Soil Organic Carbon Storage

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Crop residue returning (RR) is a promising option to increase soil organic carbon (SOC) storage, which is linked to crop yield promotion, ecologically sustainable agriculture, and climate change mitigation. Thus, the objectives of this study were to identify the responses of SOC storage and sequestration rates to RR in China's croplands. Based on a national meta-analysis of 365 comparisons from 99 publications, the results indicated that RR increased SOC storage by 11.3% compared to residue removal ($p < 0.05$). Theoretically, when combined with low nitrogen fertilizer input rates (0–120 kg N ha^{-1}), single cropping system, paddy-upland rotation, lower mean annual precipitation (0–500 mm), alkaline soils (pH 7.5–8.5), other methods of RR (including residue chopping, evenly incorporating, and burying) or long-term use (>10 yrs), an increase in SOC storage under RR by 11.6–15.5% could be obtained. The SOC sequestration rate of RR varied from 0.48 (Central China) to 1.61 (Southwest China) Mg C ha^{-1} yr^{-1}, with a national average value of 0.93 Mg C ha^{-1} yr^{-1}. Higher SOC sequestration rates enhanced crop production. However, decreases in SOC sequestration rate were observed with increases in experimental durations. The phenomenon of "C saturation" occurred after 23 yrs of RR. Overall, RR can be used as an efficient and environmentally friendly and climate-smart management practice for long-term use.

Keywords: residue returning ; soil organic carbon storage ; soil carbon sequestration

1. Introduction

Soil is the largest organic carbon (C) pool on earth [1]. The dynamics of soil organic carbon (SOC) can be used to indicate changes in SOC sequestration capacity (an indicator to evaluate C sequestration ability of soil, which depends on soil type, nutrient reserves, soil depth, etc. The C sequestration capacity could affect soil quality and mitigation function of climate change) and crop productivity [2][3]. Due to the large SOC stock, small fluctuations may cause large changes in atmospheric CO2 concentration, finally affecting global climate changes. In this sense, increasing SOC sequestration is one of the most important strategies to reduce atmospheric CO2 concentrations and to mitigate the greenhouse effect [4], with a significant potential to mitigate climate change [5].

The adoption of appropriate farming managements can reduce the mineralization and decomposition of organic matter (OM) and increase SOC storage [6]. Thus, increased C sequestration and reduced greenhouse gas emissions [7] can be attributed to improved soil fertility, ultimately promoting crop production and economic viability [8].

Crop residue returning (RR), which means to return the aboveground and belowground biomasses into field after harvesting, is a worldwide recommended management practice due to the benefits in enhancing soil quality and productivity. RR can improve soil structure [9], increase systematic biodiversity [10], enhance SOC sequestration capacity, and partially replace fertilizer input [11], thereby increasing crop yield and farmland system production capacity [6][12] in a sustainable manner. Therefore, scientific and rational implementation of RR is critical to maintain soil quality, high crop production, and sustainability. RR can be affected by various factors such as tillage practices [13][14], returning mode [15], climatic conditions [16], and duration [17][18]. Previous studies on RR have mostly focused on single factors such as tillage practices [19], returning mode [20], returning amount [21], and nitrogen fertilizer input rate (NFIR) [6]. For example, a 7-yrs field experiment in north-west China revealed that conservation tillage enhanced SOC storage compared to conventional tillage [19]. Similarly, Chalise et al. [20] suggested that mulch retention could be more beneficial to increase soybean yield and soil water storage compared with another returning mode (RR without cover crops). In a 12-yrs experiment, the authors found that with an increasing residue amount, C sequestration was enhanced [21]. In a national meta-analysis conducted by Zhao et al. [6], optimal NFIR and RR could also increase SOC sequestration capacity. However, a more comprehensive analysis of the factors affecting SOC storage, particularly at a larger spatial scale, is lacking. In addition, the temporal changes in SOC sequestration under RR are not fully understood, making it essential to quantitatively analyze numerous research results.

2. Conclusion

A national meta-analysis was conducted to explore the factors influencing SOC storage and sequestration under RR. As an environmentally friendly and ecologically sustainable practice, RR improved crop yield and soil fertility by increasing SOC storage (11.3%, $p < 0.05$) and sequestration rate (0.93 Mg C ha^{-1} yr^{-1}) in China's croplands. Improvements in management practices might further enhance soil C sequestration capacity, and RR combined with a lower nitrogen fertilizer input rate (0–120 kg N ha^{-1}), single cropping system, paddy-upland rotation, other methods of RR (including residue chopping, evenly incorporating, and burying), or long-term use (>10 yrs) are recommended to enhance SOC storage by 11.6–15.5%. Additionally, return duration, NFIR, amount of residue, and initial SOC content should be considered when investigating the responses of SOC to RR. Generally, RR can be used as an efficient and climate-smart management practice for long-term use. More complete datasets are needed to obtain results underpinning our understanding of the factors impacting SOC sequestration and storage under RR in China's croplands.

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