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Paddy Soil Tillage Impacts on SOC Fractions

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Quantifying soil organic carbon (SOC) has long been considered to improve our understanding of soil productivity, soil carbon dynamics, and soil quality. And also SOC could contribute as a major soil management factor for prescribing fertilizers and controlling of soil erosion and runoff. Reducing tillage intensity has been recommended to sequester SOC into soil. On the other hand, determination of traditional SOC could barely identify the tillage practices effect. Physical soil fractionation has been reported to improve interpretation of soil tillage practices impact on SOC dynamics. However, most of these researches were focused onupland soils and few researches were conducted on paddy soils. Therefore, the objective of this research was to evaluate paddy soil tillage impact on SOC by physical soil fractionation. Soils were sampled in conventional-tillage (CT), partial-tillage (PT), no-tillage (NT), and shallow-tillage (ST)plots at the National Institute of Crop Science research farm. Samples were obtained at the three sampling depth with 7.5-cm increment from the surface and were sieved with 0.25- and 0.053-mm screen. Soil organic carbon was determined by wet combustion method. Significant difference of SOC contentwas found among sampling soil depth and soil particle size. SOC content tended to increase at the ST plot with increasing size of soil particle fraction. We conclude that quantifying soil organic carbon by physical soil particle fractionation could improve understanding of SOC dynamics by soil tillage practices.

Key words : Soil organic carbon, Soil particle fractionation

Introduction

Maintenance of soil organic matter (SOM) has long been considered as a key factor in sustainability of the soil resources and crop productivity management. Soils high in SOM generally have greater nutrients and available water-holding capacity than soils of similar texture with less SOM (Brady and Weil, 1999). Soil tillage can affect the amount and turnover of SOM (Angers and Carter, 1996; Lal et al., 2004). Compared with conservation tillage, no-till practice may impact on plant residue input and soil aggregate turnover (Franzluebbers et al., 1994). Cultivation usually incorporates plant residues into the soil and disturbs soil structure by destroying soil macro-aggregates (Cambardella and Elliott, 1993), accelerating SOM decomposition. In long-term tillage, residue management, and N-fertility, an increase inSOC increased the porosity of surface soils (Dou and Hons, 2006). If we are to manage the C balance in cropland, we must understand the factors that determine whether the C contained in crop residue is retained in the soil or released as CO2 into the atmosphere (Buyanovsky and Wagner, 1987).

Physical fractionation showed better relationship of carbon dynamics with soil organic matter structure and function when compared with chemical fractionation (Christensen, 2001). During physical fractionation, SOM maybe separated into various pools with different turnover rates. Compared with particulate organic matter (POM), finer organic matter more tightly associated with soil minerals is considered more resistant, with turnover times of hundreds or thousands of years (Golchin et al., 1994). Cambardella and Elliott (1993) reported that POM-carbon was significantly correlated with macro-aggregates in soil. Particulate organic matter has been considered as an active organic matter pool that has various roles of nutrients and water use efficiency in agricultural lands (Cambardella and Elliott, 1992). Particulate organic matter (POM) mainly consists of decomposed plant residues and POM is considered to be the first intermediate pool in the decay continuum between crop residue and stable organic matter and is more sensitive to changes in management than total SOC

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(Gregorich and Janzen, 1996). Particulate organic matterhas been reported to be more labile and therefore more responsive to management practice (Cambardella and Elliott, 1992). Six et al., (2002) reported that 20% of the difference in whole SOC stocks between the agricultural and the afforested soils. They concluded SOC is stabilized for a relativelylonger term within microaggregates formed in afforested and forest systems and suggested a fractionation scheme to isolate microaggregate associated SOC for assessing the impact of land use, land management and climate change on C storage. Water-stable aggregation showed a significant positive relationship to fractionation of soil organic carbon and diversity of rotation or reduction of tillage increased POM and WSA and this may help to curb soil loss by maintaining surface conditions resistant to erosion (Pikul Jr. et al., 2007). Biologically active soil C pools, including soil microbial biomass and carbon mineralization, have been observed to increase rapidly in response to conservation management techniques with high organic matter inputs and reduced soil disturbance (Franzluebbers and Stuedemann, 2003).

No-tillage increased SOC concentration in all physical size fractions compared with conventional tillage. Increased cropping intensity and N fertilization significantly increased SOC sequestration in most size fractions only under no-tillage. Particulate organic matter C was proportionally more affected by tillage than total SOC, indicating that this fraction was more sensitive to management. From this research, they concluded that no-tillage associated with enhanced cropping intensity and N fertilization sequestered greater SOC (Dou and Hons , 2006).

Numerous previous researches (Gregorich and Janzen, 1996; Karlen and Cambardella, 1996) have been emphasizing the importance of POM as a key factor of nutrient water management in the soil ecological system. However, few studies have reported for determining POM carbon by physical fractionation in the paddy soils especially focused on paddy soil tillage practices. Therefore, the objective of this research was to determine of soil organic carbon associated with paddy soil tillage practices by using physical soil particle fractionation.

Methods and Materials

Site description Paddy tillage experiment field, approximately 0.5 ha, was established in 1998 and is located at the National Institute of Crop Science Research Farm in Suwon (37° 16′26″N, E126° 59′53″E). Tillage management practices were shown in Table 1. Raw straw (about 7,000 kg ha^{-1} yr^{-1}) was applied for each plot. N, P, and K fertilizers were applied 110, 70, 80 kg ha^{-1} until 2003 and 90, 54, 45 kg ha^{-1} thereafter. The soil in the research site described as a Gangseo soil, which is moderately well-drained and moderately rapid permeability (coarse-loamy, mixed, nonacid, mesic family of Fluvaquentic Eutrudepts), by the National Institute of Agricultural Science andTechnology (NIAST, 2000). These soils have grayish brown fine sandy loamy Ap horizon and mottled brown to dark brown, yellowish brown or grayish brown fine sandy loam cambic B horizon. C horizons are brown to dark brown with grayish brown mottles and have stratified loamy fine sand to loam textures. They are developed in coarse loamy alluvial materials on broad continental alluvial plains.

Soil sampling and particle fractionation for soil organic carbon determination Soil samples were collected prior to plowing in March 2006. Individual samples consisted of 10 to 15 composited cores (13-mm diameter) per plot that were divided into depth increments of 0 to 7.5, 7.5 to 15, and 15 to 22.5cm. Soil was sieved to pass a 2.0-mm screen (visible pieces of crop residues and roots were removed) and dried at the air temperature. Fractionation procedures were conducted on soil samples to isolate SOC fractions described in the conceptual model of Six et al. (2000b). In brief, soil samples (10 g) were dispersed in sodium hexa-metaphosphate for 24 h, stirred with a malt mixer

Table 1. Description of tillage practices in the research field.

Tillage practice	Description	Initiation
Conventional-tillage (CT)	Puddle prior to plowing with 12-15 cm depth	Continuous
Partial-tillage (PT)	Till with 8-cm width and 5-cm depth	Since 2001
No-tillage (NT)	None till	Since 2001
Shallow-tillage (ST)	Puddle with 8-12 cm depth	Since 1998

for 5 min, and transferred to a set of sieves having mesh sizes of 0.25 and 0.053 mm. Soils were carefully washed on the screen with water and remains were centrifuged and dried at the 60℃. Organic carbon remaining on the 0.25-mm screen was termed coarse fraction SOC and had a size range of 0.25 to 2.0 mm. Organic carbon retained on the 0.053-mm screen was called medium fraction SOC and had a size range of 0.053 to 0.25 mm. Organic carbon passed through on the 0.053-mm screen was called fine fraction SOC and had a smaller than 0.053 mm. Soil on each sieve was transferred to aluminum weighing containers, and the mass of organic carbon was determined by wet combustion method. Ground soil samples (i.e., 0.2 to 0.3 g) were used to digest with $K_2Cr_2O_7$ by heating at 200℃ for 2 hours and were titrated using diphenylamine indicator. Data were analyzed using SAS (SAS, 2002). A GLM model was used for individual treatment comparisons at P=0.05, with separation of means by Duncan's multiple range test.

Results and Discussion

Soil organic carbon content The soil organic carbon (SOC) contents were significantly affected by tillage practices. The greatest SOC content was observed in shallow-till treatment (ST). Compared with ST, SOC content were 66, 55 and 48% less in CT, PT and NT, respectively. SOC content was significantly different with soil depth of 0 to 22.5cm. The SOC content was highest in depth of 0 to 7.5 cm and decreased with increasing soil depth. At the depth of 0 to 7.5 cm, SOC content was greater 75 and 130% than at the depth of 7.5 to 15cm and 15 to 22.5cm, respectively. SOC content was significantly different by fraction of soil particle size. SOC contents tend to decrease with reducing the soil particle size. The greatest SOC content was observed in the coarse fraction of soil particle. Compared with coarse fraction, SOC content was 45 and 74% less in medium and fine fraction of soil particle, respectively (Table 2).

Unfractionated soil particles tend to decreased in SOC content with increasing of soil depth. At the ST, changing in SOC content by increasing soil depth was relatively slower than other tillage practices.

Table 2. Analysis of variance of SOC by tillage practices, soil depth, and soil particle fraction.

Treatment	SOC
Tillage	
Conventional-till	8.0b
Partial-till	8.6b
No-till	9.0b
Shallow-till	13.3a
F-value	7.39
P	<0.001
Soil depth	
0- to 7.5-cm	14.5a
7.5- to 15-cm	8.3b
15- to 22.5-cm	6.3b
F-value	31.285
P	<0.001
Soil particle fraction	
Less than 0.25mm	12.9a
0.25mm - 0.053mm	8.9b
Greater than 0.053mm	7.4c
F-value	13.45
P	<0.001

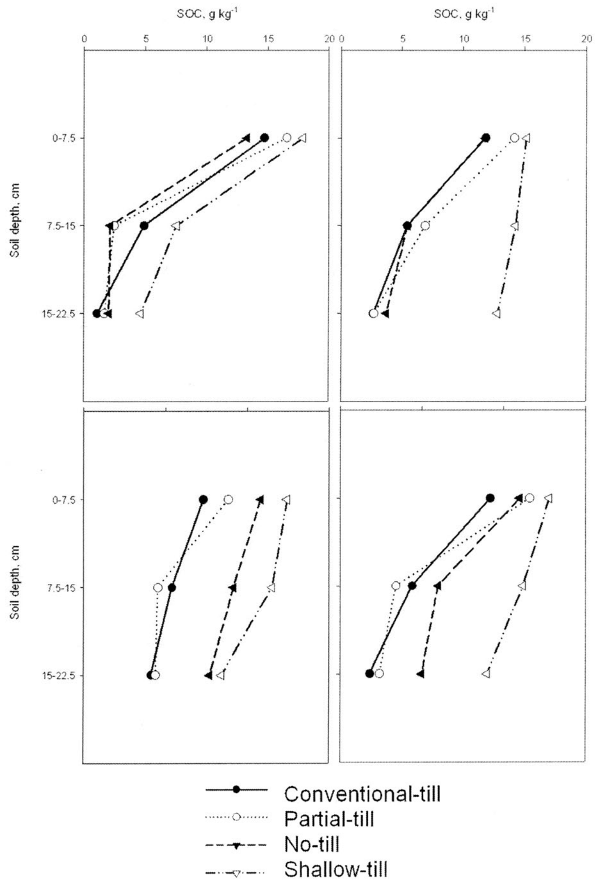

Fig. 1. Dynamics of SOC by tillage practices, soil depth, and soil particle fraction. The fSOC, mSOC, cSOC, and wSOC stand for fine fraction of SOC (i.e., particle size is less than 0.053 mm in diam.), medium fraction of SOC (i.e., particle size is less than 0.25 mm and greater than 0.053mm in diam.) , coarse fraction of SOC (i.e., particle size is greater than 0.25 mm in diam.), and whole SOC (i.e., particle size is less than 2 mm in diam.), respectively.

Coarse fraction of soil particle in SOC content for ST and NT was relatively high compared to PT at all soil depth. SOC content tended to slightly decreased with increasing soil depth. SOC content in medium fraction of soil particlewas slightly decreased in ST with increasing soil depthotherwise, others showed rapid decrease of SOC content with increasing soil depth. SOC contents in fine fraction of soil particle were rapidly decreased for all tillage practices with increasing soil depth. No significant difference of tillage practice on SOC content was found in fine fraction of soil particle. From physical fraction of soil particle, relatively large fraction showed the large differences of SOC content among tillage practices with soil depth (Fig. 1).

In this research, we fractionated soil particle using wet sieving technique and investigated the dynamics of SOC from soil tillage practices. In conclusion, the coarser size of soil particle was the greater effect of tillage practices in paddy soil on SOC content and relatively high SOC storage rate was observed at the shallow-tillage plot. This result imply that SOC storage rate could affected by soiltillage practices and physical soil particle fractionation techniques may help to improve understanding SOC dynamics in the paddy soils

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