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Long-term tillage impacts on soil organic matter components and related properties on a Typic Argiudoll

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ABSTRACT

Soil organic matter affects a number of soil processes and properties. A better understanding of soil-profile distribution of organic matter components and related soil properties under long-term tillage systems is thus needed. The objective of this study was to evaluate the impacts of 33 years no-till (NT), double disk (DD), chisel (CH), and plow tillage (PT) under corn (*Zea mays L.*)–soybean (*Glycine max* L.) rotation on soil organic C (SOC), particulate organic matter (POM), pH, and wet aggregate stability to 100 cm soil depth on a Sharpsburg silty clay loam (fine, montmorillonitic, mesic Typic Argiudolls) in eastern NE. After 33 years, NT and DD management increased SOC by 1.2 times and mean weight diameter (MWD) of aggregates by 2 times compared with CH and PT at the 0–10 cm depth. At the 0–20 cm, NT had 1.1 times higher SOC concentration than CH and PT. When compared with data collected 24 years prior to this study, SOC at the 0–20 cm increased by 12.5% across NT, DD, and CH and by 2.7% for PT. No-till had 5 times higher total POM concentration than PT, 4.7 times higher than CH, and 2.4 times higher than DD at the 0–10 cm depth. However, at the 10–20 cm, PT had higher POM than other tillage systems, which is most probably due to mixing and burial of residues at the bottom of the plow layer. Soil pH did not differ among tillage treatments at the 0–10 cm, but it differed in this order: PT > CH > DD > NT at the 10–20 cm and PT = CH = DD > NT at the 20–40 cm depth. The lower pH under NT, DD, and CH in deeper soil depths may be due to the limited or no lime mixing in these systems compared with PT. When compared with data (pH 5) collected 33 years prior to this study, soil pH increased by 0.9 in NT, 1.4 in DD, 1.5 in CH, and 1.9 units in PT at 0–20 cm depth, probably due to surface application and incorporation of lime. Overall, 33 years of NT increased near-surface soil organic matter components and soil aggregation compared with the PT.

1. Introduction

Enhancing soil organic matter components and other properties in intensively managed agro-ecosystems is essential to maintain soil productivity and environmental quality. Soil organic matter plays an important role in improving soil biological, chemical, and physical properties (Grigera et al., 2006; Blanco-Canqui et al., 2013). It moderates many soil processes such as soil structural development, nutrient cycling, water retention capacity, and soil buffering capacity, among others. Management practices such as NT can alter soil organic matter components and soil structural properties in the long term.

A number of studies have reported the effects of tillage and cropping systems on SOC and other properties (Blanco-Canqui and Lal, 2008; Pikul et al., 2007; Varvel and Wilhelm, 2010). Yet, there are several gaps that deserve further investigation. One, because changes in soil properties are often measurable in the long term, more studies assessing soil properties in experiments of long duration is warranted to better discern management effects. Two, studies have mostly measured soil properties near the surface layers (Pikul et al., 2007; Presley et al., 2012; Blanco-Canqui et al., 2009; Munkholm et al., 2013; Jabro et al., 2011; Katsvairo et al., 2002) and only a few have measured for the whole soil profile of at least 100 cm depth (Blanco-Canqui et al., 2011; Varvel and Wilhelm, 2011). Continuous tillage systems may change soil properties in deeper layers of the soil profile in the long term. Conclusions about soil response to NT with data from only the upper surface layers may provide an incomplete view of soil profile changes in soil properties (Baker et al., 2007; Blanco-Canqui et al., 2009). For example, Angers and Eriksen-Hamel, (2008) found that NT soils contained significantly more SOC than moldboard plowed

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soils at the 0–20 cm depth, but, at the 21–35 cm, moldboard plowed soils had more SOC than NT soils.

Furthermore, effects of tillage systems on SOC and related properties appear to be site specific. For example, on a silty clay loam in eastern NE, Varvel and Wilhelm, (2010) reported significantly higher SOC values in NT compared with PT at the 0–7.5 and 15–30 cm depths after 24 years of management. However, on a silt loam in MN, after 23 years of management, NT had 1.3-fold greater SOC pool in the 0–20 cm soil depth, but it had 2-fold lower SOC pool in the 20–25 cm depth, but equivalent in the 0–45 cm depth when compared with PT (Dolan et al., 2006). Similarly, on a clay loam in Canada, after 13 years, NT had greater SOC pool in the 0–5 cm, lower at 20–30 cm, and equal in the 0–60 cm depth compared with PT (Poirier et al., 2009). Across different soil textural classes, Angers et al. (1997) found no differences in SOC between NT and PT treatments to a 60 cm depth in eastern Canada after 11 years of management. The extent to which NT affects SOC concentration may vary, depending on NT management duration, climate, cropping system, and other factors, which warrants further assessment of NT effects on soil properties.

Studies specifically on POM concentrations under different tillage systems are also few. In South Dakota, Pikul et al. (2007) reported that NT increased fine POM by 19% on a sandy clay loam and 37% on a clay loam compared with PT at 0–5 cm depth after 4 and 10 years of management, respectively. Also, on a silty clay in South Dakota, Mikha et al. (2006) reported 44% greater POM concentration in NT than in PT at 0–7.5 cm depth. The previous studies have evaluated POM concentrations near the soil surface and not for deeper depths in the soil profile. We hypothesize that, in the long term, tillage systems may change POM concentrations in both topsoil and subsoil.

Additionally, a number of studies have reported tillage effects on aggregate stability within the topsoil and found improvement in soil aggregate stability in NT compared with PT (Blanco-Canqui et al., 2009; Kahlon et al., 2013; Stone and Schlegel, 2010). More information is needed on aggregate stability from deeper soil depths for long-term tillage systems. Soil aggregation is one of the important characteristics that mediates many soil chemical, physical, and biological properties and maintains soil productivity. The magnitude to which tillage systems affect soil aggregation may vary, depending on regional climate, soil type, residue management practice, and crop rotation (Puget and Lal, 2005; Paustian et al., 1997). Also, tillage and fertilization management may affect soil pH, depending on crop residue management, N application method, tillage intensity, and lime application. Additional information on the long-term effects of NT practices on soil-profile distribution of pH is needed. Available studies show that NT can decrease soil pH (Dick, 1983; Wicks et al., 1988), but application of lime can ameliorate this decrease near the soil surface (Blevins et al., 1983). Little information is available on the effect of tillage systems on soil pH for deeper horizons.

The objective of this study was to compare the impacts of long-term (33 years) NT, DD, CH and PT systems on SOC and POM concentrations, aggregate stability, and soil pH. Our hypothesis was that NT management increases concentrations of SOC and POM, improves soil aggregate stability, and reduces pH in both the topsoil and subsoil in the long term. We hypothesized that NT may decrease soil pH due to surface application of N fertilizers and the lack of soil mixing.

2. Materials and methods

2.1. Site description

An ongoing long-term tillage experiment established in 1981 at the University of Nebraska's Rogers Memorial Farm (40°50′44″ N lat, 96°28′18″ W long, 380 m altitude) near Lincoln, NE was used for this study. The soil is classified as Sharpsburg silty clay loam (fine, montmorillonitic, mesic Typic Argiudolls) and the mean annual precipitation for the past 10 years is presented in Table 1. Two experimental rainfed fields were established in 1981 such that both crop phases of a two-year crop rotation was present each year. Individual tillage and planting system treatments were arranged in plots 9 m wide and 23 m long. At the beginning of the experiment, soybean–grain sorghum (*Sorghum bicolor* L.) rotation was used, but this rotation was changed to corn–soybean in 2005. Within each experimental field, study treatments were arranged in a randomized complete block design and replicated three times.

The initial treatments laid out in 1981 in both fields were six: NT, NT-cultivated, single disk, DD, CH, and PT. The management for two treatments (NT-cultivated and single disk) were modified in 2007. Thus, in this study, we focused only on four tillage systems (NT, DD, CH, and PT), which have been managed under the same practices since experiment establishment. For discussion purposes, DD and CH are considered as reduced tillage systems. The plots under PT system were moldboard plowed to 20 cm depth in the fall and disked twice in the spring to a depth of 15 cm, once about 3 weeks before planting and once the week of planting. The plots under CH were chisel plowed in the fall to about 30 cm depth and disked once in the spring to a depth of 15 cm, the week of planting and disked in early spring. The plots under DD were disked twice in the spring to a depth of 15 cm, once about 3 weeks before planting, and once the week of planting.

Table 1
Mean annual precipitation from 2004 to 2013 for the study site in eastern Nebraska.

Month	Average yearly precipitation (mm)										
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	10-yr average
January	10	7	23	16	11	10	21	30	4	16	15
February	17	50	2	33	14	16	25	20	53	14	24
March	72	15	66	71	29	5	45	17	23	54	40
April	23	56	91	87	97	38	64	83	89	102	73
May	66	55	34	207	105	30	94	152	76	214	103
June	74	72	12	58	218	157	251	87	91	63	108
July	64	135	53	31	91	47	148	39	8	25	64
August	52	65	103	147	45	81	71	175	8	28	78
September	82	7	100	79	148	32	95	34	44	51	67
October	11	70	27	114	122	107	3	24	49	72	60
November	55	52	2	1	31	2	50	42	4	31	27
December	11	23	77	53	10	61	6	40	38	6	34
Annual	537	608	590	898	930	585	874	744	486	676	693