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Effects of Maize Residue Quality and Soil Water Content on Soil Labile Organic Carbon Fractions and Microbial Properties

LI Zengqiang[1,2], ZHAO Bingzi[1,*] and ZHANG Jiabao[1]

[1] *State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008 (China)*
[2] *University of Chinese Academy of Sciences, Beijing 100049 (China)*

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ABSTRACT

Investigating the effects of residue chemical composition on soil labile organic carbon (LOC) will improve our understanding of soil carbon sequestration. The effects of maize residue chemical composition and soil water content on soil LOC fractions and microbial properties were investigated in a laboratory incubation experiment. Maize shoot and root residues were incorporated into soil at 40% and 70% field capacity. The soils were incubated at 20 °C for 150 d and destructive sampling was conducted after 15, 75, and 150 d. Respiration, dissolved organic carbon (DOC), hot-water extractable organic carbon (HEOC), and microbial biomass carbon (MBC) were recorded, along with cellulase and β-glucosidase activities and community-level physiological profiles. The results showed that the cumulative respiration was lower in root-amended soils than in shoot-amended soils, indicating that root amendment may be beneficial to C retention in soil. No significant differences in the contents of DOC, HEOC and MBC, enzyme activities, and microbial functional diversity were observed between shoot- and root-amended soils. The high soil water content treatment significantly increased the cumulative respiration, DOC and HEOC contents, and enzyme activities compared to the low soil water content treatment. However, the soil water content treatments had little influence on the MBC content and microbial functional diversity. There were significantly positive correlations between LOC fractions and soil microbial properties. These results indicated that the chemical composition of maize residues had little influence on the DOC, HEOC, and MBC contents, enzyme activities, and microbial functional diversity, while soil water content could significantly influence DOC and HEOC contents and enzyme activities.

Key Words: community-level physiological profile, dissolved organic carbon, enzyme activities, hot-water extractable organic carbon, maize roots, maize shoots

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INTRODUCTION

Soil organic carbon (SOC) is an important indicator of soil quality and productivity because it affects soil physical, chemical, and biological properties and processes. However, changes in SOC content as a result of alterations in soil management practice are difficult to detect because of the relatively high background levels and natural soil variability (Haynes, 2005). Therefore, many studies have attempted to identify labile pools of SOC that are more sensitive to changes in management or environmental conditions than total SOC (Ghani *et al.*, 2003). Soil labile organic carbon (LOC) fractions, such as dissolved organic carbon (DOC), hot-water extractable organic carbon (HEOC) and microbial biomass carbon (MBC), play an important role in soil nutrient availability and microbial activity (Huang *et al.*, 2008). Furthermore, LOC fractions are characterized by their rapid turnover, and are seen as early indicators of changes in SOC and soil quality (Haynes, 2005).

Plant residues are considered to be an important source of LOC fractions in soil (Kalbitz *et al.*, 2000; Haynes, 2005). Previous studies have shown that the contents of LOC fractions are directly and/or indirectly influenced by aboveground residue (shoot/leaf residues) chemical composition (Don and Kalbitz, 2005; Langenbruch *et al.*, 2014). The water-soluble organic compounds of residues directly contribute to LOC fractions through leaching (Kalbitz *et al.*, 2000). The chemical composition of a residue also affects the activity of microbes responsible for residue decomposition, which could indirectly influence the production of LOC fractions (Uselman *et al.*, 2007). Furthermore,

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[*] Corresponding author. E-mail: bzhao@issas.ac.cn.

belowground residues (roots) generally contain less nitrogen (N) and water-soluble organic compounds, and have higher lignin and polyphenol contents than aboveground residues (Silver and Miya, 2001). Earlier studies showed that roots contribute more carbon (C) to SOC than aboveground residues (Johnson *et al.*, 2007). Little information, however, is available on the effects of root residues on the LOC fractions.

Soil microbes are the primary decomposers of residues and are influenced by the chemical composition of the residues (Williams *et al.*, 2006; Fanin *et al.*, 2014). Fanin *et al.* (2014) reported that residues with high soluble C led to a structural shift to relatively more gram-negative bacteria. Residues with different chemical compositions are decomposed by distinct microbial communities since microbes differ in their ability to produce and release enzymes. Water-soluble organic substrates can be utilized by a wide range of bacteria and fungi. Complex compounds, such as cellulose and lignin, are decomposed by only a limited number of microbially released enzymes (Meidute *et al.*, 2008). However, previous studies have also reported structural changes without corresponding functional changes due to the functional redundancy of soil microbes (Marschner *et al.*, 2003). The community-level physiological profile (CLPP), based on the ability of microbes to oxidize different C substrates, can be used to estimate the potential functional diversity of microbial communities (Garland and Mills, 1991). Zak *et al.* (1994) suggested that soil microbial functional diversity is more relevant to soil functions than microbial community composition. Therefore, further research is needed to estimate the effects of residue chemical composition on the changes in microbial functional diversity.

Soil water content is an important environmental factor that can significantly influence the contents of the LOC fractions (Kalbitz *et al.*, 2000; Ponizovsky *et al.*, 2006; Wang *et al.*, 2013). Previous studies reported higher DOC and MBC contents at higher soil water contents (Christ and David, 1996; Wang *et al.*, 2013). Drought limits the desorption and mobilization of labile organic matter from soil particles (Ponizovsky *et al.*, 2006) since substantial amounts of potentially labile organic matter exist in the adsorbed phase (Christ and David, 1996). Furthermore, drought decreases microbial metabolic activity by increasing the soil water potential stress, and by decreasing the diffusion of soluble substrates and/or microbial mobility (Griffiths *et al.*, 2003). Then, the LOC fractions decrease as a result of reduced biological activity because less LOC is released during the decomposition of residues and/or humus (Clark *et al.*, 2012).

Maize (*Zea mays* L.) is a major cereal crop grown in the North China Plain (NCP), one of the major agricultural production areas in China. It has been gradually accepted by local farmers that returning crop residues to soils helps maintain soil fertility and productivity. This study focused on determining the LOC fractions and microbial properties for maize above- and belowground residue amended soils under different soil water content regimes. Our specific objectives were: 1) to make a brief comparison of the LOC fraction contents and microbial properties between above- and belowground residue amended soils; 2) to investigate the effects of different soil water content regimes on soil LOC fraction contents and microbial properties; and 3) to clarify the relationships between soil LOC fraction contents and microbial properties.

MATERIALS AND METHODS

Soil and residue materials

The soil used in this study was collected from the Fengqiu Agro-Ecological Experimental Station of Chinese Academy of Sciences in Pandian, Fengqiu County, Henan Province, China (114°24′ E, 35°00′ N). The soil was taken from the top 20 cm using a shovel on September 30, 2011. It was classified as a Calcaric Fluvisol according to World Reference Base for Soil Resources (Shi *et al.*, 2010) and had a sandy loam texture. The soil was air-dried and sieved (2-mm) before it was used. The basic soil properties were as follows: pH (H_2O), 8.07; total organic C (TOC), 8.01 g kg^{-1}; total N (TN), 0.74 g kg^{-1}; available N, 37.5 mg kg^{-1}; available phosphorus, 30.3 mg kg^{-1}.

The maize residues were collected at maturity from the field where the soil samples were collected. The plants were harvested and their main stems were cut at ground level. The aboveground maize residues comprised of stems, leaves, and corncobs, which were referred to as shoots hereafter. The belowground maize residues were only roots and were referred to as roots hereafter. Both the shoots and roots were then washed carefully with tap water, followed by rinsing with distilled water, drying at 80 °C to a constant weight, and grinding to pass through a-0.5 mm sieve. The chemical properties of the shoots and roots were measured before use and are shown in Table I. Water-soluble organic matter and phenolics were determined according to Bending *et al.* (1998). Cellulose and lignin were determined according to Van Soest and Wine (1968).