Soil Organic Matter in Long-Term Tillage and Cropping System Studies

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Abstract

Some reports advocate that no-tillage (NT) management builds up soil organic matter (SOM) compared with conventional tillage, (CT) while others disagree for some environments. The purpose of this study was to determine the influence of cropping history and soil type on changes in SOM as affected by long-term NT and CT treatments. Three soil types and six cropping systems from seven experiments in Florida and Argentina were included in this study. Soils samples were collected in 2 in. increments from the 0 to 6 in. depth and in a 6 in. increment from the 6 to 12 in. depth in all seven experiments. In every treatment of all experiments SOM decreased progressively with increasing soil depth. No-tillage was higher in SOM near the soil surface compared to CT. Amounts of SOM between tillage was greater for NT in four or seven cropping systems studies when averaged over the 0 to 12 in. depth suggesting that NT may build up SOM in most cases compared to CT. Build up of SOM in the soil surface layer is offset by a proportionate loss in the lower depths within the 0 to 12 in. sampled area for some cropping systems.

Introduction

Minimum tillage and double-cropping systems are being adopted rapidly by the agricultural community in the U.S. and other countries. Minimum tillage is described as "Planting directly into an unprepared seed-bed and the elimination of tillage operations through harvest, whereas, multiple-cropping is growing two or more crops in the same year on the same land area" (Gallaher, 1979a).

The increasing use of minimum-tillage and double-cropping in the southeastern U.S. requires a better understanding of their effect on soil organic matter (SOM) content (Gallaher, 1979b). Several authors (Corella, 1989; Gallaher, 1979b; Gallaher and Ferrer, 1987; Gallaher. et al., 1987: Ortiz and Gallaher, 1984) report that the amount and distribution of SOM from decay of residues will be altered after several years in a reduced-tillage system. Two Indiana studies (Cruz. 1982; Fernandcx, 1976) on soils differing widely in natural SOM content. showed that SOM increased near the soil surface (0 to 4 in.) with reduced tillage, and was maintained or increased slightly below the 4 in. soil depth with no-tillage (NT) treatments compared with conventional tillage (CT) treatments at the 0 to 2 in. depth in a 6 yr-old experiment. Ortiz and Gallaher (1984) found that NT treatments had 11%' more SOM than CT treatments in the 0 to 2 in. depth. Accumulation of SOM in the top 4 in. was reported by Gallaher, (1979b); and Gallaher and Ferrer (1987).

In Ohio (Dick, 1983) the increase in SOM for NT over CT was 2.5 times on a dark silty clay loam and 2.2 times on a light-colored slit loam. Below the 3 in. soil depth, SOM was about equal for the two systems on the light soil, but was reduced for NT on the dark soil, possibly through restricted rooting. Research in Kentucky (Blevins et al., 1977) showed that the SOM level in the top 2 in. of soil under an original bluegrass (*Poa pratensis* L.) sod was reduced only slightly after *5* yr of continuous corn *(Zea mays* L.) when NT, cover crops, and high fertility levels were used. Moldboard plowing reduced SOM by 4.6% in the 0 to *2* in. layer. Different cropping systems affected the C and N status of soil in a short time period (Sprague and Triplett, 1986). In general, systems returning small amounts of residue resulted in larger losses of C and N than systems returning large amounts of residue.

The purpose of this study was to determine the influence of cropping history and soil type on changes in SOM as affected by long-term NT and CT treatments.

Materials and Methods

Three soil types and six cropping systems from seven long-term experiments in Florida and Argentina were included in this study. The three experimentss from Argentina were under investigation by INTA (Instituto Nacional de Techologia Agricola) at Marcos Juarez, Cordoba. The four experiments from Florida were under investigation by the Inst. of Food and Agr. Sci., Gainesville, and Williston, FL. Experiments from Argentina were from a Typic Agriudoll soil and included: 1) an 11 yr-old monocrop corn *(Zea mays* L.) study, 2) a 10 yr-old monocrop soybean *(Glycine max* L. Merr) study, and 3) a 6 yr-old wheat *(Triticum aestivum* L.)/soybean double cropping study. Three of the four Florida experiments were conducted on Grossarenic Paleudults near Gainesville and included: 1) a 10 yr-old rye *(Secale cereale* L.)/summer crop (grain sorghum, *Sorghum bicolor* L. Moench) the first 4 yr or corn the last 6 yr) study. 2) an 11 yr-old oatigrain sorghum study, and *3)* an 11 yr-old oat/soybean study. The fourth Florida experiment was on a Typic Haplustalf, located at Williston, and was a 6 yr-old monocrop corn study.

All seven experiments had randomized complete block designs and had the same NT and CT variables in common. In all cases the soil samples were taken in the fall of the year at the end of the growth of the summer crop and just prior to plowing CT plots. In each experiment soil samples were taken in 2 in. increments from the 0 to 6 in. depth and in a 6 in. increment from the 6 to 12 in. depth. Samples were air dried, ground, and sieved to pass a 2 mm stainless steel screen. The Potassium Dichromate procedure (Walkley. 1947; Allison, 1965) was used to determine SOM on three replications from each experiment. The statistical analysis was done using MSTAT (1987 version 4.0).

Results and Discussion

In all seven experiments SOM decreased with soil depth for both tillage treatments, hut the decrease was more pronounced in NT (Tables 1 and 2). No-tillage was higher in

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Table 1. Effect of tillage, soil depth, cropping system and soil type on soil organic-matter.

Cropping System	Loc.	S. Type	Depth	NT	CT		Difference
			-- in.	----------------	%	---------	-----
Corn monocrop	ARC	Mollisol	0 - 2	3.27a	2.94a	*	+0.33
			2 - 4	2.88 b	2.85a	NS	+0.03
			4 - 6	2.57 c	2.45 b	NS	+0.12
Corn monocrop	FLA	Alfisol	0 - 2	1.99a	1.59a	*	+0.40
			2 - 4	1.64 h	1.33 b	*	+0.31
			4 - 6	1.49 c	1.19 c	*	-0.30
Rye-summer crop	FLA	Ultisol	0 - 2	2.05a	1.62a	*	+0.43
			2 - 4	1.41 b	1.32 b	*	+0.09
			4 - 6	1.14 c	1.32 b	*	-0.18
Wheat-soybean	ARC	Mollisol	0 - 2	3.44a	2.89a	*	+0.55
			2 - 4	2.68 b	2.80a	*	-0.12
			4 - 6	2.43 c	2.70 h	*	-0.27
Soybean monocrop	ARG	Mollisol	0 - 2	3.36a	2.94a	*	+0.42
			2 - 4	2.72 b	2.73 b	NS	-0.01
			4 - 6	2.36 c	2.53 c	*	-0.17
Oat-soybean	FLA	Ultisol	0 - 2	2.55a	2.05a	*	+0.50
			2 - 4	1.51 b	1.69 b	*	-0.18
			4 - 6	1.16 c	1.49 c	*	-0.33
Oat-sorghum	ARG	Ultisol	2 - 4	1.57 b	1.59 b	NS	-0 02
			4 - 6	1.20 c	1.44 c	*	-0.24

Data in columns within a cropping system followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan multiple range test. Data in rows with NS = non significant and * = significantly different at the 0.05 level of probability. ARG = Argentina, FLA = Florida, NT = no-tillage, CT = conventional tillage.

Table 2. Effect of tillage, soil depth, cropping system and soil type on soil organic matter.

Cropping System	Location	Soil	NT	CT		Difference
			- % in 0 - 6 in. depth --			
Corn monocrop	Argentina	Mollisol	2.91	2.75	*	+0.16
Corn monocrop	Florida	Alfisol	1.71	1.37	*	+0.34
Sye-summer crop	Florida	Ultisol	1.53	1.43	*	+0.10
Wheat-soybean	Argentina	Mollisol	2.85	2.80	NS	+0.05
Soybean monocrop	Argentina	Mollisol	2.81	2.73	NS	+0.08
Oat-soybean	Florida	Ultisol	1.74	1.74	NS	0.00
Oat-sorghum	Florida	Ultisol	1.77	1.61	*	+0.16
			- % in 6 - 12 in. depth -			
Corn monocrop	Argentina	Mollisol	1.73	1.63	NS	+0.10
Corn monocrop	Florida	Alfisol	0.94	1.08	*	-0.14
Rye-summer crop	Florida	Ultisol	0.88	0.74	*	+0 14
Wheat-soybean	Argentina	Mollisol	1.68	1.41	*	+0.27
Soyhean monocrop	Argentina	Mollisol	1.67	1.12	*	+0.55
Oat-soybean	Florida	Ultisol	1.05	0.98	NS	+0.07
Oat-sorghum	Florida	Ultisol	0.91	1.02	NS	-0.11
			- % in 0 - 12 in. depth -			
Corn monocrop	Argentina	Mollisol	2 32	2.19	NS	+0.13
Corn monocrop	Florida	Alfisol	1.33	1.?3	*	+0.10
Rye-summer crop	Florida	Ultisol	1.21	1.09	*	+0.12
Wheat-soybean	Argentina	Mollisol	2.27	2 11	*	+0.16
Soybean monocrop	Argentina	Mollisol	2.24	1.93	*	+0.31
Oat-soybean	Florida	Ultisol	1.40	1.36	NS	+0.04
Oat-sorghum	Florida	Ultisol	1.34	1.32	NS	+0.02

Date in rows followed by NS = Non significance and * = significantly different according to F test (P=0.05). NT = No-tillage, CT = Conventional tillage.

SOM in the top 2 in. compared to CT for all seven experiments. Several researchers found that NT had higher SOM at the soil surface as compared to CT systems (Blevins, 1977; Dick, 1983; Gallaher, 1979b; Gallaher and Ortiz, 1984, Gallaher, et al., 1987; Gallaher and Ferrer, 1987, Sprague and Triplett, 1986). In contrast, the data from this study does not agree with studies by Hargrove et al. (1982) who reported no increase in SOM after 5 yr of NT management. The increase in the top 2 in. for NT was at the expense of SOM losses in the 6 to 12 in. depth for both monocrop corn systems and losses in the 2 to 6 in. depth for all other systems.

Average values in the 0 to 6 in. depth showed that four of the seven experiments had accumulated more SOM in NT plots (Table 2). All four of these experiments had a summer fibrous root system of either corn or grain sorghum in common. The three systems that showed no change in SOM due to tillage treatment in the 0 to 6 in. depth had the tap rooted soybean summer crop in common.

Although there were exceptions, experiments with a tap root crop in the system tended to build up SOM in NT vs CT at the 6 to 12 in. depth while either a loss or no change occurred at this depth for systems containing fibrous root summer crops. Bruniard (1988) showed that tillage management changed the root pattern distribution in the soil profile. The root density of soybean in and oat-soybean double cropping system was higher in the 0 to 2 in. depth in NT plots and was highly correlated with SOM content.

At the top 12 in. four of the seven experiments accumulated greater amounts of SOM for NT compared to CT (Table 2). This included an experiment on a Florida Alfisol and a Ultisol and two experiments on a Argentina Mollisol. Systems showing the least change in SOM at the 0 to 12 in. depth were oat-soybean and oat-sorghum. These experiments are known to have tillage or hard pan formation which would restrict roots from deep soil penetration and may partially explain their deviate behavior (Vazquez, el al., 1989).

Mollisols had about 70% more SOM than the Alfisol and Ultisols in the 0 to 12 in. depth. The order of cropping systems ranked from highest to lowest in SOM at the 0 to 12 in. depth ws corn monocrop. Argentina > wheat-soybean, Argentina > Soybean monocrop, Argentina > oat-soybean, Florida > oat-sorghum, Florida > corn monocrop. Florida > rye-summer crop, Florida. In the Argentina experiments the ranking no doubt reflects the same or expected order of the quantity of residue returned to the soil. This principle does not appear to hold true in the Florida experiments.

Irrespective of soil type it is evident that the type of root system strongly influenced the build up or lack of build up of

SOM at any specific depth of soil by NT. These date indicate that cropping systems having fibrous root summer crops tend to build up SOM near the soil surface at the expense of losses at lower depths within the 0 to 12 in. depth. On the other hand, the lack of SOM build up by NT at the 0 to 6 in. soil depth appears to be at the expense of build up of SOM by NT at the 6 to 12 inc. depth for systems which have a tap rooted summer crop.

Conclusions

No-tillage accumulated more SOM in the 0 to *2* in. soil depth for all seven experiments irrespective of soil type or cropping system. Cropping systems which had fibrous root summer crops in the system accumulated SOM in the 0 to 12 in. soil depth at the expense of losses in SOM from the 6 to 12 in. soil depth. Cropping systems which had tap root summer crops in the system seemed to accumulate SOM in the 0 to 2 in. depth at the expense of SOM losses in the 2 to 4 in. depth. No-tillage accumulated greater quantities of SOM compared to CT in four of the seven long-term tillage studies that were investigated when averaged over the 0 to 12 in. soil depth.

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Slit-Tillage for Plow Pan Soils

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Introduction

Soil compaction in the form of plow pans, sometimes called tillage pans, is a problem on large areas of land throughout the world (DeRoo 1961, Eriksson et al., 1974. Unger et al., 198l). Plow pans are frequently a deterrent to optimum crop performance on the coarse textured soils of the Southeastern United States. The primary way in which plow pans adversely affect crop production is by reducing plant rooting into the subsoil. Often a plow pan will restrict most of a crop's roots to the plow layer. Oxygen deficiency and soil strength are the primary factors that restrict root growth in compacted soil (Barley et al.. 1967, Huck 1970, Eavis and Payne 1968, Greenwood 1969). Subsoiling is the most common management practice for promoting deep rooting on plow pan soils, however it has the disadvantages of: high power requirements; the slowing of tillage and planting operations; undesirable mixing of soil horizons; and short term benefits.

In 1979 research was begun to develop an alternative to subsoiling that would effectively promote rooting downward through plow pans but would be free of the undesirable features of subsoiling. The result was the development of a tillage method called slit-tillage and the development of various means of applying slit-tillage to crops or to individual plants. Slit-tillage is the cutting of a narrow. vertical slit through a compacted layer of soil. such as a plow pan. to promote rooting downward through the compacted layer into

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