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Research paper

Long-term fertilization increases soil organic carbon and alters its chemical composition in three wheat-maize cropping sites across central and south China

Y.T. He[a,b], X.H. He[c,d], M.G. Xu[a,*], W.J. Zhang[a,*], X.Y. Yang[e], S.M. Huang[f]

[a] National Engineering Laboratory for Improving Quality of Arable Land, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

[b] Research Institute of Forestry Policy and Information, Chinese Academy of Forestry, Beijing 100091, China

[c] College of Resources and Environment, Southwest University, Beibei, Chongqing 400715, China

[d] School of Biological Sciences, University of Western Australia, Crawley, WA 6009, Australia

[e] State Key Laboratory of Soil Erosion and Dryland Farming, Northwest A & F University, Yangling, 712100 Shaanxi, China

[f] Institute of Plant Nutrition, Resources and Environment, Henan Academy of Agricultural Sciences, Zhengzhou, 450002, China

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ABSTRACT

Soil organic carbon (SOC) is at the core of soil fertility. Although fertilization strategies can alter SOC stocks, their effects on SOC chemical composition is less known. Using the solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy, we examined changes in the SOC chemical composition of three soils (0–20 cm depth) from an annual wheat-maize double-cropping system across central to south China. These soils had been subjected to 22 years (1990–2012) long-term fertilization. Compared with no-fertilization control, SOC stocks were significantly increased under chemical fertilization (NPK), NPK plus straw (NPKS), and NPK plus manure (NPKM). The O-alkyl C (labile C), not the alkyl C (persistent C), was consistently increased across the three fertilized treatments. Additionally, all fertilized treatments decreased the ratio of alkyl-C/O-alkyl-C (SOC decomposition index) or aliphatic-C/aromatic-C (SOC complexity index), indicating that the SOC decomposition was delayed, or SOC was converted into a more complicated structure. The soil C of NMR-determined functional groups (alkyl C, O-alkyl C, aromatic C, and carbonyl C) was positively correlated with the cumulative C input ($P < 0.05$). The conversion rate of functional groups was highest in O-alkyl C, indicating a largest contribution to the increase of SOC accumulation. Soil C:N ratio, pH, and clay were the main factors affecting the functional-group conversion rates, whereas annual precipitation, temperature, and accumulated temperature (> 10 °C) played smaller roles. In conclusion, these results can be applied to the improvement of agricultural soil C sequestration capacity through changing SOC chemical structure under long-term fertilizer managements.

1. Introduction

Soil organic carbon (SOC) is a key indicator of soil fertility and health (Baldock et al., 2004; Liu et al., 2006) and soil fertility can be improved through soil C sequestration. In doing so, knowledge of soil C quantity and forms are required, because various C-containing compounds of soil C differ in their stability against decomposition under distinct environments. However, understanding the highly heterogeneous nature of external C input and the complexity of C compounds in soil remains a major challenge.

Fertilizer application (both chemical and organic) to agricultural soils is widely used as a common management practice to maintain or increase soil fertility and SOC stock. In general, fertilization with organic fertilizers alone or plus chemical fertilizers tend to increase SOC concentrations (Blair et al., 2006; Bhattacharyya et al., 2010; Ding et al., 2012; Maillard et al., 2015), whereas chemical fertilization alone yielded inconsistent outcomes (Purakayastha et al., 2008; Lemke et al., 2010; He et al., 2015). Despite a clear documentation of SOC gains and losses through fertilization, only contradictory data are available for the effects of long-term fertilization strategies on SOC that could affect SOC chemical composition. Potentially, the elucidation of the chemical composition of SOC can be tackled by a number of new techniques, such as Pyrolysis-field Ionization Mass Spectroscopy (Py-FIMS) (Leinweber and Schulten, 1995), Off-line TMAH thermochemolysis-GC/

* Corresponding authors at: Ministry of Agriculture Key Laboratory of Crop Nutrition and Fertilization, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China.

E-mail addresses: xuminggang@caas.cn (M.G. Xu), zhangwenju01@caas.cn (W.J. Zhang).

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