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RESEARCH ARTICLE

Responses of soil microbial respiration to plantations depend on soil properties in subtropical China

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Abstract

Assessing the impact of plantation on microbial respiration (MR) is vitally important to understand the interactions between belowground metabolism and land use change. In this study, cumulative MR was determined by alkali absorption method in 1, 3, 7, 14, 21, 28, 35, 42, 49, and 56 days from the soil in a representative plantations in the subtropical region of China. The treatment of plantations contained no plant (CK), orange trees (*Citrus reticulata*)+Bahia grass (*Paspalum notatum*) (GB), orange trees (*C. reticulata*)+Bahia grass (*P. notatum*)+soybean (*Giycine max* (L.) Merrill) (GBH). Results showed that plantation had significant effects on microbial respiration and the responses of microbial respiration to plantation from different soil layers and topographies were different: in 0–20 cm in uphill: GB>GBH>CK; in 20–40 cm in uphill: GBH>CK>GB; in 0–20 cm in downhill: GBH>CK>GB; in 20–40 cm in downhill: GB>CK>GBH. Furthermore, plantation also altered the relationships between MR and soil properties. In CK, microbial respiration was positively correlated with NH_4^+ and soil total N, and negatively correlated with soil moisture, pH, NO_3^-, and microbial biomass carbon (MBC). In GB, microbial respiration under GB significantly negatively correlated with dissolved organic carbon (DOC). In GBH, microbial respiration under GBH was positively correlated with NH_4^+, MBC, total soil carbon (TC), and total soil nitrogen (TN), and negatively correlated with soil moisture (SM), pH, NO_3^-, and DOC. The underlying mechanisms could be attributed to soil heterogeneity and the effects of plantation on soil properties. Our results also showed that plantation significantly increased soil C storage, which suggested plantation is a key measure to enhance soil C sequestration and mitigate global CO_2 emission, especially for the soil with low initial soil carbon content or bared soil.

Keywords: soil microbial respiration, plantation, soil properties, subtropical forest

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1. Introduction

The area of natural forest loss was estimated to be 2.3 million km² during the period from 2000 to 2012 (Hansen *et al.*

2013). Such land-use changes make a major contribution to the greenhouse gases emissions (IPCC 2007). Tree plantation is an effective method to restore forests and mitigate greenhouse gases emissions by enhancing carbon (C) storage (Garten 2002; Sharrow and Ismail 2004). However, plantation with different plant species may have different effects on soil C dynamics (Guo and Gifford 2002; Nowak and Crane 2002; Kraenzel *et al*. 2003), which has been rarely tested in a specific study.

Microbial respiration refers to microbial decomposition of dead plant residues and soil organic matter (Kuzyakov and Gavrichkova 2010), which is controlled by soil microbial activities and soil C content. Soil microbial activities are influenced by soil physicochemical conditions, such as soil moisture (Yuste *et al*. 2007; Lou *et al*. 2011), soil pH (Anderson and Joergensen 1997) and soil C:N ratio (Hogberg *et al*. 2007). Plantation could change soil physicochemical properties by the shade of tree crown, above-ground litter cover, root and root exudates (Parrotta 1992; Zheng *et al*. 2005; Zhang *et al*. 2013). Plantation also influenced soil C quantity and quality by above-ground litter inputs and root inputs (Resh *et al*. 2002). In addition, soil stoichiometry could also be altered by plantation (Li *et al*. 2012). All these changes of soil conditions derived from plantation, including soil physicochemical conditions, soil C quantity and quality and soil stoichiometry, could influence soil microbial respiration. However, the effects of plantation on soil respiration were inconsistent among studies due to different plant species (Vesterdal *et al*. 2012; Huang *et al*. 2014), plantation years (Ewel *et al*. 1987) or site heterogeneity (Xu and Qi 2001; Paul *et al*. 2002).

We think that as a worldwide land use practice, the cultivated area of *Citrus reticulata* increased dramatically in recent years due to its ecological and economic values. In this study, we investigated how different plantation patterns, including no plant (CK), orange trees (*C. reticulata Blanco*)+Bahia grass (*Paspalum notatum*) (GB), orange trees (*C. reticulata Blanco*)+Bahia grass (*P. notatum*)+soybean (*Giycine max* (L.) Merrill) (GBH), affected soil microbial respiration in different soil layers (0–20 and 20–40 cm) and topographies (uphill and downhill) after 12 years, which are the typical plantation patterns in a subtropical area in China. We hypothesized that 1) different treatments of plantations changed soil physical conditions and therefore affected soil microbial respiration; 2) different treatments of plantations changed soil C pools and therefore affected soil microbial respiration.

2. Results

2.1. Effects of plantation on soil microbial respiration

Plantation treatment had significant effects on microbial respiration (Table 1). Both of the main effects of plantation and slope on microbial respiration were significant, whereas the main effect of soil layer on microbial respiration was not significant (Table 1). However, the interaction of plantation, soil layer and slope was significant (Table 1), because microbial respiration of 0–20 cm soil was not different from that of 20–40 cm soil under no plant (Fig. 1), whereas microbial respiration of 0–20 cm soil was higher in uphill slope and lower in downhill slope than that of 20–40 cm soil under GB, and microbial respiration of 0–20 cm soil was lower in uphill slope and higher in downhill slope than that of 20–40 cm soil under GBH (Fig. 1).

2.2. Effects of plantation on soil properties

Soil properties were partitioned into four categories: soil physicochemical conditions (including soil moisture, soil pH), soil microbial activities (MBC), soil C conditions (dissolved organic carbon (DOC) and total soil C), and soil N conditions (including soil NH_4^+ and NO_3^-, total soil N).

First, neither soil moisture (Table 2, Fig. 2-A and B) nor soil pH (Table 2, Fig. 2-C and D) was affected by plantation, soil layer or slope.

Second, plantation had no significant effect on MBC (Table 2). The effect of soil layer on MBC was significant: MBC in 0–20 cm was higher than that in 20–40 cm (Table 2, Fig. 2-K and L). The effect of slope on MBC was also significant: MBC in uphill slope was higher than that of downhill slope (Table 2, Fig. 2-K and L).

Third, only topography had significant effect on DOC concentration: DOC in uphill was significantly lower than that in downhill (Table 2). The interaction of soil layer and topography was significant, because DOC concentration in

Table 1 *P*-values of repeated measures analysis of variance for cumulative soil microbial respiration (CMR) using plantation treatment (T), soil layer (SL), slope (S), incubation days (D), and the interactions as fixed effects

Term	CMR
T	<0.01
SL	0.16
S	<0.01
D	<0.01
T×SL	<0.01
T×S	0.12
SL×S	<0.01
T×D	<0.01
SL×D	0.56
S×D	0.02
T×SL×S	<0.01
T×SL×D	<0.01
T×S×D	0.42
SL×S×D	<0.01
T×SL×S×D	<0.01