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Effects of crop types and nitrogen fertilization on temperature sensitivity of soil respiration in the semi-arid Loess Plateau

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ABSTRACT

Temperature sensitivity of soil respiration (Q_{10}) is an important mechanism for the possible feedback between global carbon cycle and climate system. Knowledge of how crop types and nitrogen (N) fertilization affect Q_{10} is critical for estimating soil respiration and carbon cycling in agro-ecosystem. A two-year field experiment was conducted with cold-resistant (winter wheat; *Triticum aestivum* L.) and thermophilic (spring maize; *Zea mays* L.) crops at two N fertilization levels (no fertilization (CK) and 160 kg N hm^{-1}) from October 2013 to September 2015 in semi-arid Loess Plateau. Annual mean soil respiration and Q_{10} in maize were 20% (1.85 *vs.* 1.54 $\mu mol\ m^{-2}\ s^{-1}$) and 36% (2.49 *vs.* 1.83) higher than that in wheat. Nitrogen fertilization resulted in a 35% increase in annual mean soil respiration (1.95 *vs.* 1.44 $\mu mol\ m^{-2}\ s^{-1}$) and a 11% decrease in Q_{10} (2.05 *vs.* 2.28) compared with the CK treatment. Soil respiration was positively related to root biomass, whereas no significant relationship was found between root biomass and Q_{10}. Therefore, it can be concluded that soil respiration and temperature sensitivity of soil respiration are significantly influenced by crop types and N fertilization regimes, which should be considered in calculating carbon budget in agro-ecosystem using carbon models.

1. Introduction

Temperature sensitivity of soil respiration (often measured as Q_{10}) is regarded as an important mechanism for the possible feedback between global carbon cycle and climate system (Houghton et al., 1998; Huntingford et al., 2000). Q_{10} values differ significantly across ecosystems (Peng et al., 2009), estimated Q_{10} values ranged from 1.56 to 2.70 among grassland, forest and agro-ecosystem (Chen et al., 2010b), and in agro-ecosystem, the Q_{10} value appears to depend critically on agronomic management practices. Thus, knowledge of the variation of Q_{10} values with agronomic management practices is essential for accurately estimating soil respiration and carbon cycling in agro-ecosystem.

However, most previous studies in this field have focused solely on the impacts of agronomic management practices for a single crop type or rotation system. Critical to the success of agronomic management practices is the proper choice of crop types and fertilization regimes, especially in rain-fed agricultural areas, both of which have a significant effect on the soil environment (Huang et al., 2003; Jiang et al., 2015a), crop growth (Jiang et al., 2015a), root growth and morphology (Pregitzer et al., 2000b), and substrate quantity and quality (Leifeld and Von Lutzow, 2014). Soil respiration under cold-resistant crops was more sensitive to temperature changes compared with that under thermophilic crops (Jiang et al., 2015a). Above- and below-ground biomass, as well as the ratio between them, varied significantly among crops (Govaerts et al., 2007) and fertilization practices (Pregitzer et al., 2000a,b). In addition, plant species could also influence substrate quantity and quality (Fissore et al., 2008). To sum up, all of these factors can have a significant influence on the temperature sensitivity of soil respiration (Iqbal et al., 2010; Xu and Qi, 2001; Jiang et al., 2015a; Xu et al., 2015).

Soil environment (soil temperature and moisture) has been shown to be the major factor influencing soil respiration (Davidson and Janssens, 2006). The relationship of soil temperature and

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moisture with soil respiration is usually fitted by an exponential function (Hoff, 1899) and a quadratic regression function (Zhang et al., 2014), respectively. Previous studies have demonstrated that Q_{10} increased with the increase of below-ground root system (Hertel et al., 2009; Wang et al., 2015; Wu et al., 2014). A higher above-ground biomass allowed the allocation of more photosynthetic product to roots, thus resulting in an increase in Q_{10} (Millenaar et al., 2000). Q_{10} also varied with the quantity and quality of soil organic matter (SOM) (Conant et al., 2011, 2008; Karhu et al., 2010). In addition, N fertilization also influenced Q_{10} by means of root exudation, fine root biomass, and the C:N ratio in the soil (Pregitzer et al., 2000b; Leifeld and Von Lutzow, 2014).

However, conclusive evidence is still lacking as to the effect of soil environment, crop growth, root properties and substrate quantity and quality on Q_{10} under different crop types and fertilization regimes (Annunziata et al., 2013; Fan et al., 2015; Mazzoncini et al., 2011). We hypothesized that crop types and fertilization regimes affected all of these factors, which in turn affected the temperature sensitivity of soil respiration in the semi-arid Loess Plateau. In this study, we measured soil respiration, soil temperature and moisture, and above- and below-ground biomass in wheat and maize systems in the semi-arid Loess Plateau from October 2013 to September 2015. The main purposes of this study were to determine: 1) the difference in temperature sensitivity of soil respiration between different crop types (cold-resistant and thermophilic crops) and N fertilization regimes (no fertilization and 160 kg N hm^{-1}) and 2) factors influencing the temperature sensitivity of soil respiration.

2. Materials and methods

2.1. Site description

The arable land is estimated to be about 145,000 km^2 in the Loess Plateau, and more than 70% of crops are planted in rain-fed areas and thus are particularly susceptible to climate change (Jiang et al., 2015a; Wang et al., 2013). The study site is located in Wangdonggou (35°13′N, 107°40′E; 1220 m a.s.l), Changwu Country, Shaanxi Province, China (Fig. 1). It is a typical tableland-gully region in the southern Loess Plateau in the middle reaches of the Yellow River. It has a continental monsoon climate characterized by hot summers and cold winters. In the study area, the annual mean precipitation is 560 mm, 60% of which occurs between July and September; the annual mean air temperature is 9.4 °C, and ≥10 °C accumulated temperature is 3029 °C; the annual sunshine duration is 2230 h with a total radiation of 484 kJ cm^{-2}, and frost-free period is 171 days. All meteorological data were provided by Changwu State Key Agro-Ecological Experimental Station (Fig. 2).

The soil is a uniform loam of loess deposits belonging to Cumulic Haplustolls according to American Soil Classification System and originated from parent material of calcareous loess. Soil samples collected at 0–20 cm depth in 2013 are characterized by: pH 8.3 (1:1 soil/H_2O suspension), clay content (<0.002 mm) 24%, field capacity 22.4%, permanent wilting point 9.0%, $CaCO_3$ 10.5%, SOC 6.5 g kg^{-1}, and total soil N 0.80 g kg^{-1}.

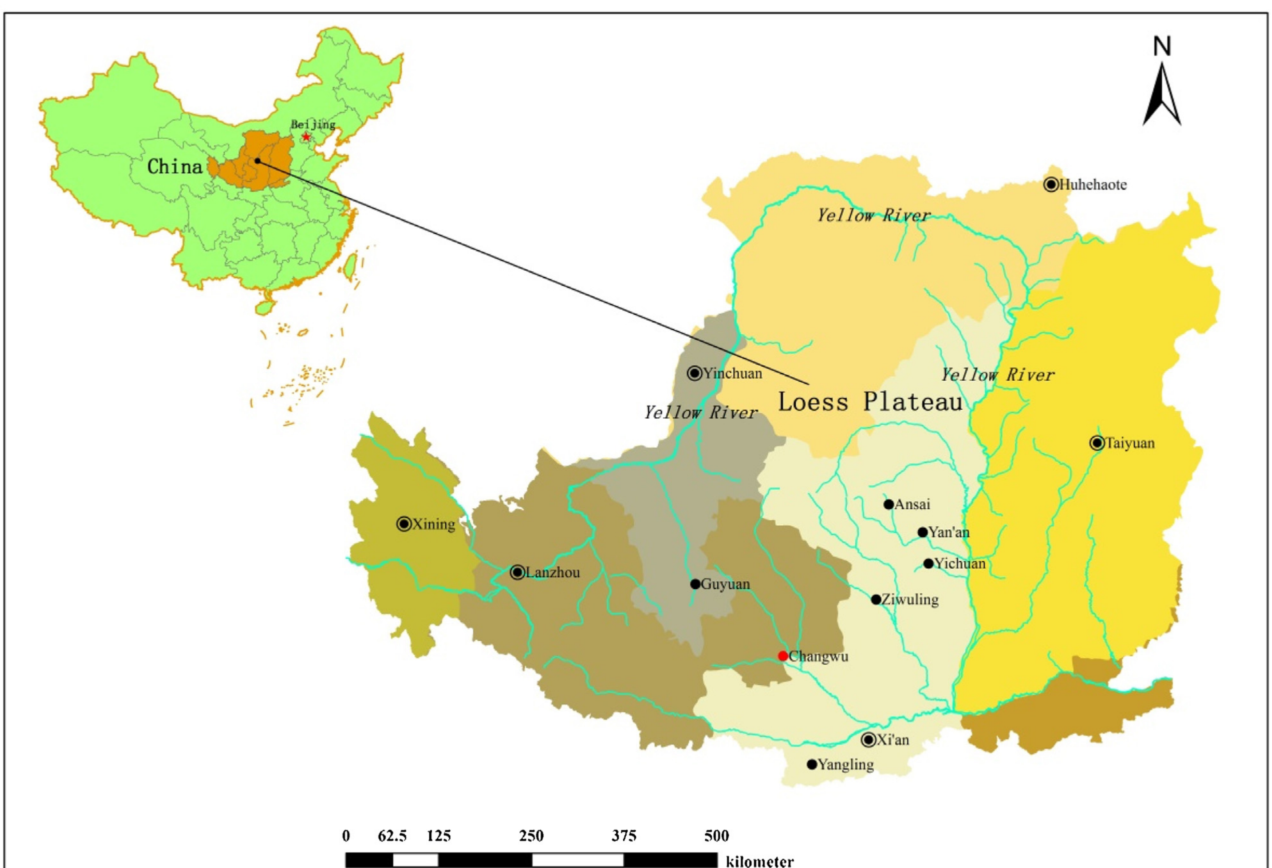

Fig. 1. A sketch map of the Loess Plateau.