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Effect of Tillage System on Distribution of Aggregates and Organic Carbon in a Hydragric Anthrosol*1

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ABSTRACT

The effect of different tillage systems on the size distribution of aggregates and organic carbon distribution and storage in different size aggregates in a Hydragric Anthrosol were studied in a long-term experiment in Chongqing, China. The experiment included three tillage treatments: conventional tillage with rotation of rice and winter fallow (CT-r) system, no-till and ridge culture with rotation of rice and rape (RT-rr) system, and conventional tillage with rotation of rice and rape (CT-rr) system. The results showed that the aggregates 0.02–0.25 mm in diameter accounted for the largest portion in each soil layer under all treatments. Compared with the CT-r system, in the 0–10 cm layer, the amount of aggregates > 0.02 mm was larger under the RT-rr system, but smaller under the CT-rr system. In the 0–20 cm layer, the organic carbon content of all fractions of aggregates was the highest under the RT-rr system and lowest under the CT-rr system. The total organic carbon content showed a positive linear relationship with the amount of aggregates with diameter ranging from 0.25 to 2 mm. The storage of organic carbon in all fractions of aggregates under the RT-rr system was higher than that under the CT-r system in the 0–20 cm layer, but in the 0–60 cm soil layer, there was no distinct difference. Under the CT-rr system, the storage of organic carbon in all fractions of aggregates was lower than that under the CT-r system; most of the newly lost organic carbon was from the aggregates 0.002–0.02 and 0.02–0.25 mm in diameter.

Key Words: aggregates, Hydragric Anthrosol, organic carbon, tillage system

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Soil aggregates, the basic unit of soil structure, have a great influence on the physical, chemical, and biochemical processes of soils (Lu and Li, 2002). Highly aggregated soil structure is the most desirable condition for plant growth because it has a beneficial impact on soil moisture status, nutrient dynamics, and soil tilth (Oades, 1984). Distribution of organic carbon in soil aggregates is one of the most important properties of soil geochemistry (Pan, 1999). Binding of organic carbon to aggregates in soils may be controlled by the soil organic mineral and biotic interaction (Six *et al.*, 2004; Wen and Guan, 2004).

The protection mechanism of soil aggregation may explain the effect of soil organic carbon sequestration (Pan *et al.*, 2003). Organic carbon in micro-aggregates was found to be more stable than that in macro-aggregates (Puget *et al.*, 2000), and the content of organic carbon, especially the newly formed, is sensitive to the changes in land use and cultivation (Six *et al.*, 1998; John *et al.*, 2005). Aggregates 0.02–0.25 and 0.25–2 mm in diameter were found to be the main carrier of organic carbon in paddy soils of the Taihu Lake region and the Paludalfs of the north Huaihe River region, China (Li *et al.*, 2000a, b; Zhang *et al.*, 2001). Therefore, it is important to study the mechanism of organic carbon sequestration based on the transformation of organic carbon at micro-aggregate level in cultivated soils.

Appropriate soil physical management is one of the key factors to maintain or improve its agricultural productivity and/or to prevent soil and environment degradation (Lal, 2000); inappropriate management (*e.g.*, intense ploughing and not using cover crops) can cause rapid soil deterioration. Cultivation causes reduction of macro-aggregates, but it does not affect micro-aggregate stability. Peixoto *et al.* (2006)

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observed that the content of organic carbon and macro-aggregates increase under the no-till system. Guggenberger *et al.* (1999) found that there is a strong correlation between tillage intensity and the turnover rate of soil organic carbon and aggregates. The content of organic carbon under no-tillage system is higher than that under the conventional tillage, which results from the reduced turnover rate of macro-aggregates in the no-till system. Huang *et al.* (2006) observed that the ridge culture with no-till system increases the organic carbon storage in a purple paddy soil (Hydragric Anthrosol). However, there are few investigations about the effect of tillage system on the size distribution of soil aggregates and the soil organic carbon distribution and storage in different size aggregates. Luo *et al.* (2003) showed a correlation between the amount of water-stable aggregates and the tillage intensity in a purple soil. The objective of this study was to compare the effects of different tillage systems on the size distribution of soil aggregates and the organic carbon distribution in different size aggregates based on a long-term experiment.

MATERIALS AND METHODS

The experimental site (30° 26′ N, 106° 26′ E, 230 m above the sea level) is located at the farm of Southwest University, Chongqing, China. The average annual temperature is 18.3 °C; the average annual precipitation is 1 105 mm with 70% in May to September; the annual sunshine time is 1 276 h; and the frost-free period is about 334 d. The soil is a Hydragric Anthrosol (the FAO soil classification) developed from the parent material of Jurassic purple shale and sandstone weathering product. The original soil physical and chemical properties were as follows: pH, 7.1; total organic carbon, 13.3 g kg^{-1}; total nitrogen, 1.74 g kg^{-1}; total phosphorus, 0.75 g kg^{-1}; total potassium, 22.7 g kg^{-1}; alkali-soluble nitrogen, 120.1 mg kg^{-1}; available phosphorus, 7.5 mg kg^{-1}; available potassium, 71.1 mg kg^{-1}; soil particle content larger than 0.01 mm in diameter, 447.4 g kg^{-1}; and particle content smaller than 0.01 mm in diameter, 144.2 g kg^{-1}.

The experiment was initiated in 1991. Three tillage treatments were installed: 1) conventional tillage with rotation of rice and winter fallow (CT-r) system, where regular tillage practices were used for rice with three times of plowing and harrowing annually, and the field was continuously submerged in water all year; 2) no-till and ridge culture with rotation of rice and rape (RT-rr) system, where ridges (five in each plot) with the top of 25 cm width were intervened with the ditches of 30 cm width and 35 cm depth, with no tillage practices performed, rape cultivated on the top of the ridges with the water level being maintained just to the bottom of the ditch, and the field submerged in water to cultivate rice after rape being harvested; and 3) conventional tillage with rotation of rice and rape (CT-rr) system, where tillage was the same as that in the CT-r system, but the field was alternately submerged and drained for rice and rape cultivation. The experiment was designed randomly with four replications for each treatment. Each plot had an area of 20 m^2, and 600 rice (Q You 6) seedlings per plot were transplanted. The annual application of fertilizers was as follows: N (urea), 125.6 kg ha^{-1}, 2/3 as basal and 1/3 as topdressing; P_2O_5 (calcium superphosphate), 60.0 kg ha^{-1} applied as basal; K_2O (potassium chloride), 75.0 kg ha^{-1}, 1/2 as basal and 1/2 as topdressing.

Soil sampling at the depths of 0–10, 10–20, 20–30, 30–40, and 40–60 cm was performed with the soil drill in 2004. All soil samples were collected as a composite from 3–5 random sites in each plot after the rice harvest. Following the quartering method, 1 kg of each sample was reserved for laboratory analyses. Aggregate-size fractionation was performed according to the method by Buyanovsky (1994) and Pan *et al.* (2003) with modifications. Briefly, 50.0 g of air-dried samples were dispersed in 500 mL of distilled water for 24 h and ultrasonically vibrated continuously for 30 min. The aggregates with size greater than 2 mm and 0.25–2 mm were separated by wet sieving. From the remaining suspension, the aggregates with size less than 0.02 mm were separated by repeated sedimentation, siphoning off the suspension at appropriate depths. The particle-size fractionation was repeated until a clear supernatant was obtained (solid < 0.1 g L^{-1} suspension). The aggregates with size < 0.002 mm and 0.002–0.02 mm were separated by centrifugation. Soil organic C (OC) and OC in the soil aggregates was analyzed by