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Differences in Decomposition and Transformation of Exogenous Straw in Several Typical Subtropical Paddy and Upland Soils: Postprint

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Abstract

Paddy soils developed from four typical parent materials (granite weathering products, Quaternary red clay, slate weathering products, and recent fluvial deposits) in subtropical regions were selected, with adjacent upland soils as a comparison, to investigate the characteristics and differences of mineralization and transformation of exogenously input straw in paddy and upland soils under 45% field water holding capacity (WHC) conditions through laboratory incubation experiments. The results showed that during the 180-day incubation period, the cumulative mineralization rate of exogenously input straw in the four selected paddy soils (18%-21%) was significantly lower than that in the corresponding upland soils (21%-28%), and the priming effect of straw input on native soil organic carbon mineralization was also markedly lower in paddy soils (5%-30%) than in the corresponding upland soils (17%-65%). The decomposition products of exogenous straw in soils were primarily allocated to particulate organic carbon (POC) and iron/aluminum-bound organic carbon (Fe/Al-OC), with allocation proportions of 9%-21% and 12%-24%, respectively, followed by humus carbon (HMC) (11%-15%), while the proportions allocated to microbial biomass carbon (MBC) and dissolved organic carbon (DOC) were minimal, at only 2%-7% and 0.1%-0.7%, respectively. Compared with upland soils, the proportions of decomposition products from exogenous straw allocated to POC, Fe/Al-OC, and MBC were higher in paddy soils, at 15%-21%, 17%-24%, and 6%-7%, respectively, whereas those in upland soils were 9%-17%, 13%-18%, and 2%-4%. Additionally, the proportion of exogenous straw decomposition products allocated to 2000-250 m water-stable macroaggregates was also higher in paddy soils (10%-13%) than in upland soils (6%-7%), with no significant differences between paddy and corresponding upland soils observed for other particle sizes. These findings indicate that the phenomenon of lower mineralization rates of exogenously input straw in paddy soils compared to upland soils may be widespread across soils developed from different parent materials, which may be attributed to stronger physical protection by water-stable aggregates, chemical binding with iron/aluminum oxides, and allocation to stable organic carbon fractions for decomposition products of exogenous straw in paddy soils, thereby contributing to the higher organic carbon accumulation in paddy soils.

Full Text

Preamble

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Decomposition and Transformation of Input Straw in Several Typical Paddy and Upland Soils in Subtropical China

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Abstract

This study investigated the decomposition and transformation of input straw in four types of paddy soils derived from different parent materials (weathered granite, quaternary red clay, weathered shale, and river alluvium) in subtropical China, using adjacent upland soils as controls. Soils were incubated at 25°C and 45% water holding capacity (WHC) for 180 days. During the incubation period, the cumulative mineralization rates of input straw in the selected paddy soils (18%–21%) were significantly lower than those in the corresponding upland soils (21%–28%). The priming effects of straw amendment on native soil organic carbon mineralization were also lower in paddy soils (5%–30%) than in upland soils (23%–65%). The decomposition products of input straw were mainly distributed in particulate organic carbon (POC, 9%–21%) and Fe/Al-bound organic carbon (Fe/Al-OC, 12%–24%), followed by humus carbon (HMC, 11%–15%), whereas only small portions were allocated to microbial biomass carbon (MBC, 2%–7%) and dissolved organic carbon (DOC, 0.1%–0.7%). In paddy soils, the conversion ratios of input straw into POC, Fe/Al-OC, and MBC (15%–21%, 17%–24%, and 6%–7%) were higher than those in upland soils (9%–17%, 13%–18%, and 2%–4%). Additionally, the 2000–250 m coarse water-stable aggregates in paddy soils tended to receive more decomposition products of input straw than those in upland soils (10%–13% vs. 6%–7%), whereas no significant difference was observed between paddy and upland soils in other aggregate size fractions. These results indicate that the mineralization of input straw may be consistently lower in paddy soils than in upland soils derived from different parent materials, possibly due to stronger physical protection within soil coarse aggregates, chemical protection through binding with Fe/Al oxyhydrates, and greater transformation into stable fractions during decomposition. This fate of input straw decomposition may contribute to higher organic carbon accumulation in paddy soils compared to upland soils.

Keywords: paddy soil; organic carbon; mineralization; priming effect; organic carbon fractions

Introduction

Soil organic carbon (SOC) accumulation depends on the balance between carbon inputs and outputs. Different agricultural management practices affect this balance. In China, paddy soils demonstrate significant carbon sequestration effects, with sequestration rates markedly higher than those of upland soils and even forest soils [1-4], indicating substantial sequestration potential. The strongest carbon sequestration capacity is observed in subtropical paddy soils, primarily attributed to increased organic matter inputs resulting from enhanced rice yields under long-term rice cultivation systems [2,5]. Our previous simulation experiments with a subtropical paddy soil derived from quaternary red clay parent material showed that, compared to upland soils, although paddy soils had larger microbial biomass and faster turnover rates, the mineralization rates of both added crop straw and native soil organic carbon were significantly lower in paddy soils [6-7]. The high carbon sequestration rates observed in subtropical paddy soils in recent decades are also associated with relatively low mineralization losses of soil organic carbon under reasonable agricultural management practices. Whether this phenomenon is universal across paddy soils developed from different parent materials requires further verification.

As a crucial source of soil organic carbon, the labile components of exogenous straw are the primary source of microbial decomposition products. After entering the soil, exogenous straw undergoes a series of physical, chemical, and microbial transformation processes. These microbial decomposition products further promote soil organic carbon accumulation by facilitating soil aggregate formation and adsorption and chemical bonding with soil minerals [8-10]. Spaccini et al. [11] suggested that in upland soils, fresh corn straw tends to transform into humic and fulvic acids, and that fresh plant residues in soils are mainly stored in hydrophilic components of humus through mineralization and decomposition, proposing that native humus promotes the accumulation of fresh crop straw in soil. Song et al. [12] also reported that newly added corn straw carbon in paddy soils is significantly positively correlated with Fe/Al-bound organic carbon, free iron oxides, and humin. We hypothesize that if the mineralization rate of exogenous straw is lower in subtropical paddy soils than in upland soils, then the distribution and stabilization of its decomposition products among different soil carbon pool fractions may also differ from those in upland soils, potentially through chemical bonding with soil mineral components and subsequent transformation into stable organic carbon fractions. This study aimed to investigate the mineralization and transformation characteristics of exogenous straw in paddy and upland soils under controlled moisture conditions (45% WHC) and to elucidate the distribution patterns of decomposition products in soil carbon fractions.

1. Materials and Methods

1.1 Experimental Soils

Four types of paddy soils with long rice cultivation histories in Hunan Province were selected as research objects, with adjacent upland soils of the same parent material serving as controls. The four parent material types were: weathered granite from Jinjing Town, Changsha County (113°20 E, 28°33 N); quaternary red clay from Pantang Town, Wangcheng County (111°32 E, 29°14 N); weathered shale from Yutian Township, Guiyang County (112°69 E, 25°94 N); and river sediments from Shuangxikou Township, Lianyuan County (111°62 E, 29°10 N). The selected paddy soils had long-term cropping systems of rice-rice-fallow or rice-oilseed rape, while upland soils were primarily planted with oilseed rape. All crops were managed under conventional fertilization practices.

At each sampling area, five random points were collected from the topsoil layer (0–20 cm). Visible plant and animal residues were removed. A portion of the soil samples was passed through a 2 mm sieve, adjusted to 45% WHC, and pre-incubated for 7–10 days at 25°C in darkness. Another small portion was air-dried indoors for determination of basic soil physicochemical properties. The basic physicochemical properties of the soils are presented in .

Basic physical and chemical properties of the soils studied (0–20 cm)

1.2 Experimental Treatments

The straw added in this experiment was crushed corn straw passed through a 10 mg/g sieve. The organic carbon and total nitrogen contents of the corn straw were 497.34 g/kg and -12.74‰, respectively. Each soil type had two treatments: no straw addition (CK) and straw addition (S).

For gas sampling, 20 g of pre-incubated soil was placed in 120 mL bottles. After treatment, the bottles were immediately sealed with silicone stoppers. The gap between the silicone stopper and bottle was sealed with glue. The stopper had a small hole in the center with a glass tube inserted, which was further sealed with a section of silicone hose as a gas sampling port [13]. The incubation bottles were then placed under constant temperature (25°C) and dark conditions. Each treatment had three replicates. Gas samples were collected on days 0, 0.5, 1, 2, 5, 10, 20, 40, 60, 80, 100, 140, and 180 of incubation.

For soil organic carbon fraction analysis, 400 g of pre-incubated soil was placed in plastic buckets. The buckets were sealed to maintain air humidity, and deionized water was periodically added to the bottom to maintain humidity. The samples were incubated under constant temperature (25°C) and dark conditions for 180 days. After incubation, soil samples were analyzed for dissolved organic carbon (DOC), particulate organic carbon (POC), microbial biomass carbon (MBC), Fe/Al-bound organic carbon (Fe/Al-OC), humus carbon (HMC), water-stable aggregates (2000–250 m, 250–53 m, <53 m), and SOC. Each treatment had three replicates.

2. Analysis and Calculation Methods

Microbial biomass carbon was determined using the fumigation-extraction method with a carbon auto-analyzer [14]. Dissolved organic carbon was measured following the method of Zhou et al. [15]. Particulate organic carbon was determined using the method of Xu et al. [16]. Soil humus composition was analyzed using the method of Dou et al. [17]. Water-stable aggregates were measured using the method of Cambardella and Elliott [18]. Soil organic carbon was determined by the K Cr O external heating method [19]. Clay content was measured using a laser particle size analyzer (Mastersizer 2000). Total nitrogen was determined by the semi-micro Kjeldahl method [20]. CO concentrations in gas samples were measured using a gas chromatograph (Agilent Technologies 7890A, USA).

The ^{13}C (‰) values were calculated as follows: ^{13}C (‰) = 1000 × (R_sample - R_standard)/R_standard, where R_sample and R_standard represent the relative abundances of the soil sample and standard sample, respectively. The proportion of organic matter components derived from exogenous straw versus native soil was calculated based on measured ^{13}C values using the following formulas:

f = (_M - _B)/(_A - _B)

where f represents the proportion of carbon derived from corn straw in the soil sample (%), _M is the ^{13}C of soil samples with added corn straw, _B is the ^{13}C of soil samples without corn straw, and _A is the ^{13}C of corn straw. All tested soils in this study were planted with C3 crops, while corn straw (C4) was relatively enriched in ^{13}C.

Before analysis, soil samples were dried, ground, and passed through a 0.149 mm sieve. For MBC, DOC, Fe/Al-OC, and HMC ^{13}C determination, the extracts were freeze-dried before analysis using a stable isotope mass spectrometer (Thermo Scientific MAT 253).

3. Statistical Analysis

All experimental results are expressed as means of three replicates. Data processing was performed using Microsoft Excel 2007 software. Differences were tested for significance using ANOVA in SPSS 13.0. The significance level was set at $P < 0.05$, and the highly significant level at $P < 0.01$.

4. Results

4.1 Mineralization Dynamics of Input Straw in Paddy and Upland Soils

During the 180-day incubation period, the mineralization of input straw in soils could be divided into three stages: 0–5 days was the rapid mineralization stage, with relatively high straw mineralization rates of 11%–14% in paddy soils and 14%–19% in upland soils; 6–20 days was the slow mineralization stage, with straw mineralization rates of 1%–2% in paddy soils and 2%–3% in upland soils; and 21–180 days was the stable mineralization stage, with relatively flat changes in straw mineralization rates of 3%–7% in paddy soils and 2%–7% in upland soils. At the end of incubation, the cumulative mineralization rates of input straw in paddy soils derived from granite weathering material, quaternary red clay, shale weathering material, and river sediments were 18%, 21%, 19%, and 21%, respectively, all significantly lower than those in the corresponding upland soils (28%, 28%, 23%, and 21%, respectively, $P < 0.05$). The difference was particularly pronounced for granite weathering material [Figure 1: see original paper].

4.2 Effects of Input Straw on Native Soil Organic Carbon Mineralization

The mineralization of native soil organic carbon increased rapidly within 0–20 days of incubation. The cumulative mineralization of native organic carbon in paddy soils under CK treatment ranged from 69.22 to 226.30 g/g, while in upland soils it ranged from 120.49 to 260.89 g/g. After adding exogenous straw, the cumulative mineralization of native organic carbon in paddy soils increased by 5%–30%, whereas in upland soils it increased by 20%–78%. The growth magnitude of native organic carbon cumulative mineralization in the selected paddy soils was significantly lower than that in upland soils of the same parent material ($P < 0.05$). In the later stage of incubation (20–180 days), the cumulative mineralization of native organic carbon in granite weathering material, quaternary red clay, shale weathering material, and river sediment-derived paddy soils was 376.17, 303.41, 167.91, and 225.38 g/g, respectively, representing increases of 5%, 9%, 30%, and 28% compared to CK ($P < 0.01$). During the same period, the cumulative mineralization of native organic carbon in the corresponding upland soils was 361.68, 286.05, 140.02, and 102.34 g/g, respectively, showing increases of 37%, 17%, 53%, and 36% ($P < 0.01$). The selected paddy soils exhibited weak priming effects, particularly for granite weathering material and quaternary red clay-derived paddy soils, which showed almost no priming effect, while upland soils showed significantly enhanced priming effects after straw addition [FIGURE:2, FIGURE:3].

4.3 Distribution of Straw Decomposition Products in Different Organic Carbon Fractions

Using granite weathering material and quaternary red clay-derived paddy and upland soils as examples, the distribution of straw decomposition products in soil organic carbon fractions after incubation was analyzed. In granite weathering material-derived paddy and upland soils, the distribution proportions of straw decomposition products were 13%–24% in Fe/Al-OC, 9%–21% in POC, 12%–15% in HMC, and only minimal allocation to MBC and DOC at 2%–7% and 0.1%–0.7%, respectively. In quaternary red clay-derived paddy and upland soils, the distribution patterns were similar, with higher proportions in paddy soils than in upland soils for all fractions. The allocation to Fe/Al-OC, POC, and HMC in paddy soils was 15%–21%, 17%–24%, and 14%–15%, respectively, compared to 9%–17%, 13%–18%, and 11%–13% in upland soils .

4.4 Distribution of Straw Decomposition Products in Water-Stable Aggregates

The distribution of straw decomposition products in water-stable aggregates is shown in [Figure 4: see original paper]. In granite weathering material-derived paddy and upland soils, the distribution proportions of straw decomposition products in the 2000–250 m, 250–53 m, and <53 m fractions were 10% vs. 6%, 7% vs. 7%, and 5% vs. 6%, respectively. In quaternary red clay-derived paddy and upland soils, the corresponding proportions were 13% vs. 7%, 7% vs. 5%, and 6% vs. 8%, respectively. The differences in distribution between paddy and upland soils were primarily observed in the 2000–250 m fraction, where paddy soils had relatively higher proportions, while no significant differences were found in the other two size fractions ($P > 0.05$).

5. Discussion

Land use type plays a key role in the dynamic changes of soil organic carbon pools, primarily by altering soil structure and nutrient status through different cropping systems and field management practices, which in turn changes soil biological, physical, and chemical characteristics, leading to differences in soil organic carbon mineralization [22-23]. Typically, paddy soils have higher microbial quantity, community, and functional diversity than upland soils, which would seemingly promote greater utilization of crop straw by microorganisms and thus higher straw mineralization in paddy soils [24-25]. Many studies have reported that straw mineralization is higher in paddy soils than in upland soils. For example, Huang et al. [26] used ^{1}C tracing technology to find that rice and corn straw mineralized faster in flooded paddy soils than in upland soils. Inubushi et al. [27] found that CO emissions from paddy soils were higher than from upland soils. Zhao et al. [28] reported that biochar application had better carbon sequestration and emission reduction effects in upland soils than in paddy soils. Jian et al. [29] also noted that the mineralization rate of autotrophic microbial assimilated carbon was significantly higher in paddy soils than in upland soils.

However, our previous studies [6,30] on straw mineralization in a subtropical paddy soil reported results inconsistent with the above literature. Despite paddy soils having much larger microbial biomass than upland soils, the mineralization rate of exogenous straw and its priming effect on native soil organic carbon mineralization were both significantly lower in paddy soils, demonstrating higher organic carbon accumulation effects. Building on this, the present study further found that the cumulative mineralization rates of exogenous straw in paddy soils developed from different parent materials were all lower than those in corresponding upland soils, suggesting a certain universality. This indicates that paddy soil organic matter turnover may involve special biogeochemical processes that are more conducive to the accumulation of exogenous straw in paddy soils.

Aerobic conditions promote soil organic carbon mineralization [31], and organic carbon mineralization decreases with increasing soil clay content, as soils with higher clay content protect crop straw decomposition [32-33]. In this study, both paddy and upland soils were incubated at 45% WHC, and paddy soils had lower clay content than upland soils to varying degrees. These conditions would seemingly favor organic carbon mineralization in paddy soils. However, our results showed that the mineralization of exogenous straw and its priming effect on native organic carbon in paddy soils were not higher than in upland soils as suggested above, but were instead significantly suppressed. This suggests that moisture conditions and clay content may not be the main factors affecting organic carbon mineralization in paddy soils.

Straw input affects soil microbial community composition and activity, thereby producing positive or negative priming effects on native soil organic carbon mineralization [34-35]. Some studies on paddy soil organic carbon mineralization have also suggested that exogenous straw addition causes significant negative priming effects [7,36] or no significant priming effect [6,30] on native soil organic carbon. Our results showed that although paddy soils had larger carbon pools and microbial biomass than upland soils, the priming effect of exogenous straw addition on native soil organic carbon mineralization was significantly lower in paddy soils than in corresponding upland soils. Granite weathering material and quaternary red clay-derived paddy soils showed almost no priming effect, while upland soils showed enhanced priming effects after straw addition, possibly due to reduced physical protection by aggregates, leading to decreased stable organic carbon fractions [37].

The decomposition rate of exogenous straw in soils is an external manifestation of soil microbial activity. Previous studies suggested that microbial quantity and activity determine soil organic carbon decomposition [38]. The MEMS framework proposed by Cotrufo et al. [39] suggests that soil organic matter decomposition includes two stages: transformation of non-biologically active organic matter into biologically active organic matter through abiotic processes (including chemical oxidation, hydrolysis, release from aggregates and biologically inaccessible pores, desorption from solid phases, and extracellular enzymatic processes), followed by biological mineralization. The former stage is the rate-limiting step in soil organic matter decomposition. In this study, paddy soils had higher microbial biomass carbon content and higher distribution proportions of straw decomposition products in microbial biomass carbon than corresponding upland soils, yet exogenous straw did not show higher mineralization rates in paddy soils. This indirectly verifies that straw mineralization in paddy soils is not entirely controlled by soil microorganisms.

Recent studies have also indicated that soil microbial biomass and its activity composition cannot effectively indicate organic carbon mineralization. Soil structure, aggregates, and associated physicochemical properties may play important roles in soil organic carbon mineralization and further affect soil organic carbon accumulation [40-41]. Zhou et al. [6] also found in their research that fresh crop straw mineralization did not decrease with increasing soil clay content. Soils containing large amounts of iron and aluminum oxides can reduce soil organic carbon mineralization and better protect organic matter and its decomposition products. Our results showed that the distribution proportions of exogenous straw decomposition products in 2000–250 m water-stable aggregates, Fe/Al-OC, and HMC in paddy soils were all significantly higher than in corresponding upland soils (10%–13%, 15%–21%, 17%–24%, and 14%–15% vs. 6%–7%, 9%–17%, 13%–18%, and 11%–13%, respectively). The lower mineralization rate of exogenous straw in paddy soils may be related to stronger physical protection by water-stable aggregates, chemical bonding with Fe/Al oxides, and allocation to humus components. Although paddy soils had higher microbial biomass, the distribution proportion of straw decomposition products in DOC was lower than in upland soils. As DOC is a direct substrate for microbial decomposition, this may lead to higher mineralization losses of exogenous straw in upland soils. The strong physical protection and chemical stabilization of organic carbon in paddy soils further promote the chemical stabilization process of Fe/Al-OC, thereby resulting in lower organic carbon mineralization rates and higher accumulation in paddy soils compared to upland soils [42]. Lei et al. [43] also noted that enhanced physical and chemical protection of organic carbon in subtropical paddy soils helps maintain high carbon sequestration rates. Song et al. [12] reported that exogenous carbon in soils is ultimately sequestered primarily through transformation into stable humus carbon fractions.

6. Conclusion

Under 45% WHC conditions for 180 days, the cumulative mineralization rates of exogenous straw and their priming effects on native soil organic carbon mineralization were consistently lower in the selected four typical parent material-derived paddy soils than in corresponding upland soils, suggesting a certain universality. Compared to upland soils, the decomposition products of exogenous straw in paddy soils received stronger physical protection by water-stable aggregates, chemical bonding with Fe/Al oxides, and allocation to stable organic carbon fractions, thereby potentially suppressing straw decomposition and mineralization and promoting its accumulation in paddy soils.

References

[1] Pan GX, Xu XW, Smith P, Pan WN, Lal R. An increase in topsoil SOC stock of China’ s croplands between 1985 and 2006 revealed by soil monitoring. Agriculture, Ecosystem & Environment, 2010, 136(1/2): 133-138.

[2] Wu JS. Carbon accumulation in paddy ecosystems in subtropical China: Evidence from landscape studies. European Journal of Soil Science, 2011, 62(1): 29-34.

[3] Kalbitz K, Kaiser K, Fiedler S, Kölbl A, Amelung W, Bräuer T, Cao ZH, Don A, Grootes P, Jahn R, Schwark L, Vogelsang V, Wissing L, Kögel-Knabner I. The carbon count of 2000 years of rice cultivation. Global Change Biology, 2012, 19(4): 1107-1113.

[4] Huang S, Sun YN, Zhang WJ. Changes in soil organic carbon stocks as affected by cropping systems and cropping duration in China’ s paddy fields: A meta-analysis. Climatic Change, 2012, 112(3/4): 847-858.

[5] Yan XY, Cai ZC, Wang SW, Smith P. Direct measurement of soil organic carbon content change in the croplands of China. Global Change Biology, 2011, 17(3): 1487-1496.

[6] Wu JS, Zhou P, Li L, Su YR, Yuan HZ, Syers JK. Restricted mineralization of fresh organic materials incorporated into a subtropical paddy soil. Journal of the Science of Food and Agriculture, 2012, 92(5): 1031-1037.

[7] Zhou P, Song GH, Pan GX, Li LQ, Zhang XH. Role of chemical protection by binding to oxyhydrates in SOC sequestration in three typical paddy soils under long-term agro-ecosystem experiments from South China. Geoderma, 2009, 153(1/2): 52-60.

[8] Cotrufo MF, Wallenstein MD, Boot CM, Denef K, Paul E. The microbial efficiency-matrix stabilization (MEMS) framework integrates plant litter decomposition with soil organic matter stabilization: Do labile plant inputs form stable soil organic matter? Global Change Biology, 2013, 19(4): 988-995.

[9] Spaccini R, Piccolo A, Haberhauer G, Gerzabek MH. Transformation of organic matter from maize residues into labile and humic fractions of three European soils as revealed by C distribution and CPMAS-NMR spectra. European Journal of Soil Science, 2000, 51(4): 583-594.

[10] Song XY, Li LQ, Zheng JF, Pan GX, Zhang XH, Zheng JW, Hussain Q, Han XJ, Yu XY. Sequestration of maize crop straw C in different soils: Role of oxyhydrates in chemical binding and stabilization as recalcitrance. Chemosphere, 2012, 87(6): 649-654.

[11] Dou S. Study on organic-mineral complexes in soil: Characteristics of humus in calcium-bonded and Fe/Al-bonded complexes. Acta Pedologica Sinica, 1999, 36(2): 166-178.

[12] Cambardella CA, Elliott ET. Methods for physical separation and characterization of soil organic matter fractions. Geoderma, 1993, 56(1/4): 449-457.

[13] Bao SD. Soil Agricultural Chemical Analysis Methods. China Agricultural Science and Technology Press, 1999.

[14] Phillips DL, Gregg JW. Uncertainty in source partitioning using stable isotopes. Oecologia, 2001, 127(2): 171-179.

[15] Kasel S, Bennett LT. Land-use history, forest conversion, and soil organic carbon in pine plantations and native forests of southeastern Australia. Geoderma, 2007, 137(3/4): 401-413.

[16] Yuan HZ, Ge TD, Wu XH, Liu SL, Tong CL, Qin HL, Wu MN, Wei WX, Wu JS. Long-term field fertilization alters the diversity of autotrophic bacteria based on the ribulose-1,5-bisphosphate carboxylase/oxygenase (RubisCO) large-subunit genes in paddy soil. Applied Microbiology and Biotechnology, 2012, 95(4): 1061-1071.

[17] Huang S. Discussion and questions on organic carbon decomposition rates in upland and paddy soils. Acta Pedologica Sinica, 1998, 35(4): 482-492.

[18] Inubushi K, Furukawa Y, Hadi A, Purnomo E, Tsuruta H. Seasonal changes of CO , CH and N O fluxes in relation to land-use change in tropical peatlands located in coastal area of south Kalimantan. Chemosphere, 2003, 50(3): 603-608.

[19] Zhao C, Li ZP, Hao R. Effects of bagasse biochar addition on mineralization of soil organic carbon in croplands. Scientia Agricultura Sinica, 2013, 46(5): 987-994.

[20] Jian Y, Li ZP, Ge T, Su YR, Wu JS. Mineralization and transformation characteristics of autotrophic microbial assimilated carbon in paddy and upland soils. Chinese Journal of Applied Ecology, 2014, 25(6): 1708-1714.

[21] Hao RJ, Li ZP, Che YP. Differences in organic carbon mineralization between aerobic and submerged conditions in paddy soils of southern Jiangsu Province, China. Agricultural Sciences in China, 2011, 10(9): 1410-1418.

[22] Xu X, Shi Z, Li DJ, Rey A, Ruan HH, Craine JM, Liang JY, Zhou JZ, Luo YQ. Soil properties control decomposition of soil organic carbon: Results from data-assimilation analysis. Geoderma, 2016, 262: 235-242.

[23] Zhang WJ, Xu MG. Research progress on decomposition, accumulation and distribution characteristics of organic matter in typical red soil regions. Soils, 2015, 47(2): 220-228.

[24] Paterson E, Sim A. Soil specific response functions of organic matter mineralization to the availability of labile carbon. Global Change Biology, 2013, 19(5): 1562-1571.

[25] Kuzyakov Y. Priming effects: Interactions between living and dead organic matter. Soil Biology and Biochemistry, 2010, 42(9): 1363-1371.

[26] Ge TD, Yuan HZ, Zhu HH, Wu XH, Nie SA, Liu C, Tong CL, Wu JS, Brookes PC. Biological carbon assimilation and dynamics in a flooded rice-soil system. Soil Biology and Biochemistry, 2012, 48: 39-49.

[27] Shahbaz M, Kuzyakov Y, Heitkamp F. Decrease of soil organic matter stabilization with increasing inputs: Mechanisms and controls. Geoderma, 2016, doi: 10.1016/j.geoderma.2016.05.019.

[28] Kascchuk G, Alberton O, Hungria M. Three decades of soil microbial biomass studies in Brazilian ecosystems: Lessons learned about soil quality and indications for improving sustainability. Soil Biology and Biochemistry, 2010, 42(1): 1-13.

[29] Kemmitt SJ, Lanyon CV, Waite IS, Wen Q, Addiscott TM, Bird NRA, O' Donnell AG, Brookes PC. Mineralization of native soil organic matter is not regulated by the size, activity or composition of the soil microbial biomass—A new perspective. Soil Biology and Biochemistry, 2008, 40(1): 61-73.

[30] Strickland MS, Callaham Jr MA, Davies CA, Lauber CL, Ramirez K, Richter Jr DD, Fierer N, Bradford MA. Rates of in situ carbon mineralization in relation to land-use, microbial community and edaphic characteristics. Soil Biology and Biochemistry, 2010, 42(2): 260-269.

[31] Ball BC. Soil structure and greenhouse gas emissions: A synthesis of 20 years of experimentation. European Journal of Soil Science, 2013, 64(3): 357-373.

[32] Cui J, Li ZX, Liu ZT, Ge BM, Fang CM, Zhou CL, Tang BP. Physical and chemical stabilization of soil organic carbon along a 500-year cultivated soil chronosequence originating from estuarine wetlands: Temporal patterns and land use effects. Agriculture, Ecosystems & Environment, 2014, 196: 10-20.

[33] Lei M, Li ZP, Liu ZT, Fang CM, Zhou CL. Effects of long-term fertilization on distribution and chemical binding forms of organic carbon in paddy soils. Chinese Journal of Ecology, 2012, 31(4): 967-974.

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