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Effects of conservation tillage on organic carbon, nitrogen and enzyme activities in a hydragric anthrosol of Chongqing, China

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Abstract

Purple paddy (Hydragric Anthrosol in FAO soil classification) is one of important soil resources in Chongqing, China. Long-term conservation tillage may alter distribution of soil organic carbon, nitrogen, and enzyme activities. The objectives of this study were to investigate the impacts of different tillage systems (conventional tillage with rotation of rice and winter fallow (CT-r) system, no-till and ridge culture with rotation of rice and winter fallow (NT-r) system, no-till and ridge culture with rotation of rice and rape (NT-rr) system and conventional tillage with rotation of rice and rape (CT-rr) system) on the depth distribution of soil total organic carbon, nitrogen and enzyme activities (catalase, intverase, and urease activity) in a purple paddy soil after 18 years. Soil total organic carbon and labile organic carbon were significant increased in surface soil layer (0-10 cm) under CT-r, NT-r, and NT-rr systems compared to that under CT-rr system. It indicated that conservation tillage practices can sequester soil organic carbon and reduced CO2/CH4 emission. Soil total nitrogen also significant increased in surface soil layer (0-10 cm) under CT-r, NT-r, and NT-rr systems with the greatest under CT-r system (36%), followed by under NT-rr system (34%), and the least under NT-r system (20%) compared to CT-rr system. No-till, ridge culture, and rotation of rice and winter fallow were increased soil catalase and urease activities, but the greatest was not observed under NT-r system, under which the catalase activities was significant decreased. Soil invertase activities were significant increased under CT-r system compared to CT-rr systems and only a little increased in 0-20 cm soil layer under NT-rr system. Conservation tillage could construct good soil biochemistry environment and maintain soil fertility, and promote agroecosystem sustainable development.

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Keywords: Conservation tillage, Soil organic carbon, Labile organic carbon, Nitrogen; Soil enzyme

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1. Introduction

The dynamical equilibrium of soil organic matter (SOM), which is one of important indicators in soil quality assessments, has directly impact on maintenance and improvement of soil fertility level. Transformation of soil organic matter is associated with the activity of microorganisms and enzymes in soil [1]. Recent researches have shown that soil organic matter is the main carrier for soil microorganisms and soil enzymes and the sources for enzymatic reaction [2]. Small changes in total soil organic matter are difficult to detect because of the generally high background levels and natural soil variability. For this reason many attempts have been made to use subpools of SOM as more sensitive indicators of change in pool size [3-6]. Changes in the lability of soil carbon have been proposed by [7] as a measure of sustainability. The labile organic carbon, which is the fraction of soil organic matter extracted by 333 $mmol \cdot l^{-1}$ $KMnO_4$ [8], rather than total amounts of organic carbon, has been suggested as a useful and more sensitive measure of a change of in organic matter status. Change in liable organic carbon can provide an early indication of short-term trends in total organic C of soils [5, 9, 10]. And labile organic matter has more closely relationship with soil basic properties compared with soil total organic matter [3].

Problem arising from conventional management in agriculture (i.e., frequent pesticide applications, excess inorganic fertilizer usage, declining soil organic matter, soil erosion and the presences of pesticide residues in food) have led to the development and promotion of conservation tillage systems that take account of the environment health and sustainability development as main concerns. Since the declining of soil organic matter, soil structure, physical and chemical properties by continually conventional tillage in the paddy field of China, which has induced sustainable productivity decreasing, the conservation tillage systems of paddy field was became developed [11]. Conservation tillage practices of paddy field is a synthesize system with mulching, reducing tillage, reasonable rotation and management practices of preventing soil and water erosion. Conservation tillage system of no-till and ridge culture, which is one of the representative conversation tillage systems of paddy field, is based on the conventional tillage system with making ridge and zero tillage, which can change the microenvironment of field and soil profile structure. Some researches have shown that soil organic matter content increased and stability of soil structure enhanced under conservation tillage systems with ridge and no-tillage practices [12-15], but few for discussing the biochemical properties under this tillage system. This paper deals with the study of the fertility of purple paddy soil after 18 years of conversation tillage practices through the determination of some chemical and biochemical properties.

2 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 soil is a Hydragric Anthrosol (the FAO soil classification) developed from the purple parent material of Jurassic purple shale and sandstone weathering product. The experiment was initiated in 1991. Four tillage treatments were installed: 1) conventional tillage with 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) conventional tillage with rotation of rice and rape (CT-rr) system, where tillage was the same as that in CT-r systems, but the field was alternately submerged and drained for rice and rape cultivation; 3) no-till and ridge culture with rice and winter fallow (RT-r) 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, and no tillage practices were performed, and field submerged in winter; 4) no-till and ridge culture with rotation of rice and rape (RT-rr) system, where ridges was the same as that in RT-r system, and no tillage practices were 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 The experiment was designed randomly with four replications for each treatment. Soil sampling at the depth of 0~10, 10~20, and 20~30 cm was performed with the soil drill in 2008. 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. Soil organic carbon and total N were determined according to the procedure described by Lu [16]. The soil labile organic carbon was determined by 333 mmol l^{-1} $KMnO_4$ extraction method [7]. Soil catalase, intverase, and urease were determined according to Yan [17]. Statistical analyses were carried out using the program SPSS 13.0 for windows and results were expressed as mean values. Analysis of variance (ANOVA) was used for determination of differences among tillage systems and each soil depth interval. All significant treatment effects were determined using the LSD at P<0.05, and correlation coefficients were calculated at P<0.05.

3 Results and discussion

3.1 Total organic carbon

Tillage and ridge culture impacts on TOC were observed not only for its content, and also for its depth distribution (Table 1). Compared with CT-rr systems, the other three systems increased TOC with the highest amplitude under CT-r, about 43%, followed by NT-r and NT-rr, about 25% and 24%, respectively. SOC decreased with soil depth increasing under CT-r, NT-r, and NT-rr systems. Compared to CT-rr systems, TOC increased in each soil layer expect that in 20-30 cm under NT-rr systems, which suggested that fallow in winter with water submerged increased TOC in each soil depth and no-till with ridge culture only increased TOC in surface soil. Paddy field with water submerged in winter can reduce the mineralization rate of organic matter by decreasing dry-wet cycle times, soil temperature, soil aeration, and aerobic microbe amounts. Ridge culture improved soil water, air and heat regime, and then accelerated mineralization rate of organic carbon through increased micro-biomass and enhanced biochemical intensity. No-till induced the soil input materials such as organic matter and fertilizer cannot entry into deep soil layer and enriched relativity in surface layer [18].

Table 1 Effects of conservation tillage on TOC, labile organic carbon, and total N

Treatments	Soil depth (cm)	TOC (g C kg^{-1} soil)	Labile organic carbon (g C kg^{-1} soil)	Total N (g N kg^{-1} soil)
CT-r	0~10	20.00 b	7.42 b	2.16 a
	10~20	18.96 c	6.20 c	1.83 b
	20~30	13.80 d	4.08 i	1.26 e
NT-r	0~10	18.63 c	6.14 c	1.90 b
	10~20	13.87 d	4.62 g	1.49 cd
	20~30	13.73 d	4.47 h	1.44 d
NT-rr	0~10	20.70 a	8.58 a	2.14 a
	10~20	13.73 d	5.98 d	1.48 cd
	20~30	11.64 g	4.95 f	1.31 e
CT-rr	0~10	12.85 e	5.62 e	1.59 c
	10~20	13.01 e	5.90 d	1.55 cd
	20~30	12.14 f	4.90 f	1.31 e

Not. Within a column and a set, number followed by different letters are significantly different (P<0.05, LSD test)

3.2 Labile organic carbon

In the 0-30 cm soil layer, the labile organic carbon increased under CT-r and NT-rr system compared to CT-rr system, about 18.3% and 7.9%, respectively, and decreased under NT-r system, about 7.1%, and depth distribution of labile organic carbon was significantly impacted by tillage and ridge culture (Table 1). Under CT-r, NT-r, and NT-rr systems, the labile organic carbon decreased with soil depth increasing. The highest labile organic carbon was observed in 0-10 cm soil layer under NT-rr, and the least was found in 20-30 cm soil layer under CT-r systems. No-till increased labile organic carbon in 0-10 cm soil layer and below that was less than it under conventional tillage systems. Labile organic carbon under rotation of rice and rape systems was higher than that under rotation of rice with fallow in wither. Wright et al. [19] suggested that the labile organic carbon influenced by tillage practices and quality and quantity of residue material, and the latter was more important from long term cultivate tillage history. While, Soon et al. [20] indicated that the impact of rotation on labile carbon fractions such as mineralization carbon, hot-water dissolve carbon was stronger than that of tillage practices. In this paper, planting rape in winter increased soil labile organic carbon, for adding the amount of returning residue material, root and its excretion, and the residue material of rape was decomposed more quickly by microbe with low C/N value compared to rice residue material.

3.3 Total N

The soil total N impacted by tillage practices and ridge culture (Table 1). In the whole cultivate layer (0-30 cm), total N was highest under CT-r system, followed by NT-rr and NT-r system, least in CT-rr system. In the surface soil layer (0-10 cm), total N was significantly increased under CT-r, NT-r, and NT-rr system compared to CT-rr system. The depth distribution of total N was obviously under no-till system and similar under conventional tillage due to its different N mineralization potential. Gao et al. [21] showed that N mineralization potential in 0-5 cm soil layer under no-till was higher than that under conventional tillage and in 5-15 cm soil layer with fallow in winter was the same while with rotation of the others was on the contrary.

3.4 soil enzyme activities

Soil catalase activity was least in each soil layer under NT-r system and was highest in each soil layer under NT-rr system (Fig. 1). No significant relationship was observed between catalase activity and TOC, labile organic carbon, total N (Table 2). It was similar with the results described by Sun et al. [22] and Wang et al. [23]. But Xiong et al. [24] indicated the significant positive correlation between catalase activity and total organic matter, which due to the impacts from fertilize and rotation [25]. Invertase activity in each soil layer under CT-r system was significant higher than it under other systems (Fig. 1). In 20-30 cm soil layer, the invertase activity under no-till system was nearly to zero. Compared with that under CT-rr system, invertase activity was higher in 0-10 cm soil layer under the other systems and was less in 10-20 cm soil layer except that under CT-r system. Invertase activity had a strong positive correlation with TOC and total N (Table 2). Sun et al. [22] observed that the positive correlation between invertase activity and total organic carbon, alki-N, but Qiu et al [26] found on significant correlation between invertase activity and soil properties. The different results due to the different agricultural management practices such as fertilize and rotation [25]. The depth distribution of urease activity has impacted by conservation tillage practices (Fig. 1). Different to it under CT-rr system, urease activity was greatest in 10-20 cm soil layer under the other systems. In 0-10 cm soil layer, urease activity was highest under NT-rr, followed by under CT-rr and NT-r systems, and least under CT-r system. Under CT-r, NT-r, and NT-rr system, urease activity was obviously higher than that under CT-rr system in 10-20 cm soil layer. There were no significant differences were found in 20-30 cm soil layer among all tillage systems. Urease activity had no strong correlation with soil total organic carbon, labile carbon, and total N (Table 2). But significant positive correlation was found between urease activity and TOC and total N described by Melerlo et al. [1], Sun et al. [22], and Qiu et al. [26]. Wang et al. [23] indicated that the relationship between urease activity and soil nutrient had impact by crop species. Several researches indicated that the closely correlation between transform of organic matter and soil enzymatic activities [19, 27, 28]. But the results of this paper showed that this relationship was not closely, due to the species and amount of soil animal and microbe had change lots after under long term conservation tillage system[29].

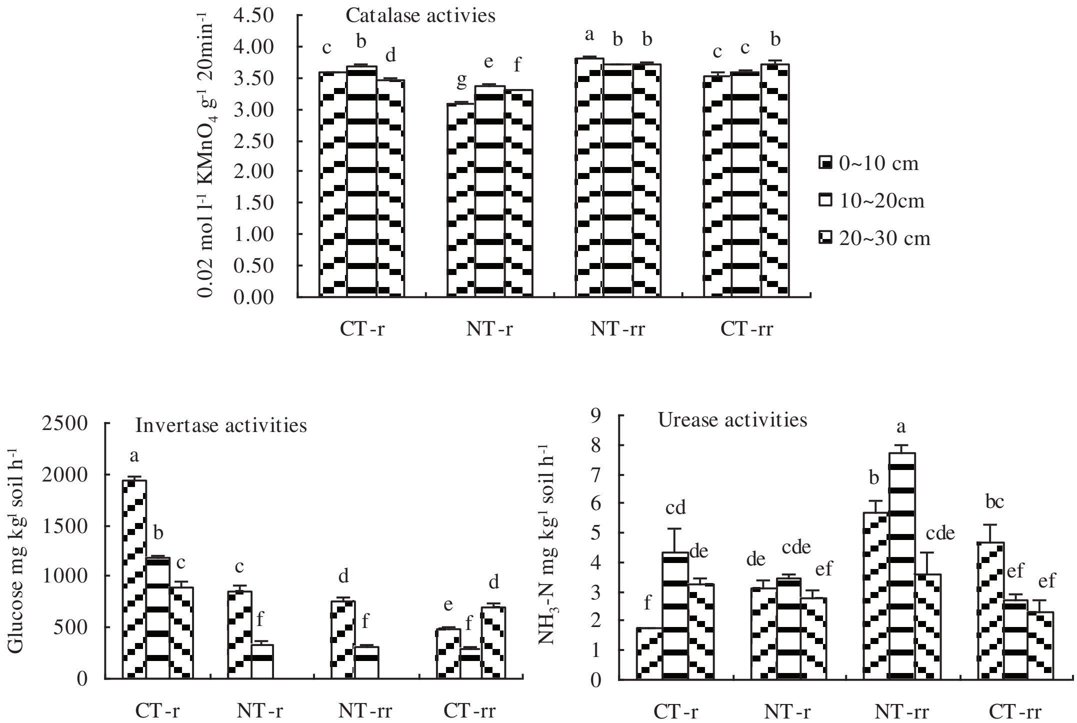

Fig.1 Effects of conservation tillage on soil catalase, invertase, and urease activies. Errors bars represent standard error of means. The different letters above the column are significant different within tillage systems and soil depths.

Table 2 Correlation coefficients between TOC, labile organic carbon, total N, enzyme activities (n=12)

	Catalase	Invertase	Urease
TOC	-0.006	0.726*	0.043
Labile organic carbon	0.381	0.508	0.282
Total N	0.046	0.668*	0.042

* Correlation is significant at the 0.05 level.

4. Conclusion

No-till, ridge culture, and submerged water in winter increased soil total organic carbon and total N with C/N ranging from 8.1 to 11.0, which indicated that these practices can enrich organic matter and especially for newly organic matter. But total organic matter under NT-r system was not the highest, the reasons of which need to further study. The labile organic carbon decreased with soil depth increasing under CT-r, NT-r, and NT-rr systems, and increased in surface soil layer compared with CT-rr systems. It indicated that conservation tillage practices can sequester soil organic carbon and reduced CO_2/CH_4 emission. Fallow in winter with submerged increased invertase activity and reduced catalase and urease activity. No-till with ridge culture enhanced the activities of catalase, invertase, and urease in surface soil layer. In conclusion, no-till and ridge culture with rotation of rice and rape (NT-rr) system was the more reasonable tillage systemin paddy field in Chongqing, China.

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