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Seasonal variation of microbial biomass carbon and dissolved organic carbon in farmland soil and influencing factors

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ABSTRACT

Field experiment, determining in-situ and laboratory simulated experiment were conducted to study the seasonal dynamics of soil respiration flux, soil microbial carbon (SMBC), and dissolved organic carbon (DOC) in agricultural soil. The impact factors such as temperature, precipitation, and biomass, were also analyzed. The results showed that soil respiration rate increased rapidly after May and reached the maximum in July to September. There was a significantly positive correlation between respiration rate and soil temperature ($p<0.01$). The seasonal variation of SMBC had greater coefficient variance, 27.1% and 18.7% for 2004 and 2005, respectively ($p<0.001$). SMBC content was lower in May, subsequently increased rapidly and SMBC content was 774-842 mg/kg in June to September. DOC content was highest in May, subsequently decreased, and declined to the lowest in July. From August to September, the DOC content increased rapidly to the highest value (177. 2 mg/kg) in September, and declined subsequently. Correlation analysis showed that there were significantly negative correlation between DOC and SMBC, 5 cm soil temperature and soil respiration. However, it correlated positively with biomass. There was significant negative correlation between SMBC content and 5 cm soil temperature.

KEYWORDS

Soil organic carbon;
Soil respiration;
Microbial carbon;
Carbon cycle.

INTRODUCTION

Soil microorganisms not only participate in the cyclic process of soil elements (e.g. carbon and nitrogen) and soil mineralization, but also play an important leading role in the decomposition and conversion of organic matters as well as the conversion and supply of nutrients. The soil microbial biomass carbon (SMBC) analysis is of important significance to studies on soil carbon cycle, soil carbon balance and chemical and biochemical characteristics of soil[1,2]. Dissolved organic carbon (DOC) participates various soil processes as the important basis of carbon cycle in terrestrial ecosystem and can affect the biological activity of soil as the main energy source of soil microorganisms[3,4]. Both DOC and SMBC are influenced by the amount of carbon source and other environmental factors. The dynamics of these influencing factors will change the amount and composition of DOC and activate microorganisms, thus influencing the carbon and nitrogen cycle in ecosystem[5,6]. Although there are abundant researches about the effect of land utilization and fertilization practice on soil organic carbon, only a few researches on the dynamic process of DOC and SMBC have been reported yet. This paper mainly discussed the seasonal variation and influencing factors of DOC and SMBC.

MATIRIALS AND METHODS

The research area locates in the Honghe Farmland (133°31′E, 47°35 ′N) in Tongjiang City, Heilongjiang Province, where covers large-scaled wetlands-reclaimed farmlands for soybean and corn all the year round. With an elevation of 55-65m, it enjoys temperate continental monsoon climate and has an annual average temperature of 1.9°C (-21°C in January and 22°C in July). The mean annual precipitation varies between 550-600 mm. It has about 125 frost-free days. The main wetlands are perennial waterlogged *Carex lasiocapa* swamp and seasonal waterlogged *Doyeuxia augustifolia* wetlands. The main wetland vegetation includes *Carex lasiocapa*, *Carex meyeriana* and *Doyeuxia augustifolia*.

Three 4m×4 m sample plots were selected in the research area. Four earth columns (diameter: 20 mm; height: 10 cm) were collected from each sample plot on every 15th from May ~ October of 2011 and 2012. After carried back to laboratory, these collected columns were redistributed and mixed and then screened by 3mm screen. Later, they were stored in refrigerator for test. The soil CO_2 flux was tested in situ. Soil temperature was recorded automatically by temperature sensing probe buried on wetland surface and 5cm depth. Precipitation was observed by automatic meteorological station. Aboveground biomass and standing litter were tested by harvest method.

Soil respiration was tested in situ in Li-6400-09 soil respiratory chamber. DOC test: 1) put 20g (dry weight) fresh soil into a conical flask with 60mL distilled water for 30min vibration leaching under room temperature; 2) centrifuge by using high-speed centrifuge and screen the supernatant liquor by 0.45μm filter membrane; 3) use the Shimadzu TOC-VCPH apparatus to test the DOC concentration in the leachate[7]. MBC was tested by chloroform fumigation- K_2SO_4 extraction. Fumigation sample and non-fumigation sample were leached and extracted with 0.5 M K_2SO_4 for 30min. The carbon concentration in the leachate was tested by Shimadzu TOC-V_{CPH} apparatus. Next, the MBC was calculated from the following formula:

MBC =*Ec*/0.38

where MBC is the microbial biomass carbon and Ec is the tested organic carbon difference between the fumigation sample and non-fumigation sample.

The relationship between SMBC/DOC and the influencing factors was analyzed through Pearson correlation analysis of SPSS 13.0.

RESULTS AND ANALYSIS

Soil temperature curves at 5cm depth during the growing season in 2011 and 2012 showed a single peak (end of July ~ beginning of August) without significant difference (Figure 1a). The total precipitations from May ~ October in 2011 and 2012 were 326.6mm and 395.7 mm, respectively. In 2011, May received the maximum precipitation, followed by July but less in rest months. In 2012, the maximum precipitation was in July, followed by August. No significant precipitation difference was found between 2011 and 2012 (Figure 1b).

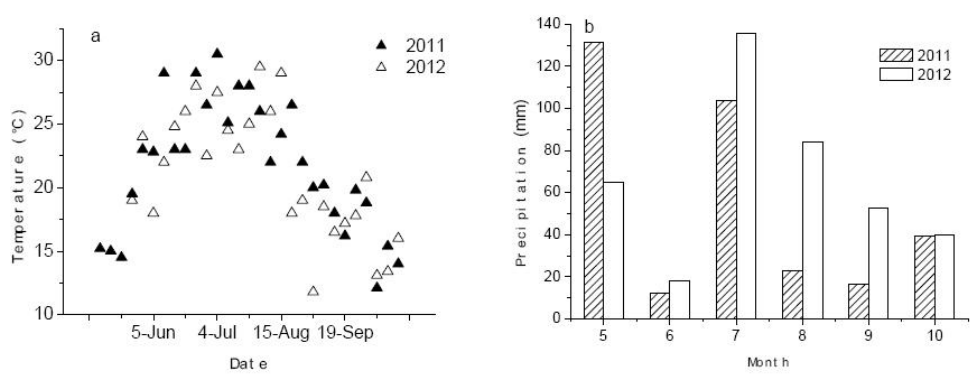

Figure 1 : Soil temperature (5cm) and precipitation change during growing season

Crop (soybean) is sowed at the end of May, germinated at the beginning of June, grew quickly from July to August and achieved the maximum aboveground biomass at the end of August. However, the aboveground biomass began to decrease in September due to the leaf falling. No significant difference of aboveground biomass between the growing seasons of 2011 and 2012 was discovered (Figure 2). Root biomass varied basically same with the aboveground biomass, but far less than the aboveground biomass.

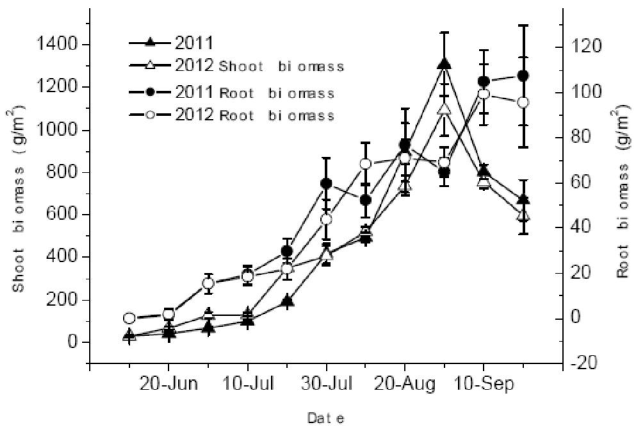

Figure 2 : Seasonal change of crop biomass

With the increase of soil temperature, soil respiratory rate increases quickly, especially from June to September (Figure 3). Although soil respiration reached the peak at different months in 2011 (August) and 2012 (July), no significant difference of soil respiration was found (p>0.05). A significant positive correlation between soil respiration and soil temperature (5cm) was observed (p<0.01). SMBC changed significantly during the growing season (Figure 3). The variable coefficients of 2011 and 2012 were 27.1% and 18.7%, respectively (p<0.001). SMBC was very low on May, 2011, but increased quickly later, reaching 774-842 mg/kg from June to September. SMBC from June to September remained basically stable. SMBC during the growing seasons of 2011 and 2012 varied same (p>0.05).

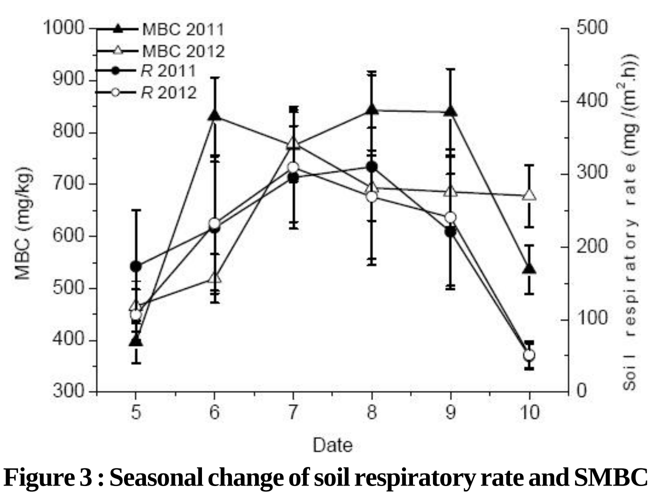

Figure 3 : Seasonal change of soil respiratory rate and SMBC

During the growing season of 2011 and 2012, DOC in surface soil ranged from 111.6-202. 2mg/kg and 121.8-194.5 mg/kg respectively, averaging at 153.0 and 159.1 mg/kg respectively and the variable coefficients valued 25.2% and 15.4% respectively (p<0.001). This indicates the obvious seasonal change of DOC (Figure 4). DOC reached the peak on May, but decreased from June to July (minimum, 111.6 mg/kg). However, it increased quickly from August to September (177. 2 mg/kg), but decreased again, reaching another low level. DOC in surface soil varied same in 2012 and 2011 (p>0.05).

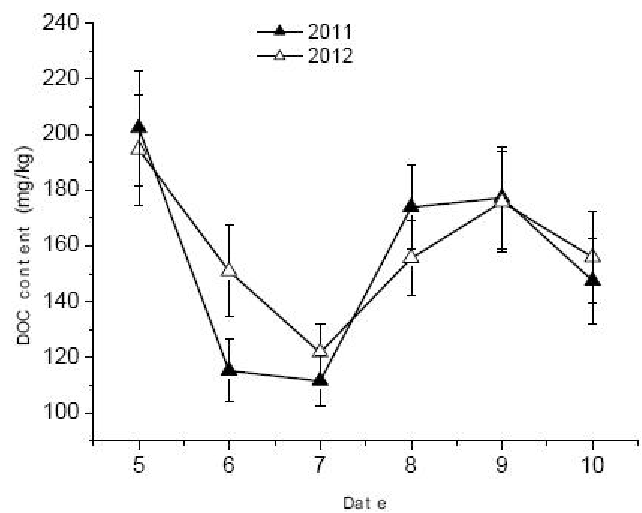

Figure 4 : Seasonal change of DOC

According to the research results, temperature, precipitation and microbial activity are inadequate to explain the high DOC on May. We believe that the high DOC on May is mainly caused by freeze-thaw action. Microorganisms died in winter can release abundant DOC and freeze-thaw action can facilitate the decomposition of organic detritus and mineralization of C and N[8-10].

The DOC from June to October is significantly correlated with MBC, soil temperature (5cm), soil respiration, root biomass and aboveground biomass (TABLE 1), but has no significant correlation with average monthly precipitation. SMBC is significantly cor-

TABLE 1: Person correlation coefficient between DOC and influencing factors

	MBC	Soil temperature (5cm)	Soil respiration	Aboveground biomass	Root biomass	Precipitation
DOC	-0.68*	-0.75*	-0.72*	0.97**	0.90**	0.23
p	0.60	0.98	0.93	0.97	0.98	0.72

Note: *$p<0.1$, **$p<0.05$; *p* is the probability of 1 Sample K-S Test data subjecting to normal distribution

TABLE 2 : Person correlation coefficient between SMBC and influencing factors

	MBC	Soil temperature (5cm)	Soil respiration	Aboveground biomass	Root biomass
SMBC	-0.68*	0.70*	0.53	0.39	0.45
p	0.96	0.98	0.93	0.97	0.98

Note: *$p<0.1$, **$p<0.05$; *p* is the probability of 1 Sample K-S Test data subjecting to normal distribution

related with DOC and soil temperature (5cm) (TABLE 2), but has no significant correlation with soil temperature, average monthly precipitation, organic carbon content and aboveground biomass.

CONCLUSION AND DISCUSSION

Both DOC content and composition in surface farmland soil present obvious seasonal changes. During the recent biological process, soluble microbial products, organic carbon consumption and plant photosynthates (e.g. standing litters and root exudates) can influence the seasonal change of DOC significantly. On May, farmlands remain uncultivated and low temperature causes low microbial activity and less organism production or consumption, the high DOC is mainly caused by freeze-thaw action rather than microbial activity.

In the research area, crops (soybean) is sowed at the end of May, germinate at the beginning of June, grow quickly during July to August, and achieve the maximum aboveground biomass and root biomass at the end of August. Therefore, DOC in surface soil increases quickly during August ~ September, reaching the peak on September. This is correlated with the amount of plant photosynthates (e.g. standing litters and root exudates). The DOC in surface farmland soil is significantly positively correlated with root biomass, which confirms the effect of root exudates to certain extent. Kalbitz et al. reported that the leaching products of litters, root exudates of plants, leaching of accumulated solid organic carbon in soil, soluble microbial products and microbial consumption will affect the seasonal change of DOC. Yano et al.[11] and Kaiser et al.[12] also believed that root exudates play an important role in DOC change. Deep research on the dynamics of root exudates, especially changes in ecosystem, has important significance to deep our understanding on carbon dynamics[11].

DOC change is significantly correlated with MBC, soil temperature (5cm) and soil respiration. Temperature influences DOC indirectly through microbial activity[13]. Soil respiration and MBC are two important indicators of soil microbial activity. DOC is significantly negatively correlated with soil temperature (5cm) and soil respiration, indicating that microbial activity is an important influencing factor of generation, consumption and composition changes of DOC. Higher microbial activity increases soluble microbial products, thus increasing DOC accordingly[14]. On the other hand, higher microbial activity can facilitate the biodegradation and mineralization of DOC, which not only decreases DOC, but also changes the composition of DOC[15].

DOC is significantly negatively correlated with MBC, indicating the slower DOC growth by soluble microbial products compared to DOC consumption by microorganisms. Such higher DOC consumption than DOC production will activate microorganisms, thus further decreasing DOC. In this paper, although there are less aboveground and root biomass and fewer root exudates from June to July, soil microbial activity increases quickly due to the higher soil temperature, thus accelerating DOC consumption by microorganisms while DOC production remained basically same. We believe this is the main reason of DOC reduction from June to July. Although Qualls reported that precipitation can decrease DOC in surface soil significantly through leaching migration[16], we found no significant correlation between DOC in surface soil and precipitation.

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