Pak. J. Agri. Sci., Vol. 51(4), 827-834; 2014
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

IMPACT OF LONG-TERM TILLAGE AND CROP ROTATION ON CONCENTRATION OF SOIL PARTICULATE ORGANIC MATTER ASSOCIATED CARBON AND NITROGEN

Irfan Aziz[1,*], Tariq Mahmood[2] and Khandakar Rafiq Islam [3]

[1]Department of Agronomy, PMAS Arid Agriculture University, Rawalpindi, Pakistan; [2]Department of Environmental Sciences, PMAS Arid Agriculture University, Rawalpindi, Pakistan; [3]Soil and Water Resources, Ohio State University South Centers, Piketon, Ohio, USA, and Soil Drainage Research, USDA-ARS, Columbus, Ohio, USA
[*]Corresponding author's e-mail:irfaz15@yahoo.com

The soil management practices may pose intense effects on the nature and properties of soils. A field experiment was conducted during 2002 to 2007 on a Vanmeter farm of the Ohio State University South Centers at Piketon Ohio, USA to assess the long term influence of tillage practices and crop rotation on soil particulate organic matter allied with carbon and nitrogen. Tillage treatments including conventional (CT) and No-till (NT) were factored into continuous corn (CC), corn-soybean (CS) and corn–soybean-wheat-cowpea (CSW) rotations by following randomized complete block design with 6 replications. The results of long-term study showed that 12 percent of significant increase was observed in the particulate organic matter (POM) in NT by the passage of time. The particulate organic carbon (POC) concentration under NT increased (15 %) significantly when CT converted in to NT over five year. Furthermore, particulate organic nitrogen (PON) increased (12%) significantly under NT than under CT. Crop rotation had significant effects on POM and the effects were more prominent in the CSW rotation. The POM, POC concentration increased with time in CC (11%) and CSW (15%) rotations. As soil depth increases, significant decrease was observed in POM, POC and PON concentrations regardless of tillage and crop rotation treatments. Tillage and crop rotation had no significant influence on the physical parameters; however, with time as a factor in the interaction significantly influenced the physical properties. Changes in the physical properties of the soil by tillage practices and crop rotation are mainly due to soil disturbance, placement, amount and type of added biomass crop in the soil ecosystem. Physical properties of soil facilitate microbial activities, support chemical functions, improve protection C and improve the quality of soil.
Keywords: Tillage system, crop rotations, organic matter, soil management, soil texture.

INTRODUCTION

Particulate organic matter (POM) is characterized as a labile fraction of undecomposed plant residues that have recognizable cellular structures, along with seeds, spores, fungal hyphae and skeletal fauna (Gregorich and Janzen, 1996). Changes in management practices such as tillage (CT) to reduced tillage systems pose dramatic effects on POM (Tiessen and Stewart, 1983; Cambardella and Elliott, 1992; Besnard *et al.,* 1996; Hussain *et al.,* 1999; Six *et al.,* 2002; Wander, 2004; Pikul *et al.,* 2007). Similarly, POM also shows a high sensitivity to changes in the management of perennial to annual cropping systems and from conventional to minimum tillage systems (Tiessen and Stewart, 1983; Besnard *et al.,* 1996; Hussain *et al.,* 1999). Extensive tillage and depletion of crop biomass can reduce soil organic matter (SOM) content, and consequently physical, chemical and biological properties of the soil are affected (Eynard *et al.,* 2004; Lal and Shukla, 2004; Li *et al.,* 2007). Puget (1997), Wander and Bidart, (2000) and Yang and Kay (2001) reported that less quantity of soil POM is mainly due to extensive tillage treatment. Moldboard plowing accelerates SOM decomposition and carbon (C) loss from the soil. Furthermore, conventional plowed soil has low rate of formation of occluded POM than soil under NT due to the rapid breakdown of macro-aggregate (Cambardella and Elliott, 1992; Six *et al.,* 2000). Moreover, plowing also has adverse influence on C and nitrogen (N) content in POM pools. While the absence of disturbances of the soil (NT) results in altering of soil surface condition and reduce microbial activity with an increase in POM and aggregate stability (Mielke *et al.,* 1986; Six *et al.,* 2000). Similarly POM has been found to accumulate in the depths of surface when tillage frequency is reduced and rates of accrual appear to be greater in fine textured soils (Amado *et al.,* 2006; Needelman *et al.,* 1999).

In spite of this, Plante *et al.* (2006) found no effect of texture on unprotected POM. In addition, some studies showed a higher POM content under NT than under CT (Liang *et al.,* 2002; Wander and Bidart, 2000; Zotarelli *et al.,* 2007). Six *et al.* (1999) examined approximately 51 percent decrease in the content of fine POM C in soils under CT. Zotarelli *et al.*

(2007) conducted a study for 14 years and reported a decrease in mineral-associated C in CT compared to NT system; however, no significant effects were observed for the conversion of tillage systems in four years. Greater protection of both fine and coarse POM under NT than under CT results in the greater fraction of soil organic carbon (SOC) as POM C under NT (Dou and Hons, 2006; Fugen *et al.,* 2008). Gale *et al.* (2000a,b) found higher concentration of POM in NT due to the accumulation of root materials and less decay of organic matter.

In a long-term rotation experiment, greater pool of soil POM was observed in continuous wheat and native grass plots (Bremer *et al.,* 1994). The decline in C decomposition with greater protection and increased residue inputs or both enhanced the amount of POM by different crop rotations (Paustian *et al.,* 2000).Holland and Coleman (1987) found that the biomass of crop and improving the expansion of fungal helped in the development and stabilization of the macro-aggregates. Layton *et al.* (1993) study revealed that the distribution of plant biomass in surface of soil reduces erosion, decreases evaporation losses and increased stability of soil aggregates and improve the amount of carbon protected as POM (Sharma and Acharya, 2000). At 15-30 cm, more POM under NT could be explained by more anaerobic conditions in deeper soil layers and the contributions of crop roots (Franzluebbers and Stuedemann, 2003). According to Doran *et al.* (1998) biochemical soil environment under NT is less oxidative compared to CT, especially at lower depths. However, Chan (1997) found an increase in POC under NT in surface soil but not at lower depths. In contrast, Cambardella and Elliott, (1992) suggested that low POM under CT was due to faster decomposition than under NT.

It is widely recognized that turnover of SOM is a biological mechanism depends on the chemical composition of substrate and the nature of their links with the mineral particles of soil (Christensen, 2001).The differences in the content of organic matter in response to tillage practices and crop rotation have been identified, but attention must now be diverted to collect quantitative information about changes in physical structures and associated C and N with respect to soil physical carbon sequestration. The fractions of SOM, including soil macro-aggregate associated POM, POC and PON etc are sensitive indicators of changes in response to management practices. According to Cambardella and Elliott (1992) POM is an uncomposited fraction (>0.05 mm) of soil organic matter, composed primarily of partially decomposed decayed materials of crops and animals, plant seeds, root parts of plants spores and fungal hyphae. This fraction lies in between fast turnover and slow turnover i.e. litter and mineral associated organic matter respectively. These fractions provide a substrate for microbial activity and act as binding agents for macro-aggregation to improve soil structural stability and facilitate soil carbon sequestration through bio-physically mediated processes and properties (Oades, 1984; Hendrix *et al*., 1986; Wander and Bidart, 2000).

It is universally recognized that the soil organic carbon especially POM plays a significant role in the formation of soil aggregates which physically protect POC and vice-versa (Tisdall and Oades, 1982; Elliott, 1986). The knowledge of the aggregate properties and associated carbon POM may be important for understanding how changes in management practices contribute to variations in the dynamics of physical soil C. It is observed that use of traditional tillage and monoculture have decreased organic matter content and ultimately influencing its composition and quality (Wander *et al.,* 1994). Many studies showed that crop rotation had a significant impact on the quality of soil organic matter (McClure, 1982; Wood and Edwards, 1992). Wood and Edwards, (1992) in a study with three crop rotations (continuous corn, continuous soybean and corn-soybean) and wheat as winter cover crop in all rotations reported that changes in the soil carbon quality were higher in continuous corn than in corn-soybean which in turn, had higher SOC than continuous soybean. So, replacing conventional tillage and monoculture systems with less disruptive NT can enhance C sequestration and improve the functional properties of the soil.

Because of the close relationship between the physical, chemical properties and plant development, information on the effect of tillage and crop rotation on these properties is becoming essential for the development of sustainable agriculture. There is a serious lack of knowledge that could address the impact of tillage and crop rotation on the concentration of POM, C and N at different depths. While differences in the carbon content in response to tillage practices or crop rotation have been recognized; however, information on carbon sequestration in various chemically-dined C pools is limited. Thus, this study was designed with objective to evaluate the impact of long term crop rotations on the concentration of soil particulate organic matter associated carbon and nitrogen.

MATERIALS AND METHODS

The study was conducted from 2002 to 2007 at Vanmeter farm located in State University South Centers at Piketon (39°02′30’’N, 83°02′00’’W), South-central Ohio, USA. The area is under temperate climate. Air temperature ranged between 0 to 24°C; relative humidity ranged between 79 to 93 per cent; soil temperature at 15 cm deep ranged between 3 to 30°C; solar radiation ranged between 9981 to 43037 kW m^{-2}; and wind velocity ranged between 5 to 9 km/h. Mean annual rainfall is 96+20 cm of which more than 50 per cent occur in April and September. The site has 170 days without any frost (Nokes *et al.,* 1997). The soil consists of 21% sand, 55% silt and 24% clay (silt loam) with 19% content of antecedent soil moisture. Moreover, the soil has a pH of 6.2; electrical conductivity 206.4 μS/cm and 44.6% total porosity. Randomized block design was used with different tillage treatments and crop rotations. Conventional tillage and No-till were factored into continuous corn (*Zea mays* L.), corn-soybean (*Glycine max* L.) and corn–soybean-wheat (*Triticum aestivum* L.) – Cowpea (*Vigna unguiculata* L.) system. In the 1st week of November, 2007 systematically random ten soil core samples were taken up to 30 cm (segmented at 0-7.5, 7.5-15, 15-22.5 and 22.5-30 cm) from each replicated plot via soil probe (1.9 cm internal diameter). After sieving, composite field moist soil was placed in a separate sample plastic bag. Then 2 mm sieve was used to sieve the soil from each sample bag and then POM allied with C and N was examined.

Determination of Soil Physical Carbon Fractions:

***Particulate organic matter*:** Particulate organic matter was determined by taking 10 g oven dried equivalent (ODE) sample of 2 mm sieved field moist soil at 80% water filled porosity in 50 mL screw-top polypropylene tubes. Then microwave eradiation (MW) done on polypropylene tubes enclosing soil in it. Moreover, for controlling accumulated pressure puncture caps were used in polypropylene tubes. The tubes were tapped for few times on bench for mixing and reheating as the initial MW has been completed. Afterwards soil samples were cooled down for half an hour at room temperature. Then samples were shaken at 250 rpm for 1 hour with 20 mL of 0.5M K_2SO_4 (pH 7.0). Finally, after shaking, samples were centrifuged at 3000 rpm for 5 min and then filtered to collect disperse and floated organic residues on filter paper as POM. The POM were transferred to a 53 μm sieve, and washed under running water then oven dried at 105^{0}C for 15 min by using a forced air oven.

Ceramic crucibles were filled with known amount of sand associated POM and burned at 480°C for 4 hours in a Muffle furnace and then analyzed for organic matter by loss on ignition as follows:

$$\text{POM (g 100-g/soil)} = (A - B)\,(B - C)^{-1}$$

Where:

A = weight of oven dried weight of ceramic crucible and sand associated POM

B = weight of ceramic crucible and sand after POM loss on ignition, and

C = oven dried weight of ceramic crucible

***Particulate organic carbon and nitrogen*:** Another sample of 15 to 20 mg finely ground (200 μ m) oven dried sand associated POM was taken, then placed in zinc capsules. Total organic carbon (POC) and total organic nitrogen (PON) content were determined by dry combustion method using CNS Elementar® analyzer. The results of sand free POC and PON contents as follows:

POC (g 100-g sand-free/soil) = % C in sand associated POM*100) $(100 - \%\ \text{sand})^{-1}$

PON (g 100-g sand-free/soil) = % N in sand associated POM*100) $(100 - \%\ \text{sand})^{-1}$

***Statistical analysis*:** Simple effects of tillage and crop rotation and their interaction were analyzed using PROC ANOVA procedure of the SAS (Anonymous, 2008). Treatment means were separated by F-protected least significant difference (LSD) at $p<0.05$.

RESULTS

Particulate organic matter and POC, and PON concentration varied significantly in response to tillage (Table 1). The POM under NT was increased (12%) significantly over time. In contrast, POM under CT decreased non-significantly over time. A significant increase (15%) in POC concentration in NT was observed when CT converted into NT over five year. However, POC over total C (TC) was significantly lower (20 %) under NT than CT. The PON, on the other hand, increased (12%) significantly under NT than under CT. There was no significant change in PON over total nitrogen (TN) in response to tillage. However, the POC/PON significantly decreased over time. Irrespective of tillage treatments, POM, POC and PON significantly decreased except PON/TN and POC/PON with increasing soil depth. However, tillage and soil depth had significant interaction on POM, POC, PON/TN and POC/PON except PON.

Crop rotation had significant effects on POM and the effects were more prominent in CSW rotation (Table 2). The POM concentration in CC and CSW rotations had increased by 8% over time but the concentration of POM in CS did not change significantly over time. Like POM, the POC increased over time in CC (11%) and CSW (15%) rotations. The POC/TC did not change over time, while CC had significantly higher POC/TC than CC and CSW, respectively. As the time passed no change was observed in PON/TN and PON concentration. On contrary the POC/PON changed over time, and the effect was significant on CS and CSW than CC. The POM, POC, PON, POC/TC, and PON/TN decreased with increasing soil depth except POC/PON. However, the POM, POC, and PON were influenced by crop rotation and soil depth interaction.

Tillage and crop rotation had non-significant interaction on POM, POC and PON concentration, POC/TC, PON/TN and POC/PON (Table 3). However, inclusion of time as a factor with tillage and crop rotation interaction significantly influenced the POM, POC and PON concentration. All the soils under NT crop rotations had 2 to 15% accumulation of POM over time as compared to CS rotation. In contrast, the POM in all crop rotations under CT decreased or remained same over time. The POC and PON increased in CC and CSW rotations under NT. The POC/TC decreased under NT-CS and NT-CSW rotations but increased significantly in CT-CS under CT. The POC/PON decreased in all crop rotations

Table 1. Tillage impacts on particulate organic matter associated carbon and nitrogen concentration at different soil depths (Averaged across crop rotation)

Tillage Trts.	Depth of soil (cm)	POM (g/kg)	POC (g/kg)	POC/TC (%)	PON (g/kg)	PON/TN (%)	POC/PON
$Initial_{(2002)}$		8.3Y*	2.7Y	21Y	0.16Y	14.0Xns	23.5X
CT_{2007}		8.2Yb**	2.7Yb	24Xa	0.16Yb	13.2Xns	19.0Ya
NT_{2007}		9.3Xa	3.1Xa	20Yb	0.19Xa	12.2Xns	17.9Ya
Tillage and soil depth interaction							
Initial	0-7.5	12.3***	3.6***	21.9ns	0.26ns	16.4***	14.4***
(2002)	7.5-15	8.1	2.7	21.5	0.15	11.2	18.9
	15-22.5	7.1	2.4	21.2	0.11	11.9	29.3
	22.5-30	5.8	2.2	19.8	0.07	16.4	31.6
CT_{2007}	0-7.5	10.6	3.2	21.9	0.24	15.8	13.8
	7.5-15	8.6	2.9	23.9	0.17	13.3	17.2
	15-22.5	7.3	2.5	24.4	0.12	11.3	20.5
	22.5-30	6.1	2.3	24.6	0.10	12.5	24.7
NT_{2007}	0-7.5	14.4	4.6	20.9	0.31	14.0	14.9
	7.5-15	9.7	3.3	20.9	0.18	11.2	17.8
	15-22.5	7.4	2.5	19.6	0.15	10.8	17.2
	22.5-30	5.8	2.1	18.2	0.10	12.8	21.6

Initial=Data collected from conventionally tilled (CT) continuous corn (CC) plots in 2002, CT_{2007}=Data collected from conventionally tilled plots in 2007, NT_{2007}=Data collected from no-till plots in 2007, POM=Sand free particulate organic matter, POC=Sand free particulate organic carbon, PON=Sand free particulate organic nitrogen, TC=Total carbon, TN=Total nitrogen, and ns=Non-significant.
*Means followed by same upper case (X to Z) letter in the column were not significantly different at $p \leq 0.05$ over time (2002 vs. 2007). **Means followed by same lower case (a to c) letter in the column were not significantly different at $p \leq 0.05$ between tillage treatments in 2007. *** indicates significant tillage and soil depth interaction.

Table 2. Crop rotation impacts on particulate organic matter associated carbon and nitrogen concentration at different soil depths (Averaged across tillage)

Tillage Trts.	Depth of soil cm)	POM (g/kg)	POC (g/kg)	POC/TC (%)	PON (g/kg)	PON/TN (%)	POC/PON
$Initial_{(2002)}$		8.3Yb*	2.7Y	21.1X	0.15X	10.7X	22.1X
CC_{2007}		9.0Xa**	3.0Xa	23.8Xa	0.17Xa	12.1Xa	19.6Xa
CS_{2007}		8.2Yb	2.6Yb	21.4Xb	0.17Xa	11.7Xa	17.7Ya
CSW_{2007}		9.0Xa	3.1Xa	20.8Yb	0.16Xa	11.5Xa	18.0Ya
Tillage and soil depth interaction							
$Initial_{(2002)}$	0-7.5	12.3***	3.6***	21.9***	0.26***	16.4***	14.4***
	7.5-15	8.1	2.7	21.5	0.15	11.2	18.9
	15-22.5	7.1	2.4	21.2	0.11	9.1	23.5
	22.5-30	5.8	2.2	19.8	0.07	6.1	31.6
CC_{2007}	0-7.5	13.3	4.1	23.8	0.28	15.7	15.1
	7.5-15	9.6	3.2	25.6	0.18	13.4	18.2
	15-22.5	7.2	2.5	22.4	0.12	10.1	20.7
	22.5-30	6.0	2.2	23.3	0.10	9.1	24.4
CS_{2007}	0-7.5	11.3	3.5	22.0	0.25	15.0	14.6
	7.5-15	8.7	2.8	21.3	0.18	12.5	16.4
	15-22.5	7.1	2.2	23.2	0.13	11.0	17.3
	22.5-30	5.9	2.1	19.3	0.10	8.5	22.6
CSW_{2007}	0-7.5	12.9	4.0	18.3	0.30	14.0	13.3
	7.5-15	9.3	3.2	20.4	0.15	10.8	18.0
	15-22.5	7.7	2.7	22.9	0.11	12.1	18.6
	22.5-30	6.1	2.3	21.6	0.07	9.0	22.3

Initial=Data collected from conventionally tilled (CT) continuous corn (CC) plots in 2002, CC_{2007}=Data collected from continuous corn plots in 2007, CS_{2007}=Data collected from corn-soybean rotation plots in 2007, CSW_{2007}=Data collected from corn-soybean-wheat rotation plots in 2007, POM=Sand free particulate organic matter, POC=Sand free particulate organic carbon, PON=Sand free particulate organic nitrogen, TC=Total carbon, and TN=Total nitrogen.
*Means followed by same upper case (X to Z) letter in the column were not significantly different at $p \leq 0.05$ over time (2002 vs. 2007). **Means followed by same lower case (a to c) letters in the column were not significantly different at $p \leq 0.05$ among crop rotation treatments in 2007. ***indicates significant crop rotation and soil depth interaction.

Table 3. Tillage and crop rotation impact on particulate organic matter associated carbon and nitrogen concentration in soil (Averaged across soil depth)

Tillage Trts.	Crop rotation	POM (g/kg)	POC (g/kg)	POC/TC (%)	PON (g/kg)	PON/TN (%)	POC/PON
$Initial_{(2002)}$		8.3Y*	2.7Y	21.1Y	0.15Y	10.7Y	22.1X
CT_{2007}	CC_{2007}	8.3Yn	2.8Yn	23.9Yns	0.15Yns	11.9Yns	20.5Xns
	CS_{2007}	7.9Z	2.6Y	26.3X	0.15Y	13.2X	18.1Y
	CSW_{2007}	8.2Y	2.8Y	23.1Y	0.16Y	12.4Y	18.5Y
NT_{2007}	CC_{2007}	9.7X	3.2X	23.7Y	0.18X	12.3Y	18.7Y
	CS_{2007}	8.5Y	2.8Y	17.5Z	0.17Y	10.3Y	17.3Y
	CSW_{2007}	9.8X	3.4X	18.5Z	0.20X	10.5Y	17.6Y

Initial=Data collected from conventionally tilled (CT) continuous corn (CC) plots in 2002, CT_{2007}=Data collected from conventionally tilled plots in 2007, NT_{2007}=Data collected from no-till plots in 2007, CC_{2007}=Data collected from continuous corn plots in 2007, CS_{2007}=Data collected from corn-soybean rotation plots in 2007, CSW_{2007}=Data collected from corn-soybean-wheat rotation plots in 2007, POM=Sand free particulate organic matter, POC=Sand free particulate organic carbon, PON=Sand free particulate organic nitrogen, TC=Total carbon, TN=Total nitrogen, and ns= Non-significant.
*Means followed by same upper case (X to Z) letter in the column were not significantly different at $p \leq 0.05$ over time (2002 vs. 2007).

under NT. A significant relationship of aggregate stability with POM, POC and PON suggested that POM associated C and N sequestration enhanced macro-aggregate formations and vice-versa (Fig. 1-2). Aggregate stability significantly accounted for 52% (R^2) of the variability in POM content of soil (Fig. 1). Likewise, aggregate stability had a moderate relationship (R^2 =0. 46) with POC content of soil (Fig. 2). Soil moisture content, type and amount of clay minerals, and weather conditions were similar in this study with the main differences are the five-year variations in the intensity of tillage and crop rotation effects on POM, POC and PON.

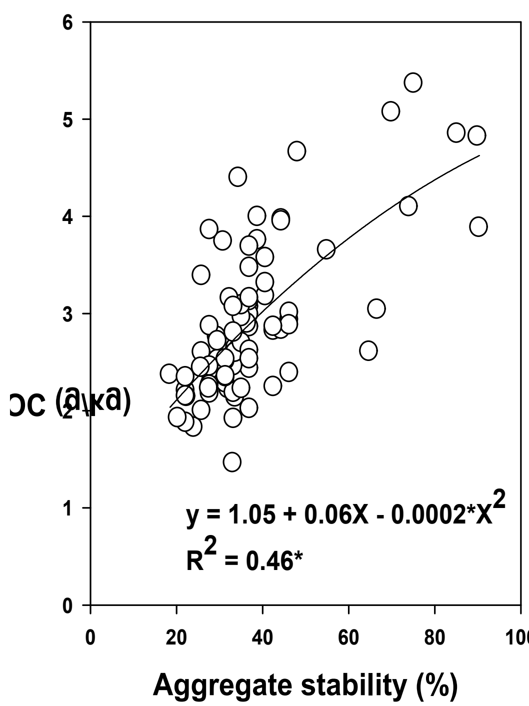

Figure 1. Relationship between aggregate stability and particulate organic carbon at different soil depths

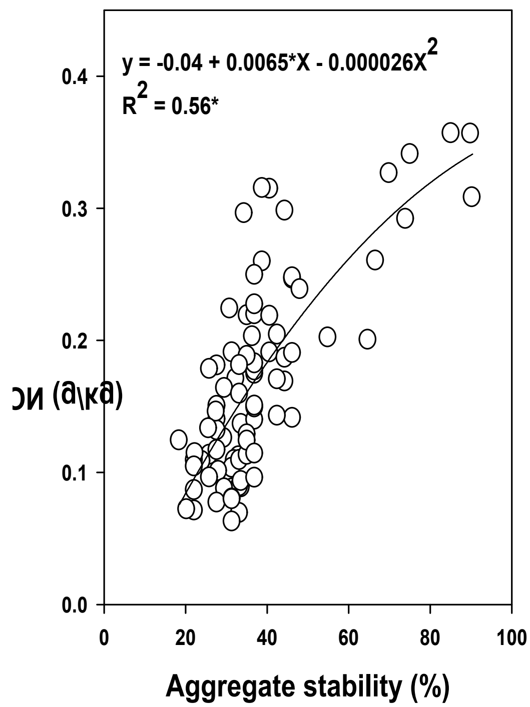

Figure 2. Relationship between aggregate stability and particulate organic nitrogen at different soil depths.

DISCUSSION

Significant temporal differences in POM among tillage and crop rotation can be the consequences of degree of soil disturbance, quality and placement of crop residues, biological activity, and protection of C in soil aggregates (Tisdall and Oades, 1982; Mikha and Rice, 2004).
Conventional tillage exposed macro-aggregate protected POM for enhanced chemical oxidation and microbial decomposition (Angers *et al.,* 1992; Blevins and Frye, 1993;

Paustian *et al.,* 1997; Islam and Weil, 2000). The loss of soil C under CT after plowing occurred as a result of increased aeration and soil temperature and enhanced drying rewetting (Paustian *et al.,* 1997). It is reported that more labile and readily mineralizable POM associated with macro-aggregates and is major source of C loss in response to cultivation (Puget *et al.,* 1995).

The soils under CT are continually exposed to weather conditions with increasing aeration and soil temperature, wetting and drying, and freezing and thawing, causes continuous breakdown of macro-aggregates. When the macro-aggregates are disrupted, more POM is exposed, resulting in a flush of microbial activity for decomposing POM, and therefore cause a rapid decrease in the content of POC in the plowing depth CT (Cambardella and Elliott, 1992; Kushwaha *et al.,* 2001; Torbent *et al.,* 2004; Zotarelli *et al.,* 2007). The macro-aggregate-breakdown is believed to be basic phenomena guiding to grater C (CO_2 emission) and N (soil erosion and leaching) loss conventional tilled soils (Six *et al.,* 2000). Moreover, the tillage has great influence on C and N contents of POM. Several previous studies reported that the transient binding agents of macro-aggregates such as POM are disrupted by tillage-induced disturbance over time (Besnard *et al.,* 1996; Six *et al.,* 2000; Gabe *et al.,* 2008).

Longer retention of residues on the undisturbed soil surface results in the higher concentration of soil aggregate allied C and N under NT system, ultimately cause efficient microbial decomposition of crop residues and greater the amount of POM in macro-aggregates (Oades 1984; Hendrix *et al.,* 1986; Angers *et al.,* 1997; Wander and Bidart, 2000). Since the organic matter is the main source of C, longer retention of crop residues in physically undisturbed NT soil invariably leads to an increase in C concentration than in physically disturbed CT soil.

It has been reported that crop residues as POM might be protected from microbial decomposition through different physico-chemical enmeshing of micro-aggregates into macro-aggregates such as the action of fungal hyphae and plant roots, and feeding and casting activities of the earthworms and soil fauna (Oades 1984; Hendrix *et al.,* 1986; Bossuyt *et al.,* 2002). These mechanisms suggest that more C and N as POC and PON were physically protected in the macro-aggregates under NT. Furthermore, a predominance of energy-efficient fungal food webs facilitates slower decomposition and greater conservation of C in aggregates of soil (Blevins and Frye, 1993; Balesdent *et al.,* 2000). So, macro-aggregates play a significant role in POM protection against losses (Ashman *et al.,* 2003).

In undisturbed soils, POM is derived primarily from roots (Gale *et al.,* 2000a,b).Greater POC and PON under NT even at 15-30 cm depth could be explained by more anaerobic conditions in deeper layers of soil, crop roots and root exudates, and biological inversion of crop residues from earthworm contributions (Franzluebbers and Stuedemann, 2003). A higher concentration of POM in the NT soil can be a result of accumulation of root materials and less organic matter decomposition (Gale *et al.,* 2000a,b). The logics mostly discussed for improvement of C and N accumulation in soil under NT is enhanced aggregate stability (Hernandez-Hernandez and Lopez-Hernandez, 2002; Zotarelli *et al.,* 2007).

The inclusion of wheat and Cowpea (cover crop) in CSW rotation is most likely related to a significant increase in POM, POC and PON content at different depths of soil or within soil profile, as compared with CS rotation.The increase in organic C and N under CSW rotation is possibly due to deeper and increased rooting volume of wheat in the soil and greater biomass N contribution from Cowpeas. The aggregation turnover is directly related with expansion of plant root and development, C cycling, and stability of soil aggregates (Kay, 1998). In addition, POM and soil aggregation are directly linked with each other. On one hand, POM is recognized as a main aggregate binding material, while on other hand physically protection of POM from bio-decomposition within macro-aggregates associated with aggregate stability (Feller and Beare, 1997; Angers and Chenu, 1998).

***Conclusion*:** The temporal effects of different tillage and crop rotations significantly influenced sand free POM, sand free POC and sand free PON of soil. The impact of tillage was more pronounced than crop rotation on sand free POM, suggesting a greater sensitivity of macro-aggregates in response to tillage. Sustainable management practices such as NT or CSW rotation significantly increased sand free POM over time. In contrast to CT, NT had greater sand free POM, sand free POC and sand free PON. The CSW rotation under no-till with diverse quality of organic matter inputs was likely to enhance microbial activities to facilitate the formation of macro-aggregate, and resulting higher aggregate formation to facilitate carbon sequestration as sand free particulate organic matter.

REFERENCES

Amado, T.J., C. Bayer, P.C. Conceicao, S. Evandro, B.H.C. Campos and M. Veiga. 2006. Potential of C accumulation in no-till soils with intensive use and cover crops in Brazil. Environ. Qual. 35: 1599–1607.

Angers, D.A. and J. Caron. 1998. Plant-induced changes in soil structure: processes and feedbacks. Biogeochemistry 42: 55–72.

Angers, D.A., A. Pesant and J. Vigneux. 1992. Early cropping-induced changes in soil aggregation, organic matter and microbial biomass. Soil Sci. Soc. Am. J. 56: 115-119.

Angers, D.A., S. Recous and C.A. Aita. 1997. Fate of carbon and nitrogen in water-stable aggregates during decomposition of ^{13}C and ^{15}N-labelled wheat straw in situ. SoilSci. 48: 295-300.
Anonymous. 2008. *SAS online doc* 9.13. SAS Institute, Inc., Cary, NC
Ashman, M.R., P.D. Hallett and P.C. Brookes. 2003. Are the links between soil aggregate size class, soil organic matter and respiration rate are facts of the fractionation procedure? Soil Biol. Biochem. 35: 435–444.
Balesdent, J., C. Chenu and M. Balabane. 2000. Relationship of soil organic matter dynamics to physical protection and tillage. Soil Tillage Res. 53: 215−230.
Besnard, E., C. Chenu, J. Balesdent, P. Puget and D. Arrouays. 1996. Fate of particulate organic matter in soil aggregates during cultivation. Eur. J. Soil Sci. 47: 495–503.
Blevins, R.L. and W.W. Frye. 1993. Conservation tillage: an ecological approach to soil management. Adv. Agron. 51: 33–78.
Bossuyt, H., K.Denef, J.Six, S. D.Frey, R.Merckx and K.Paustian. 2001. Influence of microbial populations and residue quality on aggregate stability. Appl. Soil Ecol. 16: 195–208.
Bremer, E., H.H. Janzen and A.M. Johnston. 1994. Sensibility of total, light fraction and mineralizable organic matter to management practices in a Lethbridge soil. Can. J. Soil Sci. 74: 131–138.
Cambardella, C.A. and E.T. Elliott. 1992. Particulate soil organic matter change across a grassland cultivation sequence. Soil Sci. Soc. Am. J. 56: 777–783.
Chan, K.Y. 1997. Consequences of changes in particulate organic carbon in Vertisols Nunder pasture and cropping. Soil Sci. Soc. Am. J. 61: 1376–1382.
Christensen, B.T. 2001. Physical fractionation of soil and structural and functional complexity in organic matter turnover. Eur. J. Soil Sci. 52: 345–353.
Doran, J.W., E. T. Elliot and K. Paustian. 1998. Soil microbial activity, nitrogen cycling and long-term changes in organic carbon pools as related to fallow tillage management. Soil Till. Res. 49: 3–18.
Dou, F. and F.M. Hons. 2006. Tillage and nitrogen effects on soil organic matter fraction in wheat-based systems. Soil Sci. Soc. Am. J. 6: 1896–1905.
Elliott, E.T. 1986. Aggregate structure and carbon, nitrogen and phosphorus in native and cultivated soils. Soil Sci. Soc. Am. J.50: 627-633.
Eynard, A., T.E. Schumacher, M.J. Lindstrom and D.D. Malo. 2004. Aggregate sizes and stability in cultivated South Dakota prairie Ustolls and Usterts. Soil Sci. Soc. Am. J. 68: 1360–1365.
Feller, C. and M.H. Beare. 1997. Physical control of soil organic matter dynamics formation and stabilization of aggregates. Soil Sci. Soc. Am. J. 64: 201–207.
Franzluebbers, A.J. and J.A. Stuedemann. 2003. Bermudagrass management in the southern Piedmont USA: III. Particulate and biologically active soil carbon. Soil Sci. Soc. Am. J. 67: 132–138.
Fugen, D., A.L. Wright and F.M. Hons. 2008. Sensitivity of labile soil organic carbon to tillage in wheat-based cropping systems. Soil Sci. Soc. Am. J. 72:1445-1453.
Gabe, P.O., S. Ogle, S.D. Frey, T.R. Filley, P. Keith and J. Six. 2008. Residue carbon stabilization in soil aggregates of no-till and tillage management of dry land cropping systems. Soil Sci. Soc. Am. J. 72: 507-513.
Gale, W.J., C.A. Cambardella and T.B. Bailey. 2000a. Surface residue-and root-derived carbon in stable and unstable aggregates. Soil Sci. Soc. Am. J. 64: 196-201.
Gale, W.J., C.A. Cambardella and T.B. Bailey. 2000b. Root-derived carbon and the formation and stabilization of aggregates. Soil Sci. Soc. Am. J. 64: 201-207.
Gregorich, E.G. and H.H. Janzen. 1996. Storage of soil carbon in the light fraction and macro organic matter. In: M.R. Carter and B.A. Stewart (eds.), Structure and Organic Matter Storage in Agricultural Soils. Advances in Soil Science. CRC Press, Boca Raton, FL. pp. 167–192.
Hendrix, P.F., R.W. Parmelee, D.A. Crossley, D.C. Coleman, E.P. Odum and P.M. Groffman. 1986. Detritus food-webs in conventional and no-tillage agro ecosystems. BioScience 36: 374–380.
Hernandez-Hernandez, R.M. and D. Lo´pez-Hernandez. 2002. Microbial biomass, mineral nitrogen and carbon content in savanna soil aggregates under conventional and no-tillage. Soil Biol. Biochem. 34: 1563–1570.
Holland, E.A. and D.C. Coleman. 1987. Litter placement effects on microbial and organic matter dynamics in an agroecosystem. Ecology 68: 425–433.
Hussain, I., K.R. Olson and S.A. Ebelhar. 1999. Long-term tillage effects on soil chemical properties and organic matter fractions. Soil Sci. Soc. Am. J. 63: 1335–1341.
Islam, K.R. and R.R. Weil. 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric. Ecosyst. Environ. 79: 9-16.
Kay, B.D. 1998. Soil structure and organic carbon: a review. In: R. Lal, J.M. Kimble, R.F. Follett and B.A. Stewart (Eds.), Soil Processes and the Carbon Cycle. CRC Press, Boca Raton, FL, pp. 169–197.
Kushwaha, C.P., S.K. Tripathi and K.P. Singh. 2001. Soil organic matter and water-stable aggregates under different tillage and residue conditions in a tropical dry land agroecosystem. Appl. Soil Ecol. 16: 229–241.
Lal, R. and M.K.. Shukla. 2004. Principles of Soil Physics. Marcel Dekker, New York.
Layton, J.B., E.L. Skidmore and C.A. Thompson. 1993. Winter-associated changes in dry soil aggregation as influenced by management. Soil Sci. Soc. Am. J. 57: 1568–1572.
Li, X.G., F.M. Li, R. Zed, Z.Y. Zhan and B. Singh. 2007. Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. Geoderma 15: 98–105.

Liang, B.C., B.G. McConkey, J. Schoenau, D. Curtin, C.A. Campbell, A.P. Moulin, G.P. Lafond, S.A. Brandt and H. Wang. 2002. Effect of tillage and crop rotations on the light fraction organic carbon and carbon mineralization in Chernozemic soils of Saskatchewan. Can. J. Soil Sci. 83: 65–72.

McClure, R.M. 1982. Non irrigated cropping sequence involving corn, grain sorghum, soybeans and fallow in eastern Nebraska. Ph.D. dissertation, University of Nebraska-Lincoln, Lincoln, NE (Diss. Abstr. 8309890).

Mielke, L.N., J.W. Doran and K.A. Richards. 1986. Physical environment near the surface of plowed and no-tilled soils. Soil Till. Res. 7: 355–366.

Mikha, M.M. and C.W. Rice. 2004. Tillage and manure effects on soil and aggregate-associated carbon and nitrogen. Soil Sci. Soc. Am. J.68: 809–816.

Needelman, B.A., M.M. Wander, G.A. Bollero, C.W. Boast, G.K. Sims and D.G. Bullock. 1999. Interaction of tillage and soil texture: Biologically active soil organic matter in Illinois. Soil Sci. Soc. Am. J. 63: 1326–1334.

Nokes, S.E., N.R. Fausey, S. Subler and J.M. Blair. 1997. Stand, yield, weed biomass and surface residue cover comparisons between three cropping/tillage systems on a well-drained silt loam soil in Ohio, USA. Soil Till Res. 44: 95-108

Oades, J.M. 1984. Soil organic matter and structural stability mechanisms and implications for management. Plant Soil 76:319–337.

Paustian, K., H.P. Collins and E.A. Paul. 1997. Management control on soil carbon. In: E.A. Paul, K. Paustian, E.T. Elliott and C.V Cole (eds.), Soil Organic Matter in Temperate Agroecosystems: Long-term Experiments in North America. CRC Press, Boca Raton, FL. pp. 15-49.

Paustian, K., J. Six, E.T. Elliott and H.W. Hunt. 2000. Management options for reducing CO_2 emissions from agricultural soils. Biogeochemistry. 48: 147-163.

Pikul, J.L., Jr. S. Osborne, M. Ellsbury and W. Riedell. 2007. Particulate organic matter and water stable aggregation of soil under contrasting management. Soil Sci. Soc. Am. J. 71: 766–776.

Plante, A.F., R.T. Conant, C.E. Stewart, K. Paustian and J. Six. 2006. Impact of soil texture on the distribution of soil organic matter in physical and chemical fractions. Soil Sci. Soc. Am. J. 70: 287–296.

Puget, P. 1997. Distribution of organic matter in aggregates of silty soils. Ph.D. diss. Univ. Paris XII Val de Marne.

Puget, P., C. Chenu and J. Balesdent. 1995. Total and young organic matter distributions in aggregates of silty cultivated soils. Eur. J. Soil Sci. 46: 449–459.

Sharma, P.K. and C.L. Acharya. 2000. Carry-over of residual soil moisture with mulching and conservation tillage practices for sowing of rainfed wheat (*Triticum aestivum* L.) in north-west India. Soil. Till. Res. 57: 43–52.

Six, J., E.T. Elliot and K. Paustian. 1999. Aggregate and soil organic matter dynamics under conventional and no-tillage systems. Soil Sci. Soc. Am. J. 63: 1350–1358.

Six, J., E.T. Elliott and K. Paustian. 2000. Soil macroaggregate turnover and microaggregate formation: A mechanism for C sequestration under no tillage agriculture. Soil. Biol. Biochem. 32: 2099–2103.

Six, J., R.T. Conant, E.A. Paul and K. Paustian. 2002. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant Soil 241:155–176.

Tiessen, H. and J.W.B. Stewart. 1983. Particle size fractions and their use in studies of soil organic matter: II. Cultivation effects on organic matter composition in size fractions. Soil Sci. Soc. Am. J. 47:509–514.

Tisdall, J.M. and J.M. Oades. 1982. Organic matter and water-stable aggregates in soil. Soil Sci. 33: 141–164.

Torbent, H.A., S. A. Prior and G.B. Runion. 2004. Impact of the return to cultivation on carbon sequestration. Soil Water Conser. 59: 1-8.

Wander, M.M. 2004. Soil organic matter fractions and their relevance to soil function. In: F. Magdoff and R. Weil (eds.), Advances in Agroecology. CRC Press, Boca Raton, FL. pp. 67– 102.

Wander, M.M. and M.G. Bidart. 2000. Tillage practice influences on the physical protection, bioavailability and composition of particulate organic matter. Biol. Fertil. Soils. 32: 360–367.

Wander, M.M., S.J. Traina, B.R. Stinner and S.E. Peters. 1994. Organic and conventional management effects on biologically active soil organic matter pools. Soil. Sci. Soc. Am. J. 58: 1130–1139.

Wood, C.W and J.H. Edwards. 1992. Agro-ecosystem management effects on soil carbon and nitrogen. Agric. Ecosystems Environ. 39:123-138.

Yang, X.M. and B.D. Kay. 2001. Impacts of tillage practices on total, loose and occluded-particulate and humified organic carbon fractions in soils within a field in southern Ontario. Can. J. Soil. Sci. 81:149–156.

Zotarelli, L., B.J.R. Alves, S. Urquiaga, R.M. Boddey and J. Six. 2007. Impact of tillage and crop rotation on light fraction and intra-aggregate soil organic matter in two Oxisols. Soil. Till. Res. 95: 196–206.