORS: [1]EEA INTA General Villegas, CC 153 (6230) General Villegas (BA), Argentina and [2] University of Kentucky, Dep. Agronomy, N-122 Ag. Sci. Center N, Lexington, KY 40546-0091. Corresponding author: M. Diaz-Zorita (mdzori2@pop.uky.edu).

ABSTRACT

Soil organic matter (SOM) storage in agricultural soils has a significant effect not only on productivity but can also ameliorate the greenhouse effect via atmospheric CO2 sequestration. Several reports show a larger accumulation of SOM in the top layer of soils under no till (NT) practices but no significant differences with respect to soils under chisel till (CT) when deeper layers are considered. Our objective was to determine the effects of tillage practices upon the SOM distribution with depth in Maury silt loam soils (Typic Paleudalfs) at a similar level of crop residue production. The study used selected plots with similar corn productivity from three tillage experiments at the University of Kentucky's "Spindletop" Experiment Farm. Soil samples (0 to 8 inches in 1-inch increments) and above ground residues were taken in June and November of 1999 and expressed as levels of carbon (SOC = SOM x 0.58, $C_{residue}$ = Residue dry weight x 0.40). The bulk density (BD) of each layer was estimated from resistance to penetration measurements. A significant positive difference in C levels from June to November was observed only in the residue cover of all tillage treatments and in the 0- to 1-inch layer of NT soils. Our results confirm the positive effect of NT on the surface (0 to 1 inch) storage of C in agncultural soils, but only after a decade of continuous NT. Although the BD of deeper layers (6 to 8 inches) in NT was greater than in moldboard till (MT) soils, greater C was observed in those layers under MT than under NT. The C stored in the soil explained the differences in C storage between tillage practices, and it was maximal under either CT or NT soil management practices.

INTRODUCTION

Soil organic matter (SOM) storage in agricultural soils has a significant effect not only on productivity but can also ameliorate the greenhouse effect via atmospheric CO_2 sequestration. Although the degree of SOM loss due to cultivation of soil tends to decrease as the intensity of tillage decreases, there are not clear differences in SOM storage among conservation tillage practices. Several reports show a larger accumulation of SOM in the top layer of soils under no till (NT) practices but no significant differences with respect to soils under chisel till (CT) when deeper layers are considered. The amount and quality of the residues have been proposed as significant factors controlling total SOM storage in agricultural soils (Paustian et al. 1997; Diaz-Zorita and Grove, 1999a).

Our objective was to determine the effects of tillage practices upon the SOM distribution with depth in Maury silt loam soils (Typic Paleudalfs) at a similar level of crop residue production.

MATERIALS AND METHODS

The study was performed in different tillage experiments (Table 1) at the University of Kentucky's "Spindletop" Experiment Farm near Lexington, KY on Maury silt loam soils. The plots were selected in order to give different durations of comparative tillage treatments at similar levels of corn productivity between tillage treatments within each experiment.

Table 1: Characterization of the tillage experiments used in the study.

Experiment	B123	B166	F19
Initiation (year)	1970	1991	1996
Tillage treatments	NT-MT	NT-CT-DT-MT	CT-NT1-NT2
$N_{fertilizer}$ rate (lb N/A)	150	134	118
Crop sequence	CCC	CCC	C-S-W/S
Winter Cover crop	Rye	Rye	No

References: NT = no till, MT = moldboard till, CT = chisel till, DT = disk till, NT_1 = 1 year of NT after CT, NT_2 = 2 years of NT after CT. C = Corn, S = Soybean, W/S = Wheat/Double-Crop Soybean

In each plot, soil samples were taken in l-inch increments from the surface to a depth of 8 inches in June and November 1999. After air drying and crushing to pass a 0.08-inch sieve, the SOM on each soil was determined by dry combustion. Two days after an intensive rainfall, the resistance to penetration (Eijelkamp Penetrologger) of the moist soil was measured in 0.4-in increments from 0 to 8 inches. The bulk density (BD) of the soils was estimated using a relationship between BD and penetration resistance (PR) determined for these soils under similar moisture conditions (Diaz-Zorita and Grove, 1999b).

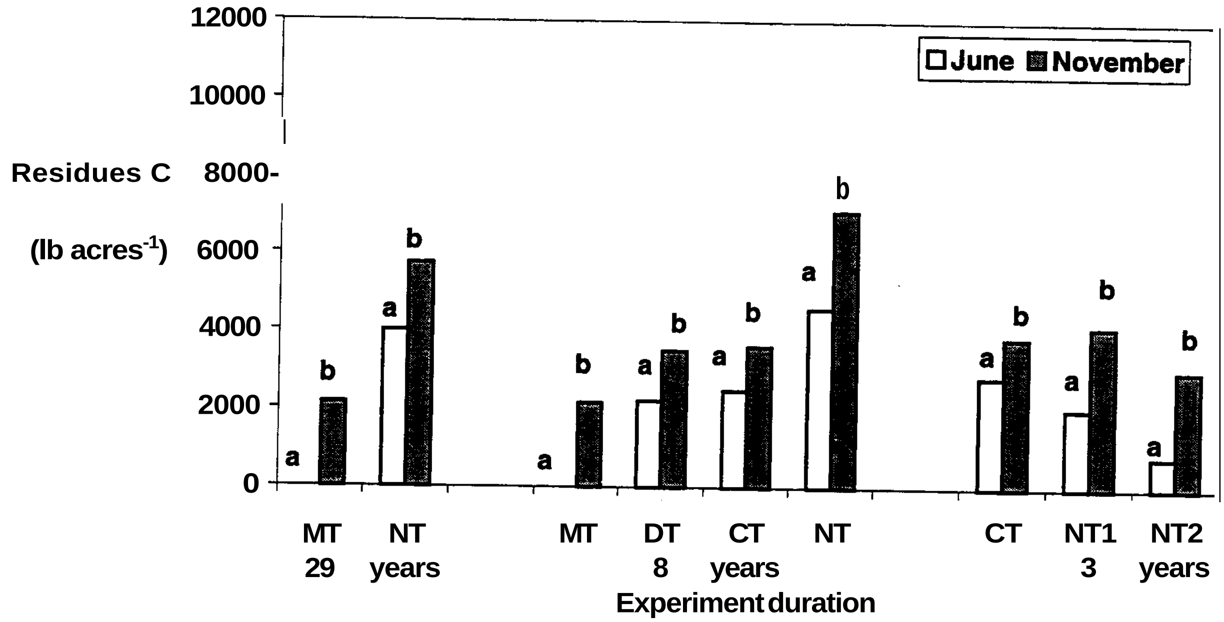
The total amount of soil organic carbon (SOC) per unit surface area was calculated from the product of estimated BD, the depth of sampling (1 inch) and considering 58.1% of the SOM to be organic C (SOC, Walkley and Black, 1934). The amount of residues was determined in June and November by collecting and weighing the residue pieces larger than 0.08 inch found in 1.94 ft^2 of plot surface. The C content of the residues was assumed to be 0.40 of its dry weight (Collins et al. 1999).

The SOC and PR results from each experiment were analyzed using appropriate analysis of variance procedures (SAS PROC MIXED, 1996), considering each experiment as a randomized block with four replications, split for sampling depth and sampling date.

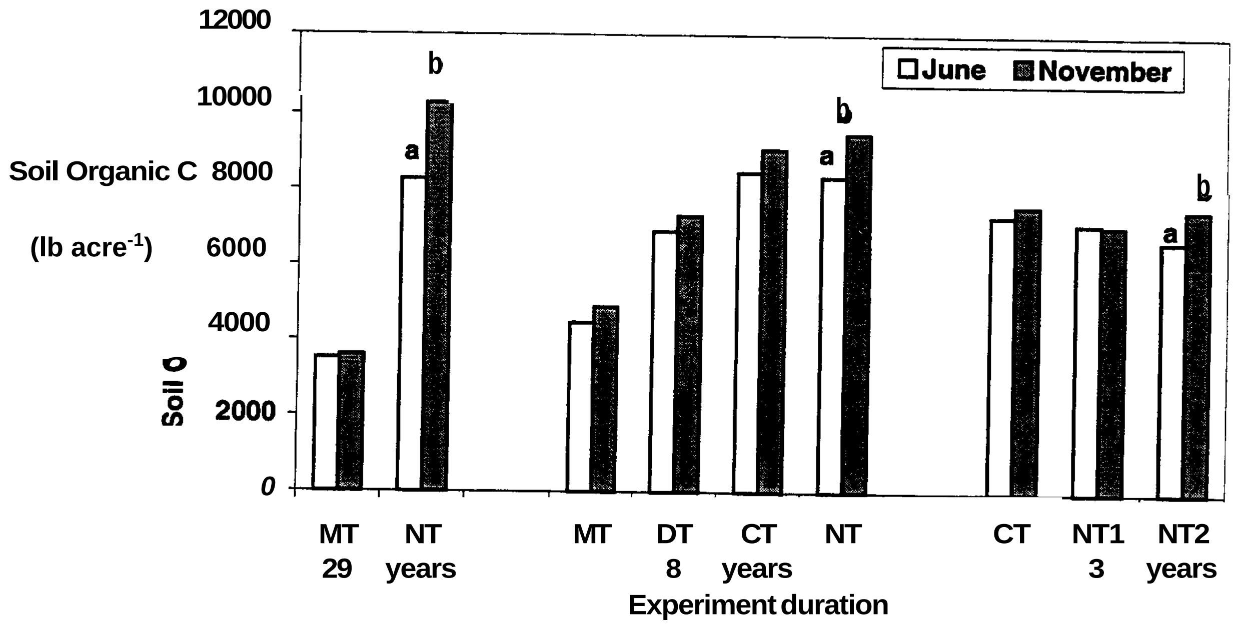
RESULTS

The amount of C in the residue layer and in the 0- to l-inch depth of NT soils was greater in November than in June (Fig. 1). The average difference in dry weight of the above ground residue levels between sampling dates (4822 lb/A) was independent of the tillage system. No significant effects of sampling date on the SOC in tilled soils and below 1 inch in the NT treatments were observed.

Figure 1 (next page): Effect of sampling date and tillage practice on residue C and soil organic C levels in the 0- to l-inch layer of Maury silt loam soils. NT = no till, MT = moldboard till, CT = chisel till, DT = disk till, NT_1 = 1 year of NT after CT, NT_2 = 2 years of NT after CT. The same letter or the absence of letters at the top of each bar indicates there was no significant difference ($p < 0.05$) between sampling dates within each tillage treatment.



June
November
Residues C
(lb acres-1)
12000
10000
8000
6000
4000
2000
0
MT
NT
29
years
MT
DT
CT
NT
8
years
CT
NT1
NT2
3
years
Experiment duration



June
November
Soil Organic C
(lb acre-1)
Soil C
12000
10000
8000
6000
4000
2000
0
MT
NT
29
years
MT
DT
CT
NT
8
years
CT
NT1
NT2
3
years
Experiment duration

Although the PR values in MT treatments were significantly lower than those in soils under NT, CT, or DT practices (Table 2), greater SOM contents were sometimes observed in deeper layers of MT treatments (Fig. 2). This behavior confirms the positive effect of NT practices on SOM accumulation in surface soil layers, suggesting a vertical redistribution of organic materials.

Table 2: Effect of four tillage systems in three tillage studies on the soil penetration resistance values (lb/in2) of a Maury silt loam soil. NT = no till, MT = moldboard till, CT = chisel till, DT = disk till, NT, = 1 year of NT after CT, NT2=2 years of NT after CT. Different letters at a given depth in the same experiment indicate a significant difference ($p < 0.05$) between tillage practices.

	Experiment duration								
Depth	29 years		8 years				3 years		
(inches)	MB	NT	CH	DT	MB	NT	CH	NT_1	NT_2
0 – 1	132a	103a	141a	42b	36b	91a	135a	131a	104a
1 – 2	249a	218a	262a	90b	100b	261a	260a	236a	218a
2 – 3	307a	315a	376a	212b	204b	407a	349a	309a	332a
3 – 4	296a	342b	418a	302b	249b	397a	381a	344a	357a
4 – 5	286a	386b	525a	396b	271 c	368b	380a	370a	355a
5 – 6	299a	394b	596a	423b	270c	368b	347a	355a	341a
6-7	329a	367a	587a	431b	245c	358b	320a	335a	351 a
7-8	348a	351a	571 a	439b	274c	352b	309a	342a	347a

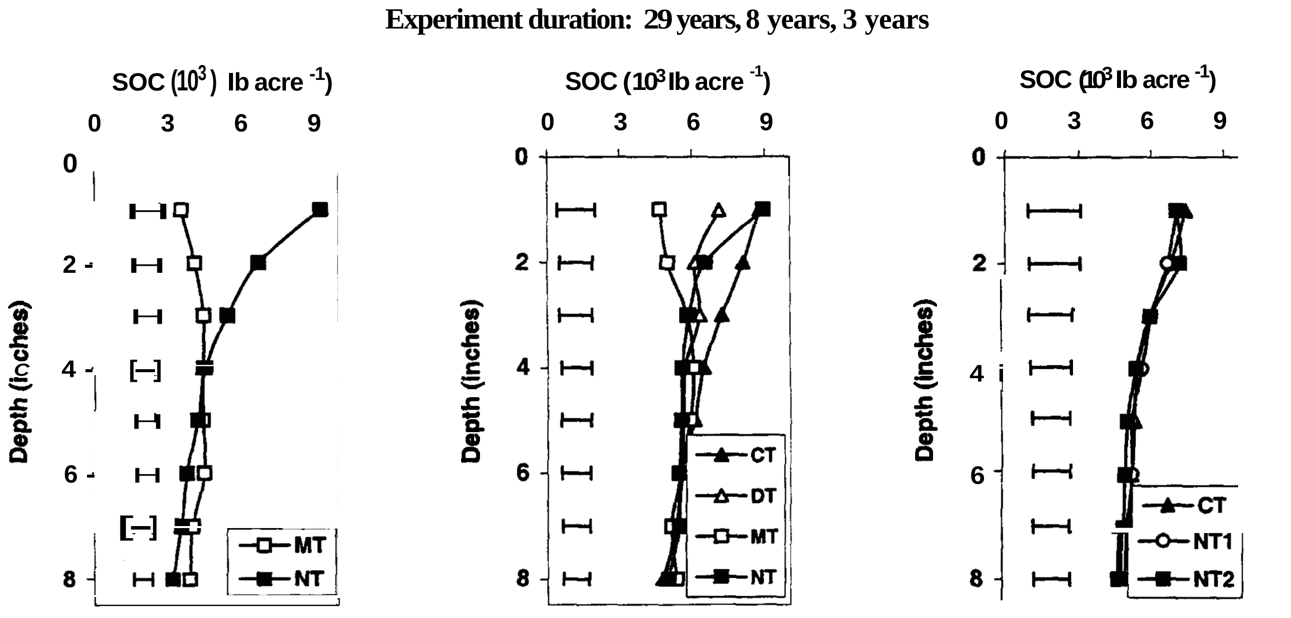


Fig. 2: Effect of four tillage systems in three tillage studies on the SOC storage in a Maury silt loam soil. Average of two sampling dates.

On average, greater C storage was observed in NT and CT treatments than in MT treatments. The differences in C accumulation between tillage practices were independent of the inclusion of the residue cover in this calculation (Table 3). This behavior suggests that the tillage effect on the absolute amount of C storage in this soil is somewhat independent of the amount of residue cover. Given a similar amount of C input from roots and above ground crop residues, differences in SOC between tillage practices can be achieved as a consequence of the promotion of SOC losses due to mineralization after aeration, breakdown, and mixing in intensively tilled systems such as MT.

Table 3: Carbon storage (1000 lb/A) in Maury silt loams under four different tillage systems in three tillage studies of different duration. Different letters in each evaluation indicate significant differences ($p<0.05$) between tillage practices in each experiment.

	Experiment duration								
	29 years		8 years				3 years		
Evaluation	**MT**	**NT**	**MT**	**DT**	**NT**	**CT**	**CT**	**NT1**	**NT2**
Soil and residue C	34.5 a	45.6 b	44.5 a	49.4 ab	54.2 bc	55.4 c	49.6 a	48.6 a	47.9 a
Only soil C	33.4 a	40.8 b	43.4 a	46.5 ab	48.4 bc	52.3 c	46.3 a	45.5 a	45.1 a

The differences in total soil C storage between MT and NT systems increased as the duration of the tillage comparison increased, as did the depth to which these significant differences in SOC between MT and NT treatments were expressed (Fig. 2 and Table 3). No significant differences in SOC level and in its vertical distribution were observed between tillage practices in the 3-year-old experiment (Fig. 2 and Table 2).

CONCLUSIONS

These results confirm the positive effect of NT on the surface (0- to 1-inch) storage of SOC in agricultural soils but only after a decade of continuous NT.

Short-term (within a season) C storage differences were only observed in the surface layer of NT soils and in the above ground residues.

Maximum SOC accumulation was obtained either under CT or NT soil management.

REFERENCES

Collins, H.P., R.L. Belvins, L.G. Bundy, D.R. Christiensen, W.A. Dick, D.R. Huggings, and E.A. Paul. 1999. Soil Carbon Dynamics in Corn-based Agroecosystems. Results from Carbon-13 Natural Abundance. Soil Science Society of America Journal 63: 584-591.

Diaz-Zorita, M. and J. H. Grove. 1999 a. Crop Sequence Effects on the Properties of Two Soils from Disparate Temperate Regions under Continuous No-Tillage Management. ASA, CSSA and SSSA Annual Meeting Abstracts, 281.

Diaz-Zorita, M., and J.H. Grove. 1999b. Effects of crop sequences under continuous no tillage management on the soil compaction of a Paleudalf. ASA, CSSA and SSSA Annual Meeting Abstracts, 292-293.

Paustian, K., H.P. Collins, and E.A. Paul. 1997. Management controls on soil carbon. In. E. A. Paul, K. Paustian, E. T. Elliott, and C. V. Cole (Eds.), Soil Organic Matter in Temperate Agroecosystems. CRC Press, Boca Raton. pp. 15-49.

SAS PROC MIXED. 1996. The SAS System for windows. Release 6.12. SAS Institute Inc., Cary, NC.

Walkley, A. and T.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and proposed modification of the chromic acid titration method. Soil Science 37: 29-38.