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RESEARCH ARTICLE

Effect of experimental warming on soil respiration under conventional tillage and no-tillage farmland in the North China Plain

TU Chun[1, 2], LI Fa-dong[1, 2], QIAO Yun-feng[1, 2], ZHU Nong[1], GU Cong-ke[1, 2], ZHAO Xin[1, 2]

[1] *Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, P.R.China*
[2] *University of Chinese Academy of Science, Beijing 100049, P.R.China*

Abstract
Understanding the response of soil respiration to global warming in agro-ecosystem is crucial for simulating terrestrial carbon (C) cycle. We conducted an infrared warming experiment under conventional tillage (CT) and no-tillage (NT) farmland for winter wheat and summer maize rotation system in North China Plain (NCP). Treatments include CT with and without warming (CTW and CTN), NT with and without warming (NTW and NTN). The results indicated that warming had no significant effect on soil moisture in irrigated farmland of NCP (P>0.05). The elevated average soil temperature of 1.1–1.6°C in crop growing periods could increase annual soil CO_2 emission by 10.3% in CT filed (P>0.05), but significantly increase it by 12.7% in NT field (P<0.05), respectively. The disturbances such as plowing, irrigation and precipitation resulted in the obvious soil CO_2 emission peaks, which contributed 36.6–40.8% of annual soil cumulative CO_2 emission. Warming would enhance these soil CO_2 emission peaks; it might be associated with the warming-induced increase of autotrophic respiration and heterotrophic respiration. Compared with un-warming treatments, dissolved organic carbon (DOC) and soil microbial biomass carbon (MBC) in warming treatments were significantly increased by 11.6–23.4 and 12.9–23.6%, respectively, indicating that the positive responses of DOC and MBC to warming in both of two tillage systems. Our study highlights that climate warming may have positive effects on soil C release in NCP in association with response of labile C substrate to warming.

Keywords: global warming, conventional tillage, no-tillage, soil respiration, dissolved organic carbon, soil microbial biomass carbon

1. Introduction

The CO_2 concentration in atmosphere has been increasing rapidly over the last 50 years and is predicted to cause global warming (Denmead 1991). The globally averaged temperature increased about 0.85°C (0.65–1.06°C) over the period 1880 to 2012 and this trend of increasing global temperature is likely to exceed at least 1.5°C for the end of the 21st century relative to 1850 to 1900 (IPCC 2013). Warmer soil temperature due to global warming will be

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TU Chun, Mobile: +86-13126565829, E-mail: tuchunabc@sina.com; Correspondence LI Fa-dong, Tel: +86-10-64889530, E-mail: lifadong@igsnrr.ac.cn

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likely to enhance the mineralization of soil organic matter (SOM) in terrestrial ecosystem and subsequently increases the efflux of carbon (C) from the soil to atmosphere. This will provide a positive feedback between climate change and soil C release (Rustad and Fernandez 1998).

The efflux of C from soil to the atmosphere occurs primarily in the form of CO_2, and is the result of soil respiration (Rs) (Rustad and Fernandez 1998). With increasing concern of global warming, soil C sequestration strategy, such as no-tillage (NT) with residual cover on surface soil, is recognized as one of the important management practice to mitigate CO_2 emission (Qin *et al.* 2010; Zhang *et al.* 2013; Mangalassery *et al.* 2015; Sheehy *et al.* 2015). Adoption of NT generally increases soil organic carbon (SOC) sequestration coupled with the increased macroaggregates due to less mechanical and artificial disruption (Mangalassery *et al.* 2015; Sheehy *et al.* 2015). On the contrary, conventional tillage (CT) causes the breakdown of the soil aggregates, increases soil aerobic condition and hastens the oxidation of SOC and soil CO_2 emission (Qin *et al.* 2010; Zhang *et al.* 2013). However, whether warming stimulates decomposition of SOC and CO_2 emission or not in these two tillage systems was little understood. A few studies reported by Hou *et al.* (2014) and Liu *et al.* (2015) who argued that warming had no significant effect on cumulative Rs in arable field, while the positive response of decomposition of SOC on the surface soil (0–5 cm) might be attributed to the CO_2 release in NT field. However, uncertainties of estimates of annual cumulative CO_2 emission based on the less frequency of sampling in their studies were still high, because CO_2 emission peaks from soil after plowing, irrigation and strong precipitation contribute main proportion to total annual soil CO_2 emission in agricultural ecosystem (Reicosky *et al.* 1999; Morell *et al.* 2010). Soil CO_2 pulse deprived from tillage operation occurs as an initial burst of CO_2 emission which lasts for several hours (Morell *et al.* 2010). This CO_2 pulse is due to soil aggregate disruption and exposition of protected SOC to decomposition (Lascalajr *et al.* 2008; Morell *et al.* 2010). The rapid changes of Rs during irrigation or precipitation events may have been caused by several possible mechanisms (Kuzyakov *et al.* 2000; Huxman *et al.* 2004; Chen *et al.* 2008). Water displaces soil pore space gas with high CO_2 concentration. Irrigation or precipitation can activate microbial metabolism and root activity, resulting in a priming effect on soil CO_2 efflux (Steenwerth *et al.* 2005). Furthermore, addition of water to an extremely dry soil could increase access to labile substrate (Huxman *et al.* 2004). Some previous studies have reported that the rapid soil CO_2 flux responses to irrigation and precipitation events lasted for 2–4 days, but accounts for larger proportion of Rs to total cumulative CO_2 emission (Reicosky *et al.* 1999; Fierer 2003; Wang *et al.* 2015). Therefore, warming effect on soil CO_2 emission peaks deprived from the disturbance of management practices and precipitation may be complex in CT and NT fields.

As a direct reservoir of readily available nutrients, the labile C pool is particularly important and exerts considerable control on ecosystem functioning. CO_2 emission is largely dominated by the small but highly bio-reactive labile carbon, such as dissolved organic carbon (DOC) and soil microbial biomass carbon (MBC). Through its impacts on microbial activity and on the turnover and supply of nutrients to plant, the labile C can alter Rs components (Ra, autotrophic respiration; Rh, heterotrophic respiration). Previous studies have reported that the labile C was sensitive to alteration in soil temperature and moisture resulting from climate change, with the positive (Belay-Tedla *et al.* 2009), neutral (Xu Z *et al.* 2010; Fu *et al.* 2012) and negative response (Dou *et al.* 2010) to warming. However, DOC and MBC have not been widely used to evaluate Rs and its source components responses to experimental warming in farmland, especially in North China Plain (NCP) where is one of the most important intensive agricultural region providing approximately one fourth of China's total grain yield in China (Liu *et al.* 2011). Hence, analyzing the DOC and MBC may provide insights into indication of global warming on soil CO_2 emission in farmland of NCP. In this study, our objectives were to investigate effects of warming on Rs, DOC and MBC based on artificial infrared warming in winter wheat and summer maize season under CT and NT systems; to quantify the contributions of CO_2 emission peaks due to management practices and precipitation to annual soil CO_2 efflux and assess the effects of warming on these CO_2 peaks in these two tillage systems; and to quantify the influences of DOC and MBC on Rs in warming condition.

2. Materials and methods

2.1. Study site

Our study was performed on a long-term conservation tillage trial at Yucheng Comprehensive Experiment Station of the China Academy of Sciences (36°50´N, 116°34´E). This site is representative of the intensive agricultural areas of the NCP, with an annual mean temperature of approximately 13.4°C and precipitation of 567 mm (Hou *et al.* 2014). A winter wheat/summer maize system is the typical cropping system; the irrigation using local groundwater was applied according to the soil moisture condition in crop growing seasons.